The London School of Economics and Political Science

Essays in Macroeconomics

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I warrant that this authorization does not, to the best of my belief, infringe the rights of any third party. I declare that my thesis consists of 55956 words.

Statement of Conjoint Work

I confirm that Chapter 4 was jointly co-authored with Prof. Philip E. Davis and Dr. Rebecca Piggott at the National Institute of Economics and Social Research. I contributed to the writing of the paper, highlighted a concern of a weak co-integrating relationship in the first stage of the panel error correction model and carried out the SUR estimation procedure.

Abstract

This thesis contains four chapters. The first chapter establishes a negative empirical correlation between the share of employees working under a temporary contract and the share of employees with high educational attainments employed in jobs for which they are over-qualified. Subsequently, I show that a search and matching model with heterogeneous jobs and workers with directed search can explain this correlation. Temporary contracts induce entrepreneurs to post, in relative terms, more vacancies for jobs with low educational requirements thus reducing the time (cost) of finding one such job. As a result, some unemployed agents with high educational levels that were previously looking for a job that matched their level of formation may find it attractive to switch and start searching for one such easy to find job for which they are over-qualified.

The second chapter compares the magnitude of fiscal multipliers at the zero lower bound in New Keynesian models with those that arise from a large-scale global semi-structural model (NiGEM). I find that, in NiGEM, once I impose the zero lower bound constraint, multipliers increase, as the literature predicts, but by a much smaller factor than in New Keynesian models. Whereas New Keynesian models predict multipliers well above one, or even larger than two, multipliers in NiGEM remain below one. All of the channels, highlighted by the literature, through which the zero lower bound operates to generate multipliers larger than one are operating in NiGEM but one. Contrary to the predictions of open economy New Keynesian models, a fiscal expansionary shock when the economy is stuck at the zero lower bound does not crowd in foreign demand for home goods in NiGEM. In addition, I also find that the results are sensitive to the degree of expectational myopia. Once I modify NiGEM to reduce the degree of expectational myopia and produce a foreign demand crowd in effect, I obtain that the predictions of the model become more in line with those of the New Keynesian literature.

The third chapter describes the cyclical behavior of the relative price of investment using

three different measures: instantaneous correlations on data detrended using the Hodrick-Prescott filter, correlations on VAR forecast errors and instantaneous correlations on frequency-domain filtered data. All three measures suggest that the relative price of equipment goods is countercyclical. Instead, the relative price of household and total private investment is countercyclical according to the correlations computed on VAR forecast errors and frequency-domain filtered data while correlations on data detrended using the Hodrick-Prescott filter suggest that the relative price of household and total private investment is procyclical.

The fourth chapter reviews the theoretical and empirical literature on macroprudential policies and tools and tests empirically the effectiveness of several macroprudential policies and tools. We find evidence that macroprudential polices are effective at curbing house price and credit growth, albeit some tools are more effective than others. These include, in particular, taxes on financial institutions and strict loan-to-value and debt-to-income ratio limits.

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Chapter 1

Dual Labour Markets and Job Skill Mismatch

1.1 Introduction

The use of temporary contracts in several European labour markets has been very popular since their introduction in the late 70's. Policy makers across several european countries introduced this type of contract to promote flexibility in labour markets that faced high levels of employment protection legislation (EPL). Their popularity gave rise to the so-called "Duality" in labour markets. The term refers to a situation where the pool of employees of a country can be broadly split up into two categories: those that enjoy high EPL, which can occur in various forms, such as legal hurdles to redundancy or contracts that specify high firing costs, and those that enjoy low EPL, such as those who work under a temporary contract. These contracts are characterized by specifying a fix duration of time of the work relationship and by entailing low separation costs. Since their introduction, there has been a large body of work to establish whether temporary contracts were a useful tool to combat unemployment. The results so far are inconclusive, as temporary contracts increase both job creation and job destruction rates.[1] However, from the policy maker point of view, unemployment may not be the only relevant dimension of a labour market. Other dimensions could be of interest and could have been affected by the introduction of temporary contracts.

[1]See, for instance, Bentolila and Saint-Paul (1992), Bentolila and Dolado (1994), Saint-Paul (1996), Cabrales and Hopenhayn (1997), Blanchard and Landier (2002) and Aguirregabiria and Alonso-Borrego (2008).

The purpose of this paper is twofold. Firstly, I establish a negative empirical correlation between the share of employees working under a temporary contract and the share of employees with high educational attainment levels employed in jobs for which they are over-qualified (a term that I shall refer to as job skill mismatch) across a panel of European countries. To my knowledge, this is the first attempt in the literature to establish an empirical relationship between temporary contracts and job skill mismatch. Secondly, I show that a search and matching model with heterogeneous jobs and workers can reproduce this negative correlation.

The model that I develop is a variation of the classic search and matching model with exogenous job destruction (see Pissarides, 2000, chapter 1), which I extend to include heterogeneous jobs and workers. There are two labour markets differentiated by the skill requirement of the jobs offered to the workers. Some jobs do not require any specific level of formation or skill and will be denoted as low skill jobs while some other jobs require the worker to have a certain level of formation or experience in order to be able to perform their job successfully. I denote the latter as the high skill type of jobs. Workers, who are exogenously endowed with different skill/formation levels, have to decide in which market they search for a job.

The model permits two types of labour contracts: a regular contract, which does not specify a set duration of the contract and entails costs upon redundancy of the worker, and temporary contracts, which last for a shorter period of time and entail lower redundancy costs. In the model, temporary contracts provide more incentives to post vacancies for low skill jobs than for high skill jobs because it is assumed that jobs with low skill requirements face a higher probability of making workers redundant than jobs with high skill requirements.[2] As a consequence, upon the introduction of temporary contracts, the share of vacancies for low skill jobs increases relative to those of high skill jobs and the time of finding one such job decreases. As the time of finding a low skill job falls relative to the time of finding a high skill job, some high skill unemployed workers find it profitable to switch labour markets and look for a low skill job.

The model allows to evaluate the welfare gain/loss derived from introducing temporary contracts. I find that temporary contracts are not always welfare improving. Within the context of the model developed in this paper, temporary contracts increase the returns from posting vacancies for all type of jobs, albeit the increase is larger for vacancies for low skill type of

[2]One could endogenize this feature of the model by modelling the job destruction process and making the cost of finding a worker for a vacancy increasing in the level of formation or experience required to become suitable for the position. Such extension would add to the complexity of the model but keep the main message unchanged.

jobs than for high skill type of jobs. If the economy already features, before the introduction of temporary contracts, too many vacancies, as would be the case if entrepreneurs enjoyed high bargaining power over wages, then the introduction of temporary contracts generates a social loss as the marginal increase in the cost of finding a job imposed upon all unemployed workers outweighs the increase in the returns from posting vacancies reaped by the entrepreneurs. However, I also show that the welfare implications from introducing temporary contracts are of second order importance compared to the welfare gains/losses derived from adjusting the bargaining power of workers/entrepreneurs.

This paper draws from two extensive bodies of literature. First, there is a long string of studies on the implications of temporary contracts on unemployment, labour market flows and their cyclical properties. Examples include Blanchard and Landier (2002), Cahuc and Postel-Vinay (2002), Boeri and Garibaldi (2007) and Costain et al. (2010). The first paper looks at the effects of temporary contracts on unemployment and labour market flows and finds that temporary contracts, increase both job creation and job destruction flows so that the effects on equilibrium unemployment are ambiguous. The second paper looks into the political economy dimension of dual labour markets and provide an explanation of why governments found it easier to introduce temporary contract while preserving the usual high EPL contracts that were in place instead of reforming the whole labour market. These papers looked at steady state dynamics. By contrast, the paper by Boeri and Garibaldi (2007) looks at the transitional dynamics of the unemployment rate when temporary contracts are introduced and finds that employment grows upon the introduction of such contracts. However, over time this effect dissipates. The latter paper shows that temporary contracts increase the volatility of the unemployment rate. During the expansionary phase of the business cycle firms hire more agents through temporary contracts given the low firing costs entailed. However, upon the arrival of a recession and the consequent squeeze on the profit margins, firms fire workers under temporary contracts. Essentially, employees under temporary contracts act as a buffer against negative shocks. The model I develop in this paper defines temporary contracts in the same spirit as this literature in that temporary contracts are essentially a synonym of low firing costs.

Second, I draw from the literature on the equilibrium outcomes of search and matching models with heterogeneous jobs and workers. One example is the paper by Albrecht and Vroman (2002) where they show that two possible equilibria can exist: a separating equilibrium where each worker only accepts jobs that are in accord with their skill level and a pooling equilibrium where high skill workers accept both low and high skill type of jobs.

The model I develop features heterogeneous agents and workers as in Albrecht and Vroman (2002). However, in my model, job search is directed. That is, labour markets are differentiated and workers decide in which market they look for a job. A worker cannot be receiving offers from both types of jobs simultaneously.

The remaining of the paper is structured as follows. Section 1.2 presents the data and the empirical results. Section 1.3 presents a static equilibrium search and matching model that highlights the key ingredient of the dynamic model that I develop in Section 1.4. Section 1.5 uses the model developed in Section 1.4 to show that the introduction of temporary contracts increases job skill mismatch. Section 1.6 performs welfare analysis and Section 1.7 concludes.

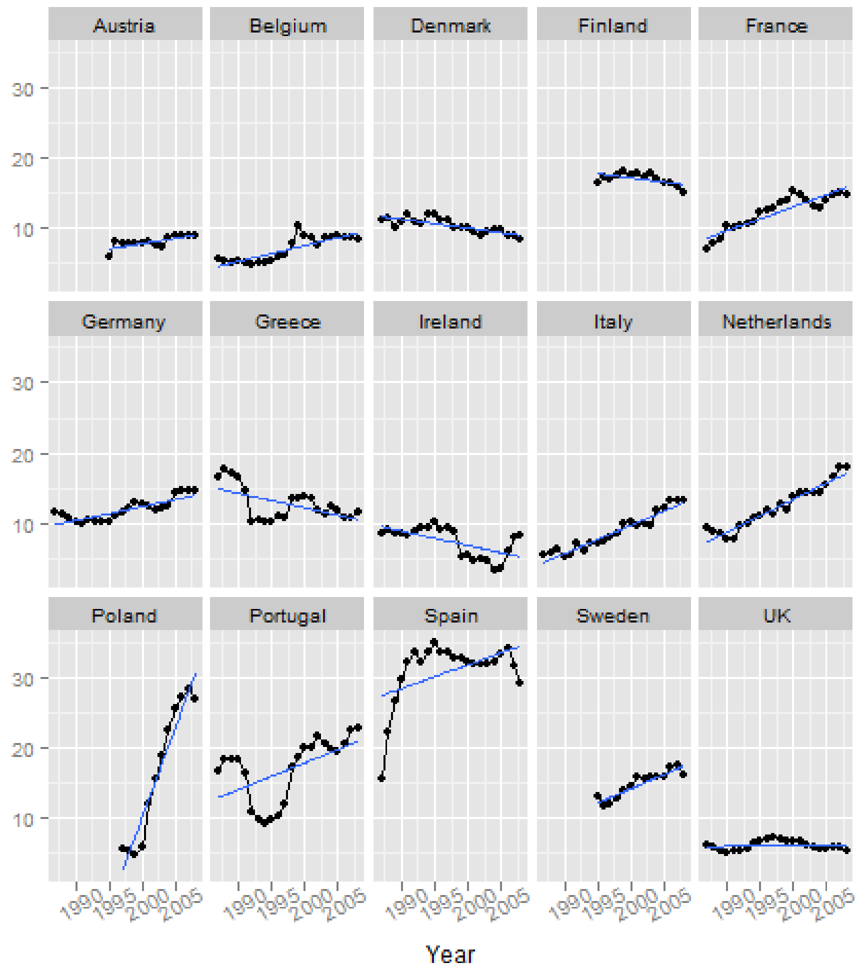
1.2 Empirics

I use data publicly available from Eurostat's Labour Force Survey. The dataset comprises a panel of 15 countries, the EU-15 group including Poland and excluding Luxembourg, with annual data from 1993-2008. I include Poland because the country has experienced in recent years a very strong increase in the share of employees working under a temporary contract while I exclude Luxembourg due to jumps in the time series data.

Temporary contracts have been introduced in several countries of the European Union since the late 70's. However, not all countries have implemented them with the same degree of intensity as the legal details of such contracts are very different across countries. Figure 1.1 shows the evolution, from 1987 until 2008, of the temporary rate across all countries included in the analysis. The temporary rate is defined as the share of employees working under a temporary contract out of all employees of a country. Eurostat defines a temporary contract as a contract that has a fixed specified duration of time or that will terminate if certain conditions are met, such as for instance completion of an assignment or the return of an employee who was being temporarily replaced. As one can see from the figure, there is a lot of variation across countries regarding the incidence of such contracts in the labour market.

I am interested in the evolution over time of the share of highly educated workers working for jobs for which they are over-qualified. To this end, I need to classify workers according to their occupation, educational attainment level and pay. Eurostat classifies all workers

Figure 1.1: Share of employees working with a temporary contract (in percentage points)



into ten different occupations according to the ISCO08 classification.[3] I disregard one of the groups, Armed Forces, as there are many breaks in the time series. Workers are also classified as highly educated according to Eurostat's definition, whereby an agent falls into the high education category if he or she has achieved at least a short-term tertiary educational program that lasted for at least two years or a Bachelor's degree or above.

Table 1.1 provides some descriptive statistics of each occupational group. In each column, I provide the average of the indicated value for each occupation and, in brackets, the standard deviation across the panel of countries. The second column —Share of HEW— denotes the

[3]These are: armed force occupations, managers, professionals, technicians and associate professionals, clerical support workers, service and sales workers, skilled agricultural, forestry and fishery workers, craft and related trades workers, plant and machine operators and assemblers and elementary occupations.

share of highly educated workers (HEW) that work in a certain occupation out of the total number of HEW.[4] Not to be confused by a related measure that would be the share of workers within a certain occupation that have a high degree of education (according to Eurostat's classification). The second column reports average annual earnings of each occupational category, according to Eurostat, and the last column —Temporary Rate— reports the share of employees out of all of the employees in that occupational category that work under a temporary contract.

Table 1.1: Occupations: descriptive statistics

Occupations	Share of HEW		Annual Earnings		Temporary Rate	
	Mean (%)	St. Dev.	Mean (euros)	St. Dev.	Mean (%)	St. Dev.
Managers	12.00	(4.11)	57,900	(17,000)	4.52	(2.5)
Technicians	20.04	(8.07)	34,300	(10,000)	9.67	(4.9)
Professionals	48.56	(8.54)	43,300	(14,000)	12.00	(4.9)
Clerks	7.69	(3.36)	27,100	(9,500)	11.43	(6.1)
Service & Sales	4.42	(1.91)	22,100	(8,000)	17.00	(8.1)
Skilled Agriculture	0.98	(0.61)	-	-	28.90	(8.9)
Craft & Trade	3.19	(2.64)	26,600	(10,000)	13.06	(9.0)
Assemblers	1.38	(0.81)	26,200	(9,000)	10.16	(7.2)
Elementary	1.44	(0.75)	22,100	(9,000)	19.94	(11.7)

Managers, technicians and professionals are the occupations that earn the most, hold 80 per cent of all the workers that classify as highly educated and have the least incidence of temporary contracts. The choice is subjective, but given this data I will, from here onwards, refer to these three occupational groups as the high skill, high pay occupations.

The baseline panel OLS regression equation that I run is the following one:

$$y^c_{i,t} = \alpha_i + \beta_i x^c_t + \gamma^c_i d_c + \delta_{i,t} d_t + \epsilon^c_{i,t}, \tag{1.1}$$

where subscripts $\{i, t, c\}$ denote occupation, time period and country, respectively. $y^c_{i,t}$ is the share of highly educated people working in occupation i at time period t in country c. x^c_t is country c temporary rate at time period t. d_c and d_t are country and time dummies included to capture common aggregate and individual fix effects and ϵ is the error term.

[4]The sum of the shares across the column should add up to 1. This is not exactly the case in table 1.1 because the category Armed Forces has been disregarded.

Table 1.2: Panel OLS regression output

Occupations	Specification 1	Specification 2		
	TR	TR	PR	UR
Managers	-0.19**	-0.16**	0.16**	-0.04
Technicians	-0.23**	-0.20**	-0.41**	-0.33**
Professionals	0.14	0.14	0.65**	0.33**
Clerks	0.16**	0.14**	-0.16**	0.02
Service & Sales	0.003	0.02	0.00	-0.05**
Skilled Agriculture	0.03**	0.01	-0.07**	0.00
Craft & Trade	0.03*	0.06**	0.03*	-0.05**
Assemblers	0.04**	0.04**	-0.03**	-0.01
Elementary	0.004	0.03*	-0.01	-0.04**
Adjusted $R^{2a,b}$	0.87		0.88	
Standard deviation	0.059		0.054	

[a]: average adjusted R^2.

[b]: adjusted R^2 expressed as a ratio, not as a percentage.

** and * indicate coefficient significant at the 5 and 10 per cent threshold, respectively. "TR" denotes temporary rate, "PR" denotes participation rate and "UR" denotes unemployment rate.

The results of the estimation of equation 1.1 are given in table 1.2 under the column "Specification 1". Note that each row represents a separate regression. As a result, instead of reporting a measure of goodness of fit for each regression, I report in the last two rows of table 1.2 the average adjusted R^2 and its standard deviation.

The results show that as the temporary rate increases in a country, the share of highly educated people working in high skill jobs such as "Managers" and "Technicians" falls, while the share in jobs that classify as less demanding in terms of skills such as "Clerks" increases. That I do not find a negative and significant coefficient for the occupational category "Professionals" does not come completely as a surprise. Professionals comprise people whose studies are highly specific such as doctors, architects and lawyers. These are the type of people I would expect to be less mobile occupation-wise.

There are, potentially, many confounding factors driving these estimation results. I run a second regression where I expand the set of regressors in an attempt to control for some of these. For instance, it could be that the baseline specification is simply capturing one of the consequences of the secular increase in the participation rate that has taken place during the second half of the century among European countries driven by the increased participation of woman in the labour market. Another potential problem comes from the fact that temporary contracts were introduced as a measure to bring down high unemployment rates. In times where unemployment is high, one can expect that even high skilled unemployed workers are willing to accept jobs that are not suited to their skill level given the high costs involved for finding the right type of job. As a consequence, it could be that the unemployment rate is the variable actually driving the results and temporary rate is just proxying for it. In the third column of table 1.2, called "Specification 2", I estimate the same regression equation as in (1.1) augmenting the set of controls with the participation rate and the unemployment rate of each country at each particular point in time. As one can see, the main results from the baseline specification remain.

Needless to say, this empirical analysis is just a first step towards a broader research agenda. Several factors can affect the results that I have just shown: productivity trends and quality of education provided, to name a few. I leave a more careful exploration of these elements as open avenues of future research.

In the remainder of this paper I develop a model that matches the main empirical observation presented in this section, namely, that countries that have made a more intensive use of temporary contracts have a higher proportion of highly educated workers in jobs for which they are over-educated. I advance in two steps: first, I develop a partial equilibrium model that captures in the simplest possible way the mechanism that produces the aforementioned empirical observation. Then, I develop and analyze the general equilibrium version of the model.

1.3 Static model

The model presented in Section 1.4 is built around the idea that some type of jobs —the low skill requirement type of jobs— become more profitable following the introduction of temporary contracts. In this section I develop an extremely simple search and matching model that formalizes this idea, which will then be developed further in Section 1.4.

Suppose the economy is comprised of workers that search for a job and entrepreneurs that post job vacancies. Once an unemployed worker and an empty job vacancy meet, they create a firm and produce. Workers and vacancies are homogeneous. Keeping a vacancy open costs ψ per period. In addition, and as is customary in the search and matching literature, the process of matching workers to empty vacancies is imperfect, it takes time and resources to find a job and the efforts are not always successful. To capture such process, there is a matching function that determines the number of successful matches among a pool of unemployed workers and job vacancies. To keep the analysis simple I consider, in this section, a simple version of the matching function:

$$M(v) = \varphi_0 v^{\varphi_1},$$

where v denotes the number of empty vacancies in the economy.

The model is very simple in that the number of successful matches is a function of the number of empty vacancies only, rather than function of the number of unemployed agents and empty vacancies as is standard in the literature of search and matching models (see Petrongolo and Pissarides, 2001).

The probability that a vacancy meets a worker is given by

$$q(v) = \frac{M(v)}{v} = \varphi_0 v^{\varphi_1 - 1}. \tag{1.2}$$

Once a job is created, the match may be destroyed immediately with probability λ, in which case it produces nothing. If the job is not destroyed, which happens with probability $1 - \lambda$, the match produces $y > 0$ and then the job is dissolved. Regardless, the entrepreneur has to pay cost c. This cost c captures the idea that each worker will eventually be fired. However, given the static nature of this model, the cost is paid immediately.

Thus, the value of a match for the entrepreneur is

$$J = (1 - \lambda) y - c, \tag{1.3}$$

and the value of opening a vacancy for the entrepreneur is

$$V = -\psi + \beta [q(v) J + (1 - q(v)) V],$$

where V is the value of a vacancy, J is the value of the match for the entrepreneur and $\beta = \frac{1}{1+r}$ is the discount factor. I assume parameters ensure that entrepreneurs find it profitable to create a job: $(1 - \lambda) y > c$.

A zero entry condition, $V = 0$, implies that

$$\psi = \beta q(v) J,$$

which using (1.2) and (1.3) can be rewritten as

$$v = \left(\frac{\varphi_0 ((1-\lambda) y - c)}{(1+r) \psi} \right)^{\frac{1}{1-\varphi_1}}. \tag{1.4}$$

I introduce temporary contracts in the model in a very simple way: temporary contracts allow the entrepreneur to avoid paying cost c if the job is destroyed immediately after creating it, which happens with probability λ. This modelling choice captures one of the key features of temporary contracts, namely, that they entail lower firing costs than other type of contracts.

Once temporary contracts are made available, all entrepreneurs will prefer to make use of one such contract given that they entail lower costs and the value of a match for the entrepreneur (J^T) becomes[5]

$$J^T = (1-\lambda)(y-c). \tag{1.5}$$

The number of vacancies posted in an equilibrium with temporary contracts, v^T, can be derived following the exact same steps as before, using equation (1.5) instead of (1.3):

$$v^T = \left(\frac{\varphi_0 (1-\lambda)(y-c)}{(1+r) \psi} \right)^{\frac{1}{1-\varphi_1}}.$$

It is very easy to verify that those firms that face a higher probability of not being able to produce (higher λ) benefit relatively more from the introduction of temporary contracts, which implies that the number of vacancies that will be posted in equilibrium to create that type of firms will increase by a higher proportional factor. In fact, denoting by Δ the proportional increase in vacancies induced by the introduction of temporary contracts:

$$\Delta = \frac{v^T}{v},$$

[5]Implicit in this analysis is an assumption that workers also prefer to work under a temporary contract or, even if they did not, cannot provide a suitable incentive to make entrepreneurs use other type of contracts.

I can verify that

$$\frac{\partial \Delta}{\partial \lambda} = \frac{1}{1-\varphi_1} \left(\frac{(1-\lambda)(y-c)}{(1-\lambda)y-c} \right)^{\frac{\varphi_1}{1-\varphi_1}} \frac{(y-c)c}{((1-\lambda)y-c)^2} > 0.$$

The model that I develop in the following section will have this basic mechanism at its core, which will ensure that the share of vacancies of certain types of firms —the low skill type of firms— will increase relative to other type of vacancies when temporary contracts are introduced. As the share of vacancies of the low skill type of jobs increases it will become less costly to find one such job, and, as a result, some unemployed workers that previously were looking for a different type of job will switch the pool of unemployment and begin searching for the low skill type of job.

1.4 General equilibrium model

In this section I place the mechanism developed in Section 1.3 within the context of a general equilibrium model. The model is made of two blocks: a household where all agents pool their income and make consumption decisions and a labour market where workers choose what type of job they search for and firms choose what type of workers they want to hire. The model features two types of contracts: regular and temporary contracts. Regular contracts last for an indefinite amount of time and are subject to firing costs whenever the firm wants to layoff the worker. Temporary contracts last for a shorter period of time and entail lower firing costs than regular contracts. The model encompasses the case where the government permits the use of regular contracts only.

First, I layout the labour market part of the model and its properties. I then describe the household sector and how consumption decisions are made. Afterwards I describe the equilibrium conditions of the model and analyze the results. All of the analysis is focused on steady states.

1.4.1 Labour market

I model the labour market in the spirit of the search and matching models with exogenous job destruction described in Pissarides (2000). Entrepreneurs post vacancies and workers look for jobs. The process of finding a job is costly and therefore it takes time and resources to obtain a job match. This costly search process is captured by the presence of an imperfect matching function that gives the number of successful matches, $M(u, v)$, when there are v available job vacancies and a pool u of unemployed workers searching for a job.

The economy is populated with a unit mass of heterogeneous workers and an infinite mass of potential entrepreneurs. Among the workers, there is an exogenous mass s of what I will refer to as low skill workers and a mass $1 - s$ of high skill workers. Accordingly, entrepreneurs can create two types of vacancies: vacancies with low skill requirements, v_L (low skill vacancies henceforth), and vacancies with high skill requirements, v_H (high skill vacancies henceforth). Upon a match, low skill vacancies evolve into a low skill job and high skill vacancies into a high skill job. I assume that low skill workers can only work in low skill jobs while high skill workers can work in any of the two types of jobs. I assume that model parameters are such that high skill jobs are also the jobs that entail high pay.

According to the model, a high skill type of job requires acquiring a certain set of skills in order to perform it successfully. Examples that come to mind are a pilot of an airplane or a veterinary. Instead, a low skill job any person can do without the need to acquire beforehand any set of specific skills. Bartenders or cleaners would fall into this category. Indeed, there are jobs that could potentially fall into any of the two categories. One example would be managerial types of jobs, whereby in principle any one could do it but one could think that a high degree of experience or a particular set of personal skills is highly recommended in order to perform it successfully.

There are two type of goods in this economy: goods produced by low skill jobs (which I will call low skill goods for brevity), c_L, and goods produced by high skill jobs (which I will call high skill goods), c_H. A low skill job produces y_L units of low skill goods while a high skill job produces y_H units of high skill goods. I assume that high skill workers with a low skill type of job are just as productive as low skill workers in a low skill job. I assume that low skill goods are the numeraire so that the price of the low skill good equals one, $p_L = 1$.

Job search in this model is directed, so workers decide which of job they look for. As a consequence, the labour market is split into two differentiated markets: a market for low skill type of jobs where low skill and high skill unemployed workers search for low skill vacancies and a market for high skill jobs where only high skill workers search for high skill job vacancies.[6] I denote by g the fraction of high skill unemployed workers searching for a

[6]For simplicity, I assume that once a high skill unemployed worker has made up his mind about which type of job to search for, it must devote all of its time and resources to that process. I preclude the possibility that this worker could be splitting efforts between searching, simultaneously, for both types of jobs.

low skill type of job.

I assume wages are determined through a Nash bargaining process, with the bargaining power of workers represented by the parameter ϕ_i, $i = \{L, H\}$, where sub-index i refers to the market: $i = L$ is the market for low skill jobs and $i = H$ is the market for high skill jobs. Thus, I allow the bargaining power of workers to be different depending on the market where they search for a job.

I define labour market tightness in the market for low skill jobs as:

$$\theta_L = \frac{v_L}{u_L + g u_H},$$

where $\{u_L, u_H\}$ denote the pool of low and high skill unemployed workers, respectively, and $g u_H$ denotes the fraction of unemployed high skill workers searching for a low skill job. Assuming, as is standard in the literature (see for instance Petrongolo and Pissarides, 2001), a matching function of the Cobb-Douglas type:[7]

$$M(u, v) = \bar{\mu} u^{\mu} v^{1-\mu}, \tag{1.6}$$

I get that the probability of finding a low skill job from the perspective of a worker is

$$m(\theta_L) = \frac{M(u_L + g u_H, v_L)}{u_L + g u_H},$$

and the probability of finding a suitable worker from the perspective of a vacancy for a low skill job is

$$q(\theta_L) = \frac{M(u_L + g u_H, v_L)}{v_L}.$$

Accordingly, I define labour market tightness in the market for high skill workers as:

$$\theta_H = \frac{v_H}{(1-g) u_H},$$

and the probability for the worker and a vacancy to find a match as

$$m(\theta_H) = \frac{M((1-g) u_H, v_H)}{(1-g) u_H},$$

[7] I assume the coefficients of the matching function are the same in both markets. I could easily relax this assumption but none of the main predictions of the model would be affected.

$$q(\theta_H) = \frac{M((1-g)u_H, v_H)}{v_H}.$$

Notice that by the Cobb-Douglas property, $\theta_i q(\theta_i) = m(\theta_i)$.

The Cobb-Douglas specification of the matching function does not guarantee matching probabilities falling within the $[0,1]$ interval. Thus, I impose that matching probabilities are bounded above by one. To be more precise:

$$m(\theta) = \begin{cases} \frac{M(u,v)}{u} & \text{if } \frac{M(u,v)}{u} \leq 1 \\ 1 & \text{if } \frac{M(u,v)}{u} > 1 \end{cases}.$$

The same truncation procedure holds for $q(\theta)$.[8]

Entrepreneurs can post vacancies at a cost $\{\psi_L, \psi_H\}$ depending on whether it is a low or a high skill type of vacancy. I assume that the cost of posting high skill vacancies is higher than the cost of posting low skill ones, $\psi_H > \psi_L$. Without this assumption it would not be possible to obtain an equilibrium where high skill workers take longer, on average, to find a high skill job than a low skill one, which is necessary to ensure that high skill workers face a relevant trade-off between looking for a high pay job that takes a long time to find or for a low pay job that is relatively easy to come by. Vacancies cannot be changed after forming a match with a worker.

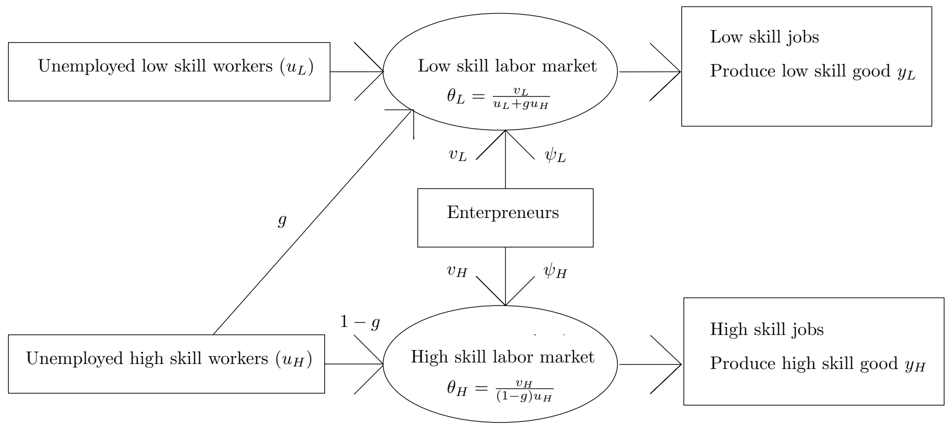
I assume an exogenous and constant job destruction rate. Turning the decision of terminating a working relationship endogenous would add realism but does not change the main properties of the mechanism that drives the results of the model. At every point in time, there is a probability λ_i, where $i = \{L, H\}$ denotes the type of job, that the match is destroyed.[9] Critically, I assume that the average duration of a low skill job is lower than that of a high skill job, $\lambda_L > \lambda_H$. This assumption, as already shown in Section 1.3, is crucial to ensure that low skill jobs benefit more than high skill jobs from the introduction of temporary contracts.

Figure 1.2 provides a graphical illustration of the labour market.

[8] An alternative elegant way to guarantee that matching probabilities fall within the $[0,1]$ interval is to use a matching function specification as in Den Haan et al. (1997)

[9] The job destruction shock (λ_i) incorporates both the case where the job is destroyed out of the employer's will as well as the case where the worker is the one that terminates the relationship. This difference is of relevance as the former case triggers firing costs while the latter should not. The model can be easily expanded to capture both instances by specifying two differentiated job destruction processes. However, there is no qualitative gain from introducing this layer of complexity. Thus, I assume that all layouts in the model trigger firing costs.

Figure 1.2: The labour market: pools and flows



1.4.1.1 Labour market flows

The amount of low skill unemployed workers in every period is given by the flow into and out of unemployment. As I do not allow for the "out of the labour force" category I can characterize the change in low skill unemployment as

$$u_{t+1}^{L} = u_t^L + \lambda_L \left(s - u_t^L\right) - m\left(\theta_t^L\right) u_t^L.$$

Tomorrow's unemployment rate of low skill workers is given by today's rate plus the share of low skill workers that loose a job minus the share of unemployed low skill workers who find a new job.[10] Recall that s denotes the share of low skill agents in the population. Following the same logic, the number of high skill unemployed workers at every point in time is given by

$$u_{t+1}^{H} = u_t^H + \left(j_t \lambda_L + (1 - j_t)\lambda_H\right)\left(1 - s - u_t^H\right) - \left(g m\left(\theta_t^L\right) + (1-g)\, m\left(\theta_t^H\right)\right) u_t^H,$$

where j_t represents the share of employed high skill workers working in a low skill job. j_t is also a measure of job skill mismatch in the economy.

At steady state these expressions become

$$u_L = \frac{\lambda_L}{\lambda_L + m\left(\theta_L\right)} s, \tag{1.7}$$

[10] *Strictu sensu*, u_L is the mass of low skill unemployed workers and $\frac{u_L}{s}$ is the unemployment rate among low skill workers. However, for the remainder of the paper, I use both terms, interchangeably, to refer to u_L, unless I specifically spell them out. A similar point applies to u_H.

$$u_H = \frac{j\lambda_L + (1-j)\,\lambda_H}{j\lambda_L + (1-j)\,\lambda_H + gm\,(\theta_L) + (1-g)\,m\,(\theta_H)}\,(1-s)\,. \tag{1.8}$$

I can also characterize the evolution of j_t, the share of employed high skilled workers working in low skill jobs, as the difference between those high skill workers who find and those who lose their low skill job:

$$j_{t+1}\left(1-s-u_{t+1}^H\right) - j_t\left(1-s-u_t^H\right) = m\left(\theta_t^L\right) g_t u_t^H - \lambda_L j_t\left(1-s-u_t^H\right),$$

which in steady state becomes

$$j = \frac{m\,(\theta_L)}{\lambda_L}\frac{gu_H}{1-s-u_H}. \tag{1.9}$$

Equations (1.7), (1.8) and (1.9) define a system of three equations in six unknowns: u_L, u_H, g, j, θ_L, θ_H. Thus, I need to layout three further conditions to pin down the whole system.

1.4.1.2 Regulatory framework: regular and temporary contracts

I consider two types of contracts: regular and temporary contracts. The model encompasses the case where only regular contracts are allowed. Regular contracts last until the arrival of the exogenous job destruction shock λ_i. Once the match is terminated, firms pay firing costs f which, for simplicity, I assume are the same across all types of firms.

The term firing costs is usually related to the severance package that entrepreneurs pay to the worker after the worker has been made redundant. From a theoretical perspective, such transfer may be of little economic relevance as it can be compensated for in the wage bargaining process between the two sides of the working relationship, see for instance Lazear (1990).[11] By contrast, in this model, firing costs denote the red tape cost component of laying off a worker: those costs that constitute payments to third parties such as labour courts and labour authorities or just simply the time and resources spent to process the layoff. These costs are potentially significant. For instance, Kramarz and Michaud (2010) find that, in France, the marginal cost of an individual layoff is on average one quarter in terms of wages and 10 months for a collective dismissal, of which they estimate that one third corresponds to red-tape cost. Bentolila et al. (2010) report that in Spain, firms are willing to

[11] Indeed, this is the case in the model presented in this paper as I assume Nash wage bargaining.

pay severance payments to workers that are in excess of statutory or collectively-bargained payments in order to resolve dismissals in a quick manner and avoid going to court.[12]

Thus, I model firing costs as a tax that entrepreneurs pay to the government when the match is terminated. This specification implies that entrepreneurs perceive f as a cost when deciding whether to post a new job vacancy but workers do not perceive them as a transfer obtained from the termination of the job. According to this modelling strategy, firing costs do not represent a destruction of resources as I assume that the government will distribute these rents back to the household who ultimately distributes all of the income across its members.

Temporary contracts last on average a shorter period of time than regular contracts and entail much lower firing costs. For simplicity, I will assume that they trigger no firing costs: $f^T = 0$. To model the lower expected duration of temporary contracts I assume that temporary contracts expire with a probability δ every period and, in addition, are also exposed to the arrival of the job destruction shock λ_i.

Once a temporary contract expires, the entrepreneur and the worker can move onto a regular contract. The move from a temporary contract to a regular contract is done via a renegotiation of the wage and does not require the worker entering the pool of unemployed agents at any point in time. It is possible to show that, upon a match, all entrepreneurs will want to offer a temporary contract first, and once the temporary contract expires, a regular contract. The intuition is simple, as in this model temporary contracts are, in essence, regular contracts that entail lower firing costs. As such, entrepreneurs will always find it advantageous to offer such contracts first. By contrast, as I show in Appendix 1.8.1, workers would prefer a regular contract from the start, as the threat that firing costs represent for the entrepreneur in the event of a layoff improves the bargaining position of the worker. To preclude the possibility that the worker obtains a regular contract from the start by negotiating a lower wage with the entrepreneur, I assume workers cannot commit to such low wage.

Temporary contracts expire at the beginning of the period before production has taken place while job destruction shocks arrive at the end of the period after production has taken place. As a job under a temporary contract is still subject to the exogenous job destruction shock λ_i, $i = \{L, H\}$, the expected duration of a match that uses temporary contracts remains unchanged relative to the duration of an hypothetical job that only uses regular contracts. If

[12] While the wage bargaining process, in the model presented in this paper, internalizes severence payments between entrepreneurs and workers, I assume that the premia that firms are willing to pay in order to avoid processing a layoff through a court are not.

a temporary contract receives a job destruction shock, then the match is terminated and it is not possible to get the entrepreneur and worker to agree to keep working under a regular contract.

1.4.1.3 Value functions

I list below the set of value functions that govern the decisions of entrepreneurs and workers. In all instances, except when stated otherwise, subscript $i = \{L, H\}$ denotes the type of job.

$$J_i^T = (1-\delta)\left(p_i y_i - w_i^T + \beta\left[\lambda_i V_i + (1-\lambda_i) J_i^T\right]\right) + \delta \max\{V_i, J_i\}, \quad (1.10)$$

$$J_i = p_i y_i - w_i + \beta\left[\lambda_i (V_i - f) + (1-\lambda_i) J_i\right], \quad (1.11)$$

$$V_i = -\psi_i + \beta\left[q(\theta_i)\max\left\{V_i, J_i^T\right\} + (1 - q(\theta_i)) V_i\right], \quad (1.12)$$

$$W_i^T = (1-\delta)\left(w_i^T + \beta\left[\lambda_i U_i + (1-\lambda_i) W_i^T\right]\right) + \delta \max\{U_i, W_i\}, \quad (1.13)$$

$$W_i = w_i + \beta\left[\lambda_i U_i + (1-\lambda_i) W_i\right], \quad (1.14)$$

$$U_i = b + \beta\left[m(\theta_i)\max\left\{U_i, W_i^T\right\} + (1 - m(\theta_i)) U_i\right]. \quad (1.15)$$

J_i^T and J_i denote the value, for the entrepreneur, of a job under a temporary contract and the value of a job under a regular contract, respectively. W_i^T and W_i are the worker counterparts. V_i denotes the value for an entrepreneur of posting a vacancy and U_i denotes the value for a worker of being unemployed in market $i = \{L, H\}$. w_i^T and w_i denote the wage earned by a worker in a job under a temporary contract and a job under a regular contract, respectively. p_i is the relative price of each type of good. As the low skill type of good is the numeraire, $p_L = 1$. $\beta = \frac{1}{1+r}$ is the subjective time discount factor and b captures income earned by unemployed agents, either in the form of unemployment benefits or home production. Notice that if temporary contracts expire immediately, which happens when $\delta = 1$, the model is akin to a case where the government does not allow the use of temporary contracts at all.

In all the discussion that follows, I proceed under the assumption that parameter values are such that upon a match, workers prefer to work and entrepreneurs prefer filling a vacancy rather than keeping it open, that is,

$$\max\left\{V_i, J_i^T\right\} = J_i^T, \quad \max\{V_i, J_i\} = J_i,$$

$$\max\left\{U_i, W_i^T\right\} = W_i^T, \quad \max\{U_i, W_i\} = W_i.$$

I distinguish between the total surplus of a match under a temporary contract and that of a match under a regular contract. When a match is formed under a temporary contract, the total surplus is

$$S^T = J^T + W^T - U - V, \tag{1.16}$$

whereas when a match is formed under a regular contract the total surplus is

$$S_i = J_i + W_i - U_i - V_i + f. \tag{1.17}$$

Firing costs, f, appear in S_i because continuing the match under a regular contract implies that firing costs do not have to be paid.

Using equations (1.11) and (1.14) we can rewrite equation (1.17) as

$$S_i = \frac{(1+r)\, p_i y_i + rf - rU_i}{r + \lambda_i}. \tag{1.18}$$

In addition, using equations (1.10), (1.13), (1.16) and (1.18) I can re-write the surplus of a new match under a temporary contract as

$$S_i^T = \frac{(1+r)\, p_i y_i - rU_i - \frac{(1+r)\delta}{r+\delta+\lambda_i(1-\delta)}\lambda_i f}{r + \lambda_i}. \tag{1.19}$$

Imposing the free entry condition ($V_i = 0$) on equation (1.12) delivers

$$J_i^T = \frac{(1+r)\, \psi_i}{q(\theta_i)}. \tag{1.20}$$

Entrepreneurs are willing to post new vacancies up to the point where the benefit for the entrepreneur of an extra job (the left-hand side) equals the expected cost (the right-hand side), which is the average time it takes to find a worker times the cost of keeping the vacancy open.

In order to obtain the job creation equation recall that Nash bargaining implies a proportional split among the entrepreneur and the worker of the total surplus of the match:

$$J_i^T = (1 - \phi_i)\, S_i^T, \tag{1.21}$$

and

$$W_i^T - U_i = \phi_i S_i^T. \tag{1.22}$$

Equations (1.15), (1.20), (1.21) and (1.22) provide the value of unemployment as a function of labour market tightness, θ_i:

$$\frac{r}{1+r} U_i = b + \frac{\phi_i}{1-\phi_i} \theta_i \psi_i. \tag{1.23}$$

Keeping everything else constant, the value of being unemployed in each market is increasing in the non-labour income component that unemployed agents receive; it increases in the cost of posting vacancies, as a higher cost of posting vacancies implies that entrepreneurs require a higher surplus from the match which in turn benefits the workers through Nash bargaining; it also increases in the worker bargaining power ϕ_i, as workers capture a higher share of the match surplus, and on labour market tightness, as it increases the probability of finding a job for a worker and therefore diminishes the cost of turning down the current job offer (captured by the amount of time it would take to find another match).

Once I have the expression for the value of unemployment I can plug it back into equation (1.19), and in turn, plug the result into condition (1.20) to obtain the job creation condition for each type of vacancy $i = \{L, H\}$ as a function of labour market tightness in each market, θ_i, and the price of each type of good, p_L and p_H:

$$(1-\phi_i) \frac{p_i y_i - b - \frac{\delta}{r+\delta+\lambda_i(1-\delta)} \lambda_i f}{r + \lambda_i + \phi_i m(\theta_i)} = \frac{\psi_i}{q(\theta_i)}. \tag{1.24}$$

Recall that the price of the low skill good is the numeraire, $p_L = 1$, which means that p_H (p henceforth) becomes the relative price of high skill goods relative to that of low skill goods.

The job creation condition states that entrepreneurs are willing to post vacancies until the cost of posting one such vacancy, a term captured by the right hand side of equation (1.24) which is given by cost of keeping a vacancy open times the expected amount of time that it will take before a worker fills the vacancy, equals the benefits of posting the vacancy. The benefits are captured by the left hand side of equation (1.24) and are composed of the discounted value of the payment, net of wages, that the entrepreneur receives from the match, scaled by the Nash bargaining parameter that reflects the wage bargaining power of entrepreneurs.

When $\delta = 1$, a situation where the government does not allow the use of temporary contracts, equation (1.24) becomes

$$(1-\phi_i)\,\frac{p_i y_i - b - \frac{1}{1+r}\lambda_i f}{r+\lambda_i+\phi_i m(\theta_i)} = \frac{\psi_i}{q(\theta_i)}. \tag{1.25}$$

1.4.1.4 The job creation condition

Before describing the remaining elements of the model, it is convenient to examine carefully the job creation condition. In particular, I focus on the key ingredient of the model, which was already introduced in Section 1.3: the differential impact that temporary contracts have on the incentives to post each type of vacancy as a function of the probability of paying firing costs, λ_i $i = \{L, H\}$.

From the job creation condition (1.24), it is easy to check that whenever temporary contracts are allowed, $\delta < 1$,

$$\frac{\delta}{r+\delta+\lambda_i(1-\delta)} < \frac{1}{1+r},$$

which means that temporary contracts increase the return of posting vacancies for any entrepreneur. Notice as well that whenever $\delta < 1$,

$$\frac{\partial\left(\frac{\delta}{r+\delta+\lambda_i(1-\delta)}\right)}{\partial\lambda_i} < 0,$$

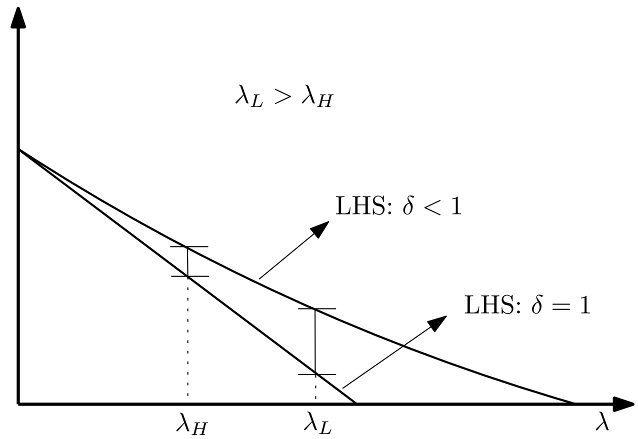
which implies that, given $\lambda_L > \lambda_H$, the reduction in the expected value of firing costs is higher for entrepreneurs posting low skill vacancies than for those posting high skill vacancies. This can easily be seen in figure 1.3, where I plot the left hand side of equation (1.24) after rewriting it in the following way:

$$(1-\phi_i)\left(p_i y_i - b - \frac{\delta}{r+\delta+\lambda_i(1-\delta)}\lambda_i f\right) = \frac{r+\lambda_i+\phi_i m(\theta_i)}{q(\theta_i)}\psi_i. \tag{1.26}$$

The left hand side of of equation (1.26) represents the returns that an entrepreneur obtains from a match and is function of, among other variables, λ_i. The larger is this term, the larger is labour market tightness, θ_i, as the right hand side of equation (1.26) is increasing in θ_i.[13]

[13] This discussion is meant for illustrative purposes and as such assumes that the relative price of the high skill good, p, is constant. In deriving the solution of the model I will take into account the endogenous

Figure 1.3: The benefits of introducing temporary contracts for the entrepreneur



The straight line in figure 1.3 represents the left hand side of equation (1.26) for the case where no temporary contracts are allowed, $\delta = 1$, while the curved line represents the left hand side of equation (1.26) when temporary contracts are allowed, $\delta < 1$. The curvature is given by the presence of the term $\frac{\delta}{r+\delta+\lambda_i(1-\delta)}$ in front of the expected value of firing cost payments, $\lambda_i f$, and captures the reduction in expected firing costs induced by the use of temporary contracts. The difference between the two lines captures the increase in returns that a match experiences once temporary contracts are made available. From figure 1.3 is easy to gauge that a firm with a higher probability of receiving a job destruction shock benefits more from the presence of temporary contracts.

1.4.2 Household sector

The economy is composed of one large household which houses a unit mass of workers and an infinite mass of entrepreneurs. Unemployed workers always search for a new job, which means that labour force participation is exogenous and equal to one. The household pools all income from workers and entrepreneurs, so all idiosyncratic risk is diversified away, and chooses how much to consume of the two types of goods that firms produce in the economy, $\{c_L, c_H\}$. In addition, the household takes as given all decisions taken by workers and entrepreneurs.

The household solves:

response of p to movements in other parameters.

$$\max_{\left\{c_t^L, c_t^H\right\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t u\left(c_t^L, c_t^H\right)$$

$$s.t.: \; c_t^L + p_t c_t^H = A_t$$

where β denotes the subjective discount factor and A_t all income that the household perceives from the agents of the economy. A_t includes total labour income from workers, firm profits, income generated by unemployed workers, the cost of posting vacancies and firing costs that the government collects and transfers back to the household. It can be expressed as:

$$A_t = (1 - j_t)\left(1 - s - u_t^H\right) p_t y_t^H + \left(j_t\left(1 - s - u_t^H\right) + s - u_t^L\right) y_t^L + b_t\left(u_t^L + u_t^H\right) - v_t^L \psi_L - v_t^H \psi_H.$$

The first term of the right hand side captures all the resources, expressed in terms of low skill goods, produced by high skill jobs. The second term expresses the income generated by low skill jobs. The third term corresponds to the total amount of income that comes from the unemployed and the last two terms captures the cost of posting vacancies. Note that firing costs do not appear as they cancel out with firm profits.

The FOC, at steady state, of the household problem states that the relative price of high skill goods equals the ratio of marginal utilities:

$$p = \frac{u_2\left(c_L, c_H\right)}{u_1\left(c_L, c_H\right)},$$

where the subscript in front of the utility function denotes the partial derivative with respect to the argument of the function.

Nothing prevents me from using a standard CES utility function and the model can be solved with such function. However, in order to find, without resorting to numerical methods, the sign of some of the total derivatives that will be derived in Section 1.5, it is convenient to use a quasi-linear utility function of the form:

$$u\left(c_t^L, c_t^H\right) = c_t^L + \ln\left(c_t^H\right).$$

In this case, the first order condition becomes

$$p = \frac{1}{c_H}. \tag{1.27}$$

The relative price of high skill goods is inversely related to the quantity available of such goods.

1.4.3 Equilibrium

In this section I present the system of equations that describe the steady state equilibrium of the model. Before doing so, I layout the condition that ensures that, in equilibrium, high skill unemployed workers are indifferent between searching for a low or a high skill job.

1.4.3.1 Labour market search choice

In the model, low skill unemployed workers can only search for low skill jobs.[14] By contrast, high skill unemployed workers have to choose whether to look for a low or a high skill type of job. They decide according to what is more profitable for them, which is captured by the value of being unemployed in each market, $\{U_L, U_H\}$. In an equilibrium with a non-corner solution, unemployment values must be equalized:

$$U_L = U_H,$$

which, using equation (1.23), implies that

$$\frac{\phi_L}{1-\phi_L}\theta_L\psi_L = \frac{\phi_H}{1-\phi_H}\theta_H\psi_H. \tag{1.28}$$

Fluctuations in the relative price of high skill goods (p) ensure that equality (1.28) holds. Suppose the value of searching for a high skill job is higher than that of a low skill job, *i.e.* $U_H > U_L$. If this is the case, high skill workers that previously where searching for a low skill job will switch and search for a high skill type of job. On aggregate, this implies a larger number of firms producing high skill goods, which increases the total amount of high skill goods available in the economy. Thus, the relative price of high skill goods has to fall for the goods market to clear, see equation (1.27). The decline of the relative price of high skill goods will decrease the incentives to post vacancies for high skill jobs and the market for high skill jobs will become more congested as the inflow of high skill unemployed

[14] Workers could actually choose not to work, but parameters values are imposed such that all unemployed workers want to find a job.

workers coming from the low skill market is not matched by the same proportional increase of vacancies for high skill jobs. Ultimately, the value of being unemployed in the high skill market will fall as the time it takes to find a job vacancy increases. This process will continue until unemployment values are equalized.

1.4.3.2 Goods market equilibrium

In equilibrium, all goods produced must be consumed. Total production of high skill goods is given by the total amount of goods produced by high skill jobs,

$$c_H = (1-j)\,(1-s-u_H)\,y_H, \tag{1.29}$$

while the total amount of low skill goods is given by the amount produced by low skill jobs plus all the goods produced by unemployed agents, which are expressed in terms of the low skill good, minus those resources spent in keeping vacancies open,

$$c_L = j\,(1-s-u_H)\,y_L + (s-u_L)\,y_L + b\,(u_L+u_H) - v_L\psi_L - v_H\psi_H. \tag{1.30}$$

Firing costs do not appear anywhere as they are a transfer of resources, not pure waste.

1.4.3.3 Equilibrium conditions

The steady state equilibrium is described as the following set of conditions:

- Equation (1.27) ensures that the household maximizes utility.[15]
- The job creation condition (1.24) for $i = \{L, H\}$ guarantees that entrepreneurs post vacancies until the benefit of doing so equals the cost.
- Equation (1.28) makes sure that high skill workers are indifferent between labour markets.
- Goods market clear (equations (1.29) and (1.30)).

[15]Given concavity properties of the objective function.

- Flows into and out of unemployment, together with the pool of high skill workers working in low skill jobs satisfy the steady state conditions given by equation (1.7), (1.8) and (1.9).

These conditions pin down the value of the following set of endogenous variables: c_L, c_H, θ_L, θ_H, u_L, u_H, g, j, p.

1.4.3.4 The role of heterogeneous goods

A question arises about the need to include heterogeneous goods in the model. The answer to this question is that heterogeneous goods allow for a mechanism that ensures that, in equilibrium, the value of being unemployed in each market is equalized.

In principle one would expect that the model with only one type of good, and no price fluctuations, as the price of the homogeneous good would be normalized to one, would still feature an equilibrium where unemployment values are equalized across both markets. The mechanism should work as follows. Suppose the value of searching for a low skill job is higher than that of searching for a high skill job, $U_H < U_L$. In such instance, some high skill unemployed workers searching for high skill jobs would switch and start searching for a low skill job. High skill unemployed workers would flow into the pool of unemployed agents searching for low skill jobs and congest the market for low skill jobs (θ_L would decrease) which would increase the expected amount of time it would take for an unemployed worker in the low skill market to find a job. Such congestion should reduce the value of searching for a low skill job up until the point where the value of being unemployed in both markets is equalized.

Turns out this is not necessarily the case. In Appendix 1.8.2 I show that the model presented in this paper with no fluctuations in the relative price of high skill goods always results in a corner solution where all high skill unemployed workers search for one type of job only.[16] There are two reasons behind this result. First, the chain of thought I outlined before did not consider the reaction of entrepreneurs to the increased flow of unemployed workers into the pool of unemployed agents. Indeed, as high skill unemployed agents flow into the pool of unemployed workers searching for a low skill job, the value of posting a vacancy for a low skill job increases, as it now takes less time to fill one such vacancy, which implies that the number

[16] Unemployment values would not be equalized in this model. If they were, it would be because model parameters have been calibrated with this target in mind.

of vacancies posted for low skill jobs increases. Thus, the reaction of θ_L is ambiguous, which leads me to the second element: if the matching function is of constant returns to scale form, what determines labour market tightness is not the number (or mass) of unemployed agents or vacancies, but rather the ratio of the two. If one adds more unemployed agents into the pool of unemployed, the value of posting vacancies increases proportionally and therefore the number of vacancies in equilibrium increases by the same proportion, leaving the ratio of the two unchanged. Ultimately, this means that the value of being unemployed in any of the two markets does not depend on the number of agents unemployed in those markets. There is no equilibrium force that ensures that unemployment values will be equalized. Adding agents into the pool of unemployed workers is akin to scaling up the economy, but does not change the vacancy to unemployment ratio.

There are many ways to break this result and the simplest of them consists in using a non-constant returns to scale matching function. However, this choice adds to the complexity of the model while the avenue that I have chosen, based on heterogeneous goods and allowing for fluctuations in the relative price of goods, adds very little further complexity while preserving many of the desirable properties of the standard constant returns to scale matching function.

1.5 Results

It is convenient to establish some notation that I will use repeatedly. In particular, I will denote the elasticity of a generic variable x with respect to δ in the limiting case where $\delta \to 1$ as:

$$\varepsilon_{x,\delta} \mid_{\delta\to 1}= \frac{dx/x}{d\delta/\delta} \mid_{\delta\to 1} .$$

Having established this bit of notation, what I will show in this Section is that under some conditions on the parameters of the model, the introduction of temporary contracts increases the share of high skill workers working in low skill jobs, or, more precisely, that the elasticity of j against δ, for the limiting case where $\delta \to 1$, is negative:

$$\varepsilon_{j,\delta} \mid_{\delta\to 1}< 0. \tag{1.31}$$

I compute the derivative at the limiting case where δ approaches 1 for two reasons: first, $\delta = 1$ represents a situation where temporary contracts are not allowed. Second, it allows me to derive an analytical proof of the sign of the elasticity. Nevertheless, in Section 1.5.2

I relax this assumption and resort to numerical methods to compute the value of $\varepsilon_{j,\delta}$ for a range of values of δ.

Proposition:

Suppose the matching function takes the functional form given by (1.6), Nash bargaining weights in both labour markets are equal to the elasticity of the matching function with respect to unemployment ($\phi_L = \phi_H = \mu$), the probability of receiving a job destruction shock is higher for a low skill job than for a high skill job ($\lambda_H < \lambda_L$) and the cost of a vacancy for a low skill job is smaller than that of a high skill job ($\psi_L < \psi_H$). Then, the following set of model elasticities have the following sign:

$$\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} < 0 \tag{1.32}$$

$$\varepsilon_{\theta_H,\delta} \mid_{\delta\to 1} < 0 \tag{1.33}$$

$$\varepsilon_{\theta_H,\delta} \mid_{\delta\to 1} = \varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} \tag{1.34}$$

$$\varepsilon_{u_L,\delta} \mid_{\delta\to 1} > 0 \tag{1.35}$$

$$\varepsilon_{p,\delta} \mid_{\delta\to 1} < 0 \tag{1.36}$$

$$\varepsilon_{j,\delta} \mid_{\delta\to 1} < 0 \tag{1.37}$$

If, in addition, I assume that $\frac{\lambda_L}{\lambda_H} < \left(\frac{\psi_H}{\psi_L}\right)^{1-\mu}$, then

$$\varepsilon_{u_H,\delta} \mid_{\delta\to 1} > 0 \tag{1.38}$$

The proof is described in Appendix 1.8.3.

The parametric assumptions described in the Proposition constitute a sufficient condition. For instance, it would be possible to find that all the signs of the elasticities described in the proposition would hold for some $\tilde{\lambda}_L$ such that $\tilde{\lambda}_L < \lambda_H$, if all the remaining parametric assumptions were to hold —the intuition will be discussed briefly. Also, the assumption on the Nash bargaining parameters, $\phi_L = \phi_H = \mu$, is a version of the Hosios condition (Hosios, 1990) and simplifies the analysis required to derive the sign of the set of elasticities presented in the Proposition above. The Hosios condition is not crucial for the proof, meaning that

I could still obtain parameter conditions that guarantee condition (1.31) holds. However, a simple analytical result would not be available.

The Proposition tells us that introducing temporary contracts increases labour market tightness in both markets, leads to a decline in the unemployment rate of both type of workers, increases the relative price of high skill goods and increases the share of high skill workers working in low skill jobs.

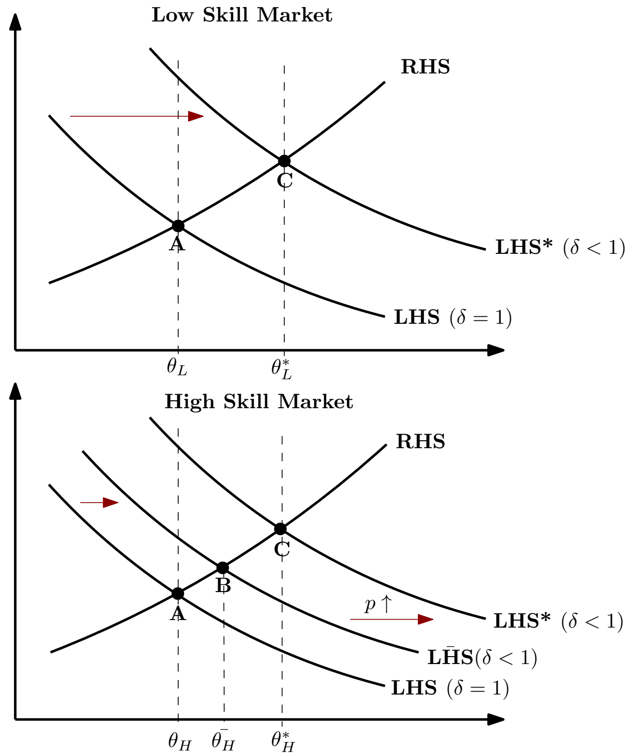
These results hinge on temporary contracts creating a stronger incentive to post low skill vacancies than high skill ones. They do so for for two different reasons. First, firing costs, unemployment benefits and the cost of posting vacancies are expressed in absolute terms. They are not proportional to, say, output. As a consequence, for a given absolute value increase in the returns of posting a vacancy, in relative terms it is the low skill type of vacancy that benefits the most, as the ratio of the change in returns to cost of opening a vacancy is higher. In fact, this channel makes the parameter requirement that $\lambda_H < \lambda_L$ a sufficient condition for deriving the results in the Proposition, but not a necessary one. It is possible to have that the expected duration of low skill job is higher than that of high skill job ($\lambda_L < \lambda_H$) and yet obtain the same set of results of the Proposition, because in relative terms it would still be the value of low skill vacancies the ones that would increase the most.[17] This channel, however, would disappear if firing costs, unemployment benefits and the cost of posting new vacancies were proportional to output in each market; see Appendix 1.8.4 for a formal proof.

Second, and following the discussion in Section 1.4.1.4, as low skill vacancies are more likely to pay firing costs ($\lambda_L > \lambda_H$), they experience a larger cost reduction, in expected terms, derived from the introduction of temporary contracts. As a consequence, the value of a low skill match increases by more than that of a high skill match. This would be true even if output produced, firing costs and costs of posting vacancies were proportional to wages in each market.

Once the effects of temporary contracts on the incentives to post each type of vacancies are understood, the remaining results follow suit. A diagram will make the intuition easier. Figure 1.4 plots the job creation condition (1.24) for both the low and high skill market. As it can be seen in equation (1.24) and using the fact that $q(\theta)$ is decreasing in θ, the cost of posting a new vacancy, the right hand side (RHS) of the equation, is increasing in labour

[17] There is, however, a lower bound for λ_L relative to λ_H, which is a function of ψ_L and ψ_H. For further details the reader is referred to Appendix 1.8.3.

Figure 1.4: Equilibrium in each labour market



market tightness, θ. The revenue, the left hand side (LHS), is decreasing in θ instead. The starting point denoted by point A in both markets is an hypothetical situation where the government does not allow temporary contracts ($\delta = 1$) and the equilibrium value of labour market tightness that comes out of this situation is denoted by θ_L and θ_H for the low and high skill market respectively.[18] Once the government allows the use of temporary contracts, the returns from opening a vacancy increase in both markets. As such, the LHS condition shifts to the right in both markets. However, for the reasons described before, the shift is larger in the low skill market so the new equilibrium in the low skill market becomes point C while that of the high skill market reaches only point B. As a result, unemployed agents in the low skill market are better off compared to those in the high skill market. At this point, some high skill workers previously searching for high skill jobs will find it profitable to switch market and start looking for a low skill job instead. As this process takes place, the amount of high skill goods produced declines, pushing up the price of such goods which in turn makes high skill jobs more profitable. As the price increases, the value of posting a new vacancy in

[18]Bear in mind that the figure is helpful for illustrative purposes but the magnitudes are not precise. For instance, in general it won't be the case that $\theta_L = \theta_H$ as it would appear to be suggested by the diagram.

the high skill market increases, as exemplified by the second shift of the LHS condition in the bottom panel of figure 1.4. Entrepreneurs post new vacancies for high skill jobs until labour market tightness in the high skill market is sufficiently high so as to make the value of being unemployed in both markets equal. At the new steady state equilibrium, unemployment has fallen in both markets and there are more high skill workers working in low skill jobs, thus increasing the level of mismatch in the economy. In Appendix 1.8.5 I provide a formal proof to show that, indeed, θ_H would increase by less than what the equilibrium in the model implies if the relative price of high skill goods was not allowed to adjust, just as it would happen if the model featured homogeneous, rather than heterogeneous, goods.

A question arises about the sensitivity of the results that I have presented so far. The sign of $\varepsilon_{j,\delta} \mid_{\delta\to 1}$ was derived under a set of restrictions on parameter values, most importantly that the Hosios condition held, $\phi_L = \phi_H = \mu$, and that the derivative was evaluated at $\delta = 1$. In Section 1.5.2 below I test the sensitivity of my results by relaxing some of these parametric assumptions. To do so, I will solve the model numerically and provide the sign of the derivative of the fraction of mismatched high skill workers with respect to the probability of temporary contracts expiring, $\frac{dj}{d\delta}$, as a function of a range of parameter values. However, before doing so, I need a reasonable calibration of the model that I can use as a benchmark.

1.5.1 Calibration

The calibration of the parameters of the model is shown in table 1.3 and has been implemented with two goals in mind: first, parameter values and model output should be reasonable and reflect real world data; second, parameters values should ensure an interior solution of the model where high skill workers find optimal to look for low skill jobs. The aim is to obtain a reasonable calibration to analyze the welfare properties of the model while acknowledging that the model is still too simple to perform a serious quantitative exercise.

The length of a model period is set to one quarter. The interest rate has been set to 1 per cent and following Petrongolo and Pissarides (2001), I set the elasticity of the matching function with respect to unemployment, μ, and the Nash bargaining parameters $\{\phi_L,\phi_H\}$ equal to 0.5.

I will match certain aspects of the data to the Spanish economy given the prominent presence of temporary contracts in that economy (see figure 1.1). Bentolila et al. (2010) estimate that unemployment benefits (b) in Spain are around 58 per cent of a worker's wage. As

Table 1.3: Model parameter values

Parameter	Value	Source
Output low skill match (y_L)	3	—
Output high skill match (y_H)	1	—
Low skill vacancy cost (ψ_L)	0.5	—
High skill vacancy cost (ψ_H)	2.5	—
Separation rate low skill match (λ_L)	0.072	Match expected job duration high skill occupations
Separation rate high skill match (λ_H)	0.058	Match expected job duration low skill occupations
Probability FTC expires (δ)	0.88	Bentolila et al. (2010)
Interest rate (r)	1%	Standard quarterly value
Firing cost (f)	$1.1 \times y_L$	Kramarz and Michaud (2010)
Share low skill workers (s)	58.9%	Match share of workers in Spain with tertiary education
Unemployment benefits (b)	$0.58 \times y_L$	Bentolila et al. (2010)
Bargaining power low skill workers (ϕ_L)	0.5	Petrongolo and Pissarides (2001)
Bargaining power high skill workers (ϕ_H)	0.5	Petrongolo and Pissarides (2001)
Coefficient matching function ($\bar{\mu}$)	0.59	Match spanish pre-crisis unemployment rate of 10%
Elasticity matching function (μ)	0.5	Petrongolo and Pissarides (2001)

unemployment benefits in this model are expressed as absolute rather than relative values, I set b equal to 58 per cent of the quarterly value of production of low skill jobs. Kramarz and Michaud (2010) estimate that the value of red-tape firing costs in Spain is around 80 days of wages, or 1.1 quarters. As with the calibration of unemployment benefits, I set firing costs f to equal 1.1 the quarterly value of production of a low skill job. I choose to scale b and f relative to the value of the production of low skill jobs because low skill jobs in the model produce the good that enters linearly in the utility function of the household, which permits an interpretation of unit of exchange. From Bentolila et al. (2010), I also obtain that the probability that a temporary contract expires, δ, equals 0.88; temporary contracts last, on average, a little longer than a quarter.

From the Spanish statistical office (INE) I get that 41.1 per cent of employed workers have a tertiary or equivalent educational degree. Thus I set s, the share of low skill workers in the economy, to 58.9 per cent. From INE I also obtain the length of time workers have been in their current employment, classified by ISCO08 occupational categories. I lump the categories, Managers, Professionals and Technicians as high skill jobs and the rest as low skill and compute average employment duration from these to obtain that on average, high skill jobs last for around 3.5 years and low skill jobs for around 2.5 years. The measure is obviously imperfect because the data reports the duration of workers in their current employment, which still has not been terminated and potentially could last much longer. It also misses those workers that change jobs with a high frequency. In all, it still captures that high skill requirement type of jobs last on average longer than those with low skill requirements.

The scaling parameter of the matching function, $\bar{\mu}$, equals 0.59 and has been calibrated to deliver an unemployment rate of 10 per cent, which equals the 2001-2008 average unemployment rate in Spain. Finally, the remaining four parameters, $\{y_L, y_H, \psi_L, \psi_H\}$, have been chosen to ensure an interior solution of the model. A combination of high values of low skill job productivity (y_L) and low values for the cost of posting low skill vacancies (ψ_L) ensures that being unemployed in the low skill market is sufficiently profitable to make some high skill workers search for a low skill job.

The INE provides data on unemployment rates by educational category which could serve to calibrate $\{\psi_L, \psi_H\}$. However, one important drawback of the model, from a quantitative viewpoint, is that, in order to produce interior solutions with high skill workers searching for low skill jobs, it cannot produce unemployment rates of low skill workers higher than those of high skill workers. Within the model, high skill workers have an incentive to search for low skill jobs only because it takes less time to find one such job. Thus, it has to be that the unemployment rate in the low skill market is smaller than that in the high skill market. This is at odds with the data, where one obtains that high skill workers have lower unemployment rates than low skill ones.

Table 1.4 shows the equilibrium value of a set of endogenous variables of the model obtained using the calibration described above.

The model predicts that around 5 per cent of unemployed high skill workers search for low skill jobs and 9 per cent of employed high skill workers are in one such job. Workers in high skill jobs earn a higher salary than those in low skill jobs, although the model would struggle to match the empirical gap between the two. It also produces salaries that are higher in regular contracts than in temporary contracts, but again, the model would find it difficult to match the empirical data on this dimension. Finally, as mentioned before, unemployment rates of low skill workers are lower than that of high skill workers. Addressing these shortcomings is left for future work.

Table 1.4: Model output

Parameter	Value
Labour market tightness low skill market (θ_L)	1.69
Labour market tightness high skill market (θ_H)	0.34
Unemployment rate low skill workers[a], in percentage terms (u_L)	8.57
Unemployment rate high skill workers[b], in percentage terms (u_H)	13.94
Share of high skill workers searching for a low skill job, in percentage terms (g)	5.25
Share of high skill workers working in a low skill job, in percentage terms (j)	9.07
Relative price of high skill goods (p)	3.11
Wage low skill workers in a regular job (w_L)	2.81
Wage low skill workers in a temporary job (w_L^T)	2.79
Wage high skill workers in a regular job (w_H)	2.86
Wage high skill workers in a temporary job (w_H^T)	2.85

[a]: value reported is the unemployment rate, defined as $\frac{u_L}{s}$.

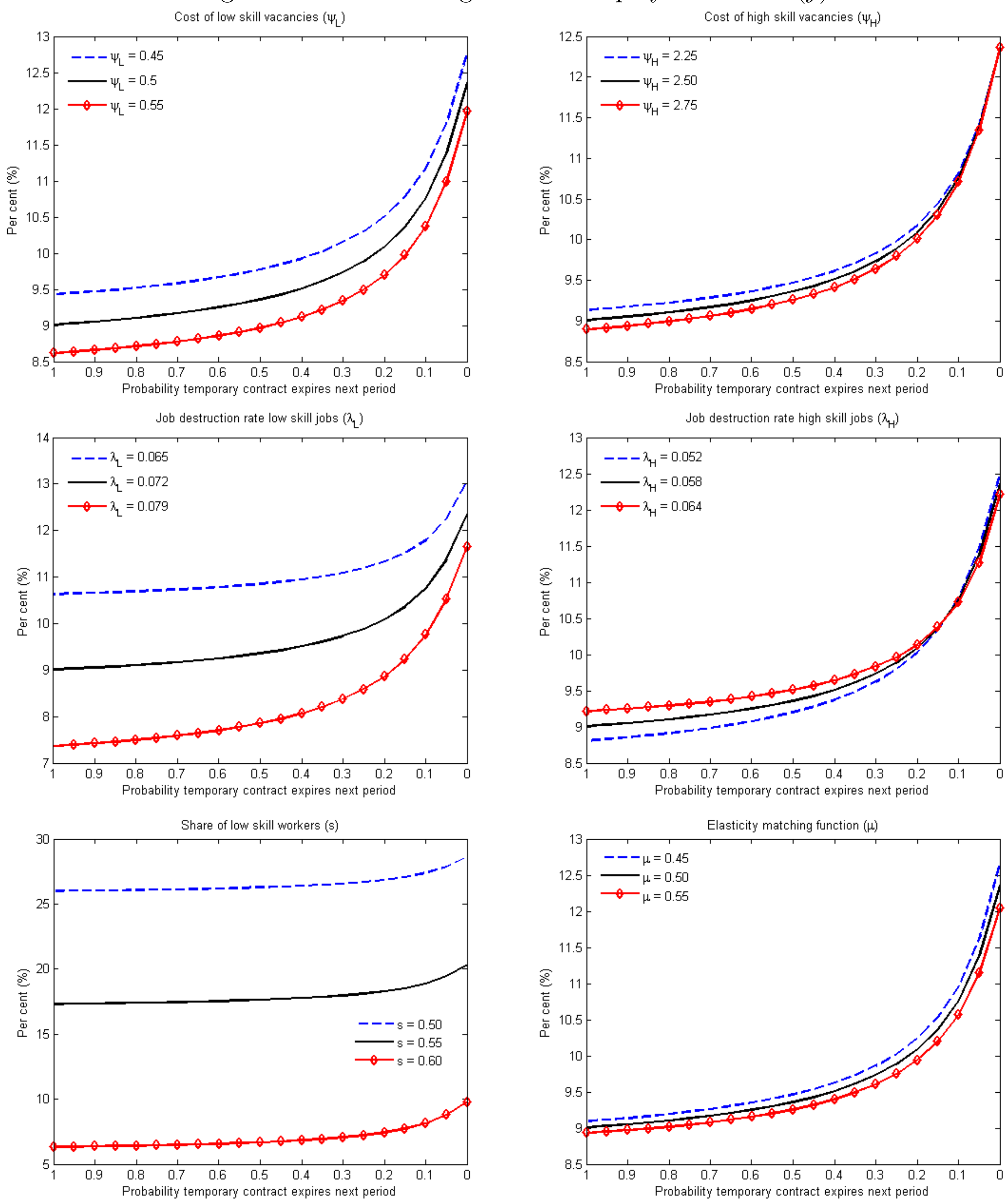
[b]: value reported is unemployment rate, defined as $\frac{u_H}{1-s}$.

1.5.2 Sensitivity analysis

One of the main conclusions in the analysis so far is that temporary contracts can induce unemployed workers with high degrees of education to look and work for jobs for which they are over-qualified. Given the centrality of this proposition in my analysis I test whether the results are sensitive to the assumption that I evaluate the elasticity of the share of high skill workers working in low skill jobs to the probability of temporary contracts expiring, $\varepsilon_{j,\delta}$, at $\delta = 1$. In addition, I also test whether reasonable deviations from the Hosios condition change the main result of the proposition, condition (1.31).

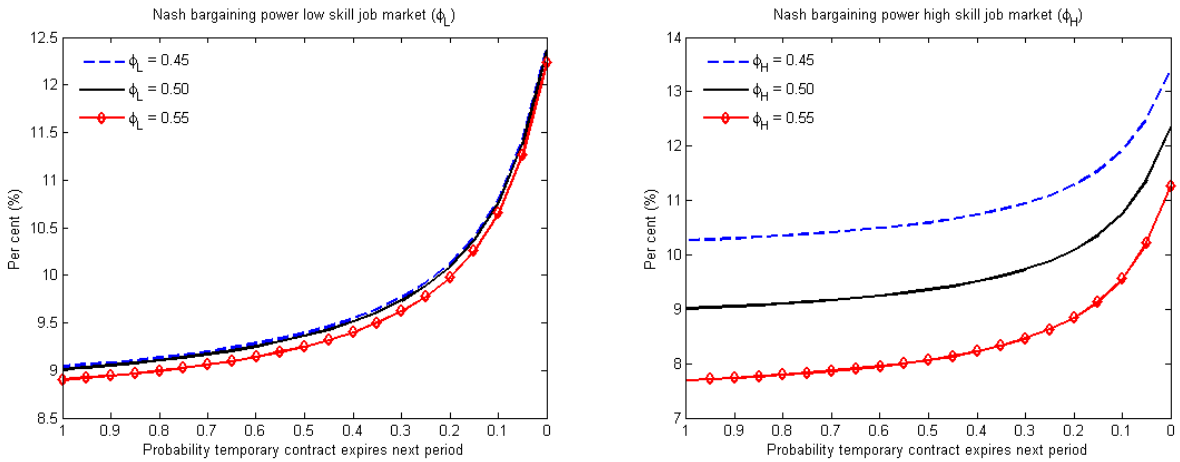
Figure 1.5 plots the share of employed high skill workers in low skill jobs (j), in percentage terms, as a function of the probability that temporary contracts expire, δ. Note that a value of 1 in the x-axis is akin to the use of temporary contracts not being allowed in the economy, while a value of 0 means that temporary contracts never expire and therefore firing costs are never paid. In each panel, I plot three lines: the straight black line plots the value of j as a function of δ using the calibration outlined in table 1.3; the dashed blue line plots j as a function of δ when there is a 10 per cent reduction in the parameter outlined in the legend and the dotted red line plots j as a function of δ when there is a 10 per cent increase in that same parameter. The only exception occurs in the panel where I plot j as a function

Figure 1.5: Share of high skill unemployed workers (j)



of δ for several values of the share of low skill workers, s, because a 10 per cent increase in s delivers a corner solution. The parameter constraints outlined in the Proposition hold for all the parameter combinations that I use to generate the plots in figure 1.5.

Figure 1.6: Share of high skill unemployed workers (j)



In all instances, I find that the introduction of temporary contracts, or the lower the probability that temporary contracts expire, induce an equilibrium outcome where the share of high skill employed workers in low skill jobs increases. In figure 1.6 I find that small deviations of the Hosios condition do not change the main result of the Proposition either: the more pervasive is the use of temporary contracts (the lower is δ), the higher is the share of high skill workers employed in low skill jobs.

1.6 Welfare analysis

In this Section, I solve for the social planner problem in order to derive the welfare implications of introducing temporary contracts, both in a qualitative and quantitative sense.

The maximization problem of the social planner is as follows:

$$\max_{\left\{u_{t+1}^L, u_{t+1}^H, v_t^L, v_t^H, c_t^L, c_t^H, g_t, j_{t+1}\right\}} \sum_{t=0}^{\infty} \beta^t \left(c_t^L + \ln c_t^H\right)$$

$$st: \; c_t^H = (1 - j_t)\left(1 - s - u_t^H\right) y_H$$

$$c_t^L = j_t\left(1 - s - u_t^H\right) y_L + \left(s - u_t^L\right) y_L + b\left(u_t^L + u_t^H\right) - v_t^L \psi_L - v_t^H \psi_H$$

$$u_{t+1}^{L}=u_{t}^{L}+\lambda_{L}\left(s-u_{t}^{L}\right)-m_{L}\left(\frac{v_{t}^{L}}{u_{t}^{L}+g_{t}u_{t}^{H}}\right)u_{t}^{L}$$

$$\begin{aligned}u_{t+1}^{H}=&\,u_{t}^{H}+\left(j_{t}\lambda_{L}+\left(1-j_{t}\right)\lambda_{H}\right)\left(1-s-u_{t}^{H}\right)\\&-\left(g_{t}m_{L}\left(\frac{v_{t}^{L}}{u_{t}^{L}+g_{t}u_{t}^{H}}\right)+\left(1-g_{t}\right)m_{H}\left(\frac{v_{t}^{H}}{\left(1-g_{t}\right)u_{t}^{H}}\right)\right)u_{t}^{H}\end{aligned}$$

$$j_{t+1}\left(1-s-u_{t+1}^{H}\right)=\left(1-\lambda_{L}\right)j_{t}\left(1-s-u_{t}^{H}\right)+m_{L}\left(\frac{v_{t}^{L}}{u_{t}^{L}+g_{t}u_{t}^{H}}\right)g_{t}u_{t}^{H}$$

The social planner maximizes household utility subject to the goods market clearing conditions and the labour market flow constraints. The social planner does take into account the general equilibrium effects coming from changes in tightness in each labour market and the consequences in terms of cost of production of each good. Firing costs do not appear in the problem because the planner is aware that firing costs are merely a transfer. The planner solves the problem dynamically and the steady state is imposed after all optimality conditions are derived.

The FOC's imply:

$$\frac{\left(1-\mu\right)\left(p_{i}y_{i}-b\right)}{r+\lambda_{i}+\mu m\left(\theta_{i}\right)}=\frac{\psi_{i}}{q\left(\theta_{i}\right)},\ i=\{L,H\} \tag{1.39}$$

with $p_L = 1$ and $p_H = \frac{1}{c_H}$ and

$$\theta_{L}\psi_{L}=\theta_{H}\psi_{H}. \tag{1.40}$$

For the sake of clarity, I have relegated the derivation of the optimality conditions (1.39) and (1.40) to Appendix 1.8.6. The social planner equilibrium equations for goods market clearing and labour market flows coincide with those derived in Section 1.4.3: equations (1.7), (1.8), (1.9), (1.29) and (1.30).

Equation (1.39) states that the social planner posts vacancies of each type of job until the expected cost of a new job (right hand side of (1.39)), which is given by the cost of opening a vacancy, ψ_i, times the expected amount of time it takes before the vacancy is matched with a worker, $\frac{1}{q(\theta_i)}$, equals the expected benefit of obtaining a match (left hand side of (1.39)). The benefit is given by the discounted value of the surplus of the match scaled by the share of the surplus appropiated by the firm, $1-\mu$. Condition (1.40) ensures that the value of being unemployed is equalized across both markets.

A comparison between the social planner conditions (1.39) and (1.40) and the decentralized economy equilibrium conditions (1.24) and (1.28), highlights two ingredients that make the latter differ with the former: the presence of firing costs and the Nash bargaining weights. If there were no firing costs and the bargaining power of workers in both markets, $\{\phi_L, \phi_H\}$, was equal to the elasticity of the matching function with respect to unemployment, μ, then the outcome in the decentralized equilibrium would coincide with that of the social planner.

That welfare is going to be decreasing as firing costs increase is of little surprise. Firing costs, in this model, introduce a wedge in the job creation condition that decreases the returns of posting a vacancy for an entrepreneur. As a consequence, there will be less vacancies in equilibrium than what would otherwise be optimal. I will not develop this case further.

Instead, I will look into the welfare implications of temporary contracts in a world where there are firing costs and the Hosios condition does not necessarily hold. As temporary contracts increase the incentives of posting vacancies for both types of jobs, temporary contracts could well be welfare decreasing if the economy was in an equilibrium where workers do not have enough bargaining power and the equilibrium features too many vacancies. Unfortunately, the job creation conditions for both low and high skill vacancies are non-linear equations and, as a result, the model cannot be solved analytically and a numerical solution is required. The model will be solved using the calibration presented in Section 1.5.1.

Welfare is defined as the present discounted value of household utility. The difference in welfare between the household in the decentralized economy and the household in the social planner economy is measured as the percentage change that the household in the decentralized economy should receive of the quasi-linear good (the low skill good) in order to achieve the same present discounted value of utility as the household in the social planner problem. Assuming the economy is in steady state, the present discounted value of the utility of the household under the social planner solution is

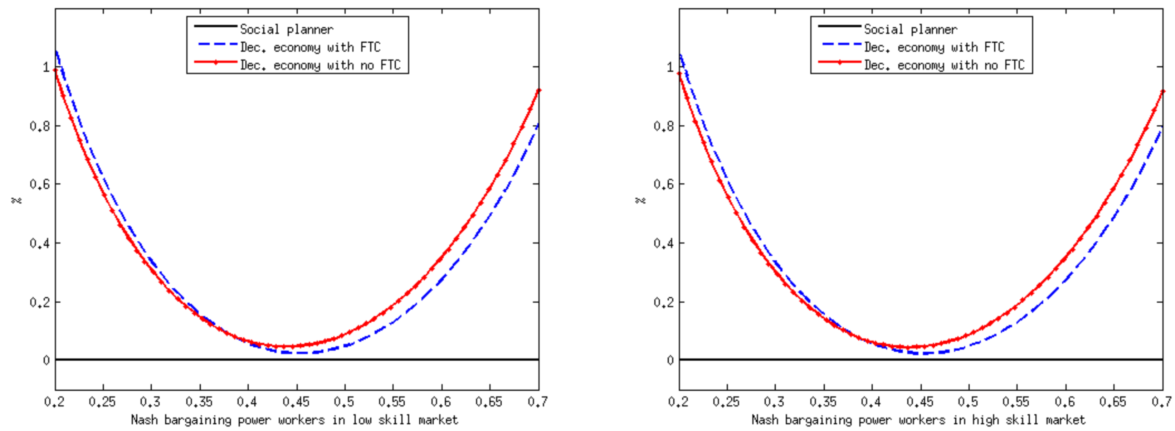
$$W^{SP} = \frac{1}{1-\beta}\left(c_L^{SP} + \ln c_H^{SP}\right),$$

where the superscript, SP, denotes the solution of the social planner problem. Thus, I define the differential in welfare between the two economies as the value of Δ that satisfies

$$W^{SP} = \frac{1}{1-\beta}\left(c_L^{DE}\Delta + \ln c_H^{DE}\right).$$

Where superscript DE denotes the equilibrium values that arise under the decentralized economy model. Note that a positive value of Δ means that the household in the social planner model achieves higher utility than in the decentralized economy one.

Figure 1.7: Welfare evaluation



Note: the y axis measures the percentage increase of the quasi-linear good that households in the decentralized economy should receive to enjoy the same level of utility of the household in the social planner solution.

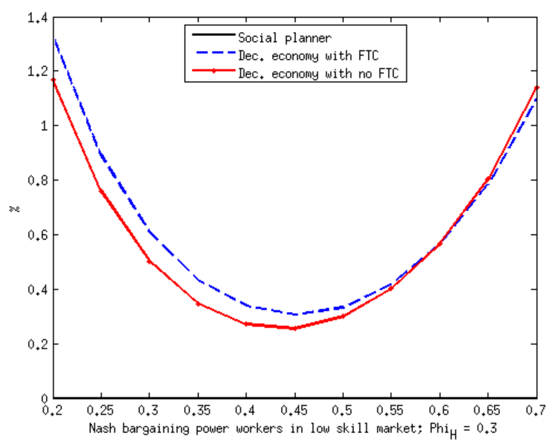
Figure 1.7 reports a welfare comparison of the social planner solution against two models: the decentralized economy model where temporary contracts are allowed and the same model where temporary contracts are not allowed. In the panel on the left I plot welfare (Δ), in percentage terms, as a function of the Nash bargaining power of workers in the low skill market, ϕ_L, while keeping the Nash bargaining power parameter of workers in the high skill market equal to the elasticity of the matching function with respect to unemployment, μ. Recall that in this calibration, μ equals 0.5. In the panel on the right I report the same exercise against a range of values of ϕ_H while keeping $\phi_L = \mu$. A value of zero implies that the household is enjoying the same utility level of the social planner solution. In both panels I plot three lines: the adjustment in welfare required in the decentralized economy model where temporary contracts are not allowed and firms can only offer regular contracts (solid red line), the adjustment required in the decentralized economy where temporary contracts are allowed (dashed blue line) and expire with 20 per cent probability ($\delta = 0.2$) and a flat black line at zero that represents the social planner outcome. Note that I use $\delta = 0.2$ instead of $\delta = 0.88$, as in the calibration reported in Section 1.5.1, because with $\delta = 0.88$ the dashed and dotted lines are barely distinguishable.

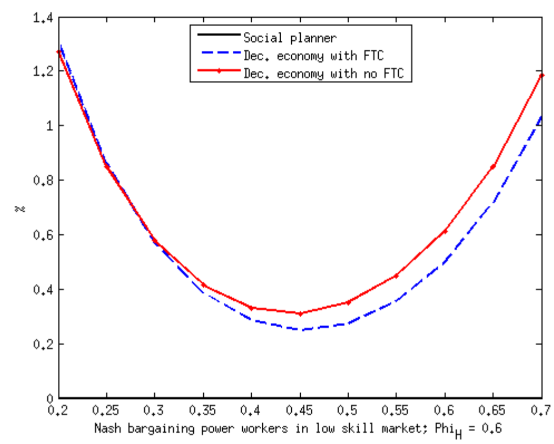
Several features arise from figure 1.7. First, introducing temporary contracts does not imply a welfare gain in all situations despite temporary contracts reducing the expected value of firing costs that entrepreneurs have to pay. As is standard in search and matching models, if the bargaining power of entrepreneurs in either low or high skill market is too high, there are too many vacancies in equilibrium. In such scenario, introducing temporary contracts, while beneficial for the economy as it closes the wedge between the entrepreneur perceived cost of posting a vacancy compared to the social cost of posting that vacancy, becomes harmful as it boosts the number of vacancies posted in equilibrium. As the labour market is already inefficiently congested with vacancies, the social cost of congesting the market further outweights the social benefits derived from reducing the wedge in the job creation condition (1.24).

Second, the welfare implications (be them gains or losses) from introducing temporary contracts are small compared to the welfare losses inflicted by departures of the Hosios condition.

Note as well that in both plots, the value of the Nash bargaining power of workers that minimizes the welfare loss is smaller than the social planner equivalent $\mu = 0.5$. Firing costs introduce a wedge in the job creation condition that reduces the incentives of entrepreneurs to post vacancies and thus generates a welfare loss. This inefficiency can be partly, but not fully offset by reducing the bargaining power of workers.

Figure 1.8: Welfare evaluation: two sided inefficiency





I also explore the welfare implications of introducing temporary contracts in the event that the Hosios Condition fails to hold in both markets simultaneously, rather than just in one market at a time. Figure 1.8 plots similar versions of the charts described in figure 1.7. The chart on the left of figure 1.8 plots the welfare implications of introducing temporary contracts for a range of values of ϕ_L when $\phi_H = 0.3 < \mu$, while the one on the right repeats the same exercise for $\phi_H = 0.6 > \mu$.

Several elements are worth highlighting from figure 1.8. First, the wider gap between welfare in the decentralized equilibrium models and that of the social planner is explained by the inefficiency present in both markets simultaneously. In figure 1.7, I allowed only one market at a time to deviate from the Hosios Condition while in figure 1.8 the deviation occurs in both markets simultaneously; hence the difference in welfare. Second, if temporary contracts are introduced in a world where one of the markets features entrepreneurs with too much bargaining power (as in the chart on the left of figure 1.8) then temporary contracts generate a welfare loss unless entrepreneurs enjoy excessively low bargaining power in the other market. The converse is also true. The intuition behing this result is similar to the one discussed before. Temporary contracts creates incentives to post vacancies. If the economy features too many vacancies in, say, the low skill market, then temporary contracts will congest the market further and introduce a welfare loss. However, the final outcome also depends on the level of congestion in the high skill market. If the market for high skill jobs was also congested with too many vacancies, welfare will decrease unambiguously following the introduction of temporary contracts. By contrast, if the market for high skill jobs featured too little vacancies, the introduction of temporary contracts would alleviate this problem. In all, for temporary contracts to be welfare improving when one market has entrepreneurs enjoying too much bargaining power it has to be that the contrary occurs in the other market.

Some interesting avenues of work regarding the welfare results are left for future work. In particular, this model does not feature any inefficiency related with having workers with high levels of education working in low skill requirement type of jobs. High skill workers switch markets according to an indifference condition that is efficient at all times except when the Hosios condition does not hold. Mechanisms that model possible inefficiencies related with this job-workers skill mismatch, such as in Barnichon and Zylberberg (2014), could prove fruitful avenues of research that could enrich the qualitative and quantitative welfare implications of the use of temporary contracts.

1.7 Conclusions

The purpose of this paper is twofold. Firstly, I establish a negative empirical correlation between the share of employees working under a temporary contract and the share of employees with high educational attainments employed in jobs for which they are over-qualified across a panel of European countries. The results are robust to the inclusion of variables that capture possible alternative stories, such as the entrance of the women in the labour market or the unemployment rate. This work constitutes a first step towards establishing an empirical connection between the use of temporary contracts and skill mismatch between jobs and workers, as many possible confounding factors, including quality of education, productivity trends and cost of capital reallocation, among others, may bias the results.

Secondly, I develop a simple search and matching model with heterogeneous jobs and workers that captures the aforementioned empirical negative correlation. The model features workers differentiated by their skill level (low and high) that search for jobs. High skill workers can decide in which market they search for a job, the trade-off being that wages in the high skill job market are higher than in the low skill market but it takes longer time to find one such job. The model delivers a negative relationship between the introduction of temporary contracts and the share of mismatched high skill workers because temporary contracts makes low skill job vacancies more profitable. The assumption is that firms fire workers in low skill jobs more often than in high skill jobs. As a result of the introduction of temporary contracts, it becomes less costly to find a low skill job vacancy which pushes some high skill workers to switch markets. Ultimately, the share of high skill workers working in a low skill job increases.

I also find that temporary contracts are not always welfare improving. Temporary contracts, in this model, increase the returns from posting vacancies for all type of jobs. If the economy features, before the introduction of temporary contracts, too many vacancies, as would be the case if entrepreneurs enjoyed high bargaining power over wages, then the introduction of temporary contracts generates a social loss as the marginal increase in the cost of finding a job imposed upon all unemployed workers outweighs the increase in the returns from posting vacancies reaped by the entrepreneurs. However, I also show that the welfare implications from introducing temporary contracts are of second order importance compared to the welfare gains/losses derived from adjusting the bargaining power of workers/entrepreneurs.

1.8 Appendices

1.8.1 Appendix A

In this section I show that workers would prefer a regular contract rather than a temporary one. That is, following the notation layed out in Section 1.4.1.3,

$$W_i > W_i^T.$$

Nash bargaining implies that

$$\phi_i \left(W_i^T - U_i\right) = S_i^T,$$

$$\phi_i \left(W_i - U_i\right) = S_i.$$

Therefore I only need to show that

$$S_i > S_i^T. \tag{1.41}$$

Using condition (1.23) to substitute into (1.18) and (1.19) I obtain that

$$S_i^T = \frac{(1+r)\, p_i y_i - (1+r)\, b - (1+r)\, \frac{\phi_i}{1-\phi_i}\theta_i\psi_i - \frac{(1+r)\delta}{r+\delta+\lambda_i(1-\delta)}\lambda_i f}{r+\lambda_i},$$

$$S_i = \frac{(1+r)\, p_i y_i - (1+r)\, b - (1+r)\, \frac{\phi_i}{1-\phi_i}\theta_i\psi_i + rf}{r+\lambda_i}.$$

Thus, condition (1.41) holds.

1.8.2 Appendix B

In this Section I show that a search and matching model like the one I've developed in the main body of the text with homogeneous goods does not necessarily produce an interior solution. The presence of homogeneous goods can be represented by a constant relative price of the high skill good, p. For simplicity, in the derivations I will omit p completely.

The relevant set of equilibrium equations (I assume for simplicity that $\delta = 1$) becomes:

$$(1-\phi_L)\, \frac{y_L - b - \frac{1}{1+r}\lambda_L f}{r + \lambda_L + \phi_L m\left(\theta_L\right)} = \frac{\psi_L}{q\left(\theta_L\right)}, \tag{1.42}$$

$$
(1-\phi_H)\,\frac{y_H - b - \frac{1}{1+r}\lambda_H f}{r+\lambda_H+\phi_H m\left(\theta_H\right)} = \frac{\psi_H}{q\left(\theta_H\right)} \tag{1.43}
$$

and

$$
\frac{\phi_L}{1-\phi_L}\theta_L\psi_L = \frac{\phi_H}{1-\phi_H}\theta_H\psi_H. \tag{1.44}
$$

These equations are, in order, the job creation condition in the low skill market, the job creation condition in the high skill market and the equilibrium condition that results from equalizing the unemployment values, $U_L = U_H$. The latter should arise as high skill workers switch into the labour market in which the value of being unemployed is the highest.

In the absence of fluctuations in the price of goods, one can realize that both $\{\theta_L, \theta_H\}$ are solely determined by equations (1.42) and (1.43), respectively. That is, labour market tightness is a function of model parameters: the expected duration of a job, the cost of posting a vacancy, the Nash bargaining power parameter, the job's productivity and the flow of resources when unemployed. It is not determined by the number (or share) of unemployed workers in that particular market. In fact, nothing guarantees that equation (1.44) will be satisfied once the equilibrium values of $\{\theta_L, \theta_H\}$ are determined.

As a consequence, in equilibrium, if the value of being unemployed in the high skill market is higher than in the low skill market, $U_H > U_L$, all unemployed high skill workers will search for high skill jobs and by the same token, the converse is also true. The intuition behind this result is that the absolute number of workers in the market does not matter to pin down labour market tightness. This is a consequence of the constant returns to scale property of the matching function. If the number of unemployed workers in the market increases, entrepreneurs will find it profitable to increase the number of vacancies posted by exactly the same proportion so that the ratio of the two remains unchanged.

1.8.3 Appendix C

In this section I derive the sign of the set of elasticities listed in the Proposition that appears in Section 1.5. In all the discussion that follows, I assume that parameters are such that there is an interior solution. In addition, I assume that the Hosios condition holds, $\phi_L = \phi_H = \mu$, $\psi_L < \psi_H$ and $\lambda_H < \lambda_L$.

I start from the job creation condition for low skill jobs, equation (1.24) for $i = L$. Remember that p_L is the numeraire and therefore, $p_L = 1$. Taking the total derivative with respect to

$\{\theta_L, \delta\}$, I find that the elasticity of the labour market tightness with respect to δ, as δ tends to 1, can be expressed as

$$\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} = -\frac{1}{\theta_L \psi_L} \frac{1-\mu}{\mu} \frac{(r+\lambda_L)\, m(\theta_L)}{r+\lambda_L+m(\theta_L)} \frac{\lambda_L f}{(1+r)^2} < 0. \tag{1.45}$$

To derive the sign I've used that $\mu \in (0,1)$ and that all the remaining variables that appear in the expression are positive. As expected, once temporary contracts are introduced labour market tightness in the market for low skill jobs increases as entrepreneurs find it profitable to post more vacancies.

From equation (1.28) we find that introducing temporary contracts increases labour market tightness in the high skill market by the same percentage amount:

$$\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} = \varepsilon_{\theta_H,\delta} \mid_{\delta\to 1} . \tag{1.46}$$

This result is an equilibrium condition. If both labour markets were differentiated and high skill workers could not search for a low skill job, the condition need not be satisfied (as already explained in Appendix 1.8.2).

To derive the endogenous response of the relative price of the high skill good, p, to the introduction of temporary contracts, I take the total derivative of equation (1.24) for $i = H$ with respect to $\{p, \theta_H, \delta\}$, and find that

$$\frac{dp}{d\delta} \mid_{\delta\to 1} = \frac{1}{y_H} \left\{ (r+\lambda_H) \frac{\lambda_H f}{(1+r)^2} - \left(\frac{\psi_H}{\psi_L}\right)^{1-\mu} \frac{r+\lambda_H+m(\theta_H)}{r+\lambda_L+m(\theta_L)} (r+\lambda_L) \frac{\lambda_L f}{(1+r)^2} \right\}. \tag{1.47}$$

The sign of this expression seems ambiguous. However, upon a closer examination it is possible to derive a simple condition that guarantees that, p, the relative price of high skill goods, increases when δ decreases:

$$\frac{dp}{d\delta} \mid_{\delta\to 1} < 0, \tag{1.48}$$

which holds if and only if the term inside the curly brackets in (1.47) is negative:

$$(r+\lambda_H) \frac{\lambda_H f}{(1+r)^2} - \left(\frac{\psi_H}{\psi_L}\right)^{1-\mu} \frac{r+\lambda_H+m(\theta_H)}{r+\lambda_L+m(\theta_L)} (r+\lambda_L) \frac{\lambda_L f}{(1+r)^2} < 0.$$

Some algebra shows that this condition is equivalent to

$$\frac{\lambda_H}{\lambda_L}\left(r+\lambda_H\right)+\left(\frac{\left(r+\lambda_H\right)\lambda_H}{\left(r+\lambda_L\right)\lambda_L}-1\right)m\left(\theta_L\right)<\left(r+\lambda_H\right)\left(\frac{\psi_H}{\psi_L}\right)^{1-\mu}. \tag{1.49}$$

where I have used condition (1.28) with $\phi_L = \phi_H = \mu$. If, as we have been assuming so far, we have that $\lambda_H < \lambda_L$ we see that the term inside the brackets is negative:

$$\frac{\left(r+\lambda_H\right)\lambda_H}{\left(r+\lambda_L\right)\lambda_L}-1<0,$$

which implies that for every possible $\theta_L > 0$, the following inequality holds:

$$\frac{\lambda_H}{\lambda_L}\left(r+\lambda_H\right)+\left(\frac{\left(r+\lambda_H\right)\lambda_H}{\left(r+\lambda_L\right)\lambda_L}-1\right)m\left(\theta_L\right)<\frac{\lambda_H}{\lambda_L}\left(r+\lambda_H\right)<\left(r+\lambda_H\right)\left(\frac{\psi_H}{\psi_L}\right)^{1-\mu}.$$

Thus, a sufficient condition that guarantees that (1.48) holds is that the second part of the above inequality is satisfied, that is:

$$\frac{\lambda_H}{\lambda_L}<\left(\frac{\psi_H}{\psi_L}\right)^{1-\mu},$$

which is equivalent to

$$\frac{\lambda_L}{\lambda_H}>\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}. \tag{1.50}$$

Under assumption (1.50), condition (1.48) holds. Note however, that this assumption is weaker than our assumption of $\lambda_H < \lambda_L$ if $\psi_L < \psi_H$, which is indeed one of our parameter assumptions. Therefore, $\lambda_H < \lambda_L$ is a sufficient condition that ensures that the derivative of the relative price of the high skill good with respect to δ is negative:

$$\frac{dp}{d\delta}\mid_{\delta\to1}<0.$$

It is possible to find $\frac{dp}{d\delta}\mid_{\delta\to1}<0$ even with a $\underline{\lambda}_L$ such that $\lambda_H > \underline{\lambda}_L > \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}$. However, the necessary and sufficient condition that ensures that $\frac{dp}{d\delta}\mid_{\delta\to1}<0$ is a function of an endogenous variable (θ_L), as it can be seen in inequality (1.49), and thus I cannot obtain a simple analytical expression for it.

I can also easily derive from equation (1.7) that unemployment of low skill workers falls when temporary contracts are introduced:

$$\varepsilon_{u_L,\delta} \mid_{\delta\to 1} = -(1-\mu)\frac{m(\theta_L)}{\lambda_L + m(\theta_L)}\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} > 0, \tag{1.51}$$

This is to be expected given that labour market tightness has increased following the introduction of temporary contracts. From equation (1.51) we can also derive that

$$\left|\varepsilon_{u_L,\delta} \mid_{\delta\to 1}\right| < \left|\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1}\right|,$$

as $0 < m(\theta_L) \leq 1$ and $\{\lambda_L, \mu\} \in [0,1]$.

It is convenient to simplify the expression for the equilibrium value of unemployment in the high skill market. Combining equations (1.8) and (1.9) we can rewrite the former one as

$$\left(g\frac{\lambda_H}{\lambda_L} + (1-g)\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}\right)m(\theta_L) = \frac{1-s-u_H}{u_H}\lambda_H. \tag{1.52}$$

Taking the total derivative with respect to $\{g, \theta_L\}$, dividing everything by $d\delta$, taking the limit of $\delta \to 1$ and again making use of equation (1.9) I get

$$\varepsilon_{g,\delta} \mid_{\delta\to 1} + \frac{1-s}{j(1-s-u_H)}\frac{\frac{\lambda_H}{\lambda_L}}{\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}\right)}\varepsilon_{u_H,\delta} \mid_{\delta\to 1} \quad = \quad -(1-\mu)\left(1 + \frac{\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}}{g\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}\right)}\right)\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} \tag{1.53}$$

Equation (1.53) is a one equation in two unknowns: $\{\varepsilon_g, \varepsilon_{u_H}\}$. We need one more equation, which comes from the FOC of the household maximisation problem, equation (1.27). Combining (1.27) with (1.29) and taking the total derivative we obtain

$$\varepsilon_{p,\delta} \mid_{\delta\to 1} = \frac{j}{1-j}\varepsilon_{j,\delta} \mid_{\delta\to 1} + \frac{u_H}{1-s-u_H}\varepsilon_{u_H,\delta} \mid_{\delta\to 1}. \tag{1.54}$$

The relative price of high skill goods is an inverse of the total amount of high skill goods produced in the economy. As a consequence, it is a function of the share of high skill workers working on high skill jobs $(1-j)$, that is, the degree of mismatch, and of the employment rate of high skill workers, $\underline{u_H}$.

Again, equation (1.54) is one equation in two unknowns $\{\varepsilon_j, \varepsilon_{u_H}\}$ so I need again one further equation to link $\{\varepsilon_j, \varepsilon_g\}$. Taking the total derivative from equation (1.9) I obtain the last equation,

$$\varepsilon_{j,\delta} \mid_{\delta\to 1} = \varepsilon_{g,\delta} \mid_{\delta\to 1} + (1-\mu)\,\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} + \frac{1-s}{1-s-u_H}\varepsilon_{u_H,\delta} \mid_{\delta\to 1}. \tag{1.55}$$

Equations (1.53), (1.54) and (1.55) conform a system of three equations in three unknowns: $\{\varepsilon_{j,\delta} \mid_{\delta\to 1}, \varepsilon_{g,\delta} \mid_{\delta\to 1}, \varepsilon_{u_H,\delta} \mid_{\delta\to 1}\}$.

Adding equations (1.53) and (1.55), and substituting $\varepsilon_{u_H,\delta} \mid_{\delta\to 1}$ out from the resulting equation using (1.54) delivers the following condition:

$$\Psi\varepsilon_{j,\delta} \mid_{\delta\to 1} = -(1-\mu)\frac{\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}}{g\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}\right)}\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1} - \Upsilon\varepsilon_{p,\delta} \mid_{\delta\to 1}, \tag{1.56}$$

where

$$\Upsilon = \left(\frac{1}{j}\frac{\frac{\lambda_H}{\lambda_L}}{\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}\right)} - 1\right)\frac{1-s}{u_H},$$

and

$$\Psi = 1 - \Upsilon\frac{j}{1-j}.$$

Turns out that, given our assumptions on the parameters that we stated at the beginning of this Section, this equation implies that it is always the case that

$$\varepsilon_{j,\delta} \mid_{\delta\to 1} < 0.$$

Let us verify this claim. The signs of the elasticities on the right hand side of equation (1.56) are know. However, I need to take into account that the difference that appears in Υ, $\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}$, may either be positive or negative.

Case 1: $\frac{\lambda_H}{\lambda_L} > \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}$

It is straightforward to see that with $j \in (0,1)$,

$$\Upsilon > 0.$$

To get $\varepsilon_{j,\delta} \mid_{\delta\to 1} < 0$, I need $\Psi < 0$. Let us verify it.

$\Psi < 0$ holds if and only if

$$1 - \left(\frac{1}{j} \frac{\frac{\lambda_H}{\lambda_L}}{\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu} \right)} - 1 \right) \frac{1-s}{u_H} \frac{j}{1-j} < 0,$$

which, after some algebra, boils down to

$$(1-j)\, u_H < \left(\frac{\frac{\lambda_H}{\lambda_L}}{\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu} \right)} - j \right) (1-s)\,.$$

Notice that

$$1 - j < \frac{\frac{\lambda_H}{\lambda_L}}{\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu} \right)} - j$$

because of $\frac{\frac{\lambda_H}{\lambda_L}}{\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu} \right)} > 1$, and

$$u_H < 1 - s$$

because we have assumed that we are in an interior solution, and thus, from equation (1.8), it has to be that $u_H < 1 - s$. Thus we obtain that $\Psi < 0$.

Finally, note that the coefficient in front of $\varepsilon_{\theta_L,\delta} \mid_{\delta\to 1}$ is positive,

$$(1-\mu) \frac{\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}}{g\left(\frac{\lambda_H}{\lambda_L} - \left(\frac{\psi_L}{\psi_H}\right)^{1-\mu} \right)} > 0.$$

Given the signs of the elasticities of p and θ_L and the signs of the coefficients in front of all the elasticities in equation (1.56), we obtain that

$$\varepsilon_{j,\delta}\mid_{\delta\to 1}<0.$$

Case 2: $\frac{\lambda_H}{\lambda_L}<\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}$

It is again very easy to establish that

$$\Upsilon<0,$$

in which case, it is also straightforward to verify

$$\Psi>0.$$

In addition we have that

$$(1-\mu)\frac{\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}}{g\left(\frac{\lambda_H}{\lambda_L}-\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}\right)}<0.$$

Again, given the signs of the elasticities of p and θ_L and the signs of the coefficients in front of all the elasticities in equation (1.56), we obtain that

$$\varepsilon_{j,\delta}\mid_{\delta\to 1}<0.$$

Finally, if one takes equation (1.56) and substitutes $\varepsilon_{p,\delta}\mid_{\delta\to 1}$ out using equation (1.54), one gets the following relationship:

$$\Upsilon\frac{u_H}{1-s-u_H}\varepsilon_{u_H,\delta}\mid_{\delta\to 1}=-(1-\mu)\frac{\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}}{g\left(\frac{\lambda_H}{\lambda_L}-\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}\right)}\varepsilon_{\theta_L,\delta}\mid_{\delta\to 1}-\varepsilon_{j,\delta}\mid_{\delta\to 1} \tag{1.57}$$

It is easy to verify that if $\frac{\lambda_H}{\lambda_L}>\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}$, then

$$\varepsilon_{u_H,\delta}\mid_{\delta\to 1}>0,$$

while if $\frac{\lambda_H}{\lambda_L}<\left(\frac{\psi_L}{\psi_H}\right)^{1-\mu}$, the sign of $\varepsilon_{u_H,\delta}\mid_{\delta\to 1}$ is ambiguous.

1.8.4 Appendix D

In this section I show that if unemployment benefits, firing costs and the cost of opening vacancies were all proportional to output, then, conditional on $\lambda_L = \lambda_H$ and $\phi_L = \phi_L = \mu$, both markets would benefit equally from the introduction of temporary contracts. To do so, suppose that in both markets, $i = \{L, H\}$:

$$b_i = \bar{b} p_i y_i,$$

$$f_i = \bar{f} p_i y_i,$$

$$\psi_i = \bar{\psi} p_i y_i.$$

Take equation (1.24) and introduce these assumptions to obtain:

$$(1-\mu)\frac{p_i y_i - b_i - \frac{\delta}{r+\delta+\lambda_i(1-\delta)}\lambda_i f_i}{r + \lambda_i + \mu m(\theta_i)} = \frac{\psi_i}{q(\theta_i)} \iff$$

$$(1-\mu)\frac{p_i y_i - \bar{b} p_i y_i - \frac{\delta}{r+\delta+\lambda(1-\delta)}\lambda \bar{f} p_i y_i}{r + \lambda + \mu m(\theta_i)} = \frac{\bar{\psi} p_i y_i}{q(\theta_i)},$$

which simplifies to

$$(1-\mu)\frac{1 - \bar{b} - \frac{\delta}{r+\delta+\lambda(1-\delta)}\lambda \bar{f}}{r + \lambda + \mu m(\theta)} = \frac{\bar{\psi}}{q(\theta)}.$$

Both markets deliver the exact same value of labour market tightness and both benefit to the same degree from the introduction of temporary contracts. More so, the general equilibrium effects derived from fluctuations in the relative price of the high skill good would disappear. If $\lambda_L > \lambda_H$, I would still obtain $\theta_L > \theta_H$ and unemployed workers in the low skill market would benefit more from the introduction of temporary contracts than those in the high skill market.

1.8.5 Appendix E

In this section I show that the increase in θ_H produced by the introduction of temporary contracts is smaller than the one implied by the model presented in the main body of the paper if the relative price of the high skill goods was not allowed to move, i.e. if the model featured homogeneous, rather than heterogeneous goods. To do so, suppose $\delta = 1$ and an equilibrium that is identical to the one of the main model of the paper. I also assume that once we introduce temporary contracts, $\delta < 1$, for some exogenous reason, p is kept constant.

From the job creation condition for high skill jobs given in equation (1.24) with $i = H$, and assuming that $\frac{dp}{d\delta} \mid_{\delta \to 1} = 0$, I get that

$$\frac{d\theta_H}{d\delta} \mid_{\delta \to 1} = -\frac{1}{\psi_H}\frac{1-\mu}{\mu}\frac{(r+\lambda_H)\, m(\theta_H)}{r+\lambda_H+m(\theta_H)}\frac{\lambda_H f}{(1+r)^2}. \tag{1.58}$$

If the relative price p was allowed to move, then from equation (1.24) and (1.28) I would have that

$$\frac{d\theta_H}{d\delta} \mid_{\delta \to 1} = -\frac{1}{\psi_H}\frac{1-\mu}{\mu}\frac{(r+\lambda_L)\, m(\theta_L)}{r+\lambda_L+m(\theta_L)}\frac{\lambda_L f}{(1+r)^2}. \tag{1.59}$$

To derive these conditions, I have substituted the value of $\frac{d\theta_L}{d\delta} \mid_{\delta \to 1}$ that I get from taking the total derivative of the job creation condition of low skill jobs.

I need to show that the value implied by equation (1.58) is bigger (or smaller in absolute value) than the one implied by (1.59). That is:

$$-\frac{1}{\psi_H}\frac{1-\mu}{\mu}\frac{(r+\lambda_L)\, m(\theta_L)}{r+\lambda_L+m(\theta_L)}\frac{\lambda_L f}{(1+r)^2} < -\frac{1}{\psi_H}\frac{1-\mu}{\mu}\frac{(r+\lambda_H)\, m(\theta_H)}{r+\lambda_H+m(\theta_H)}\frac{\lambda_H f}{(1+r)^2}.$$

With some algebra one can see that this condition holds if and only if

$$\frac{(r+\lambda_L)\, m(\theta_L)}{r+\lambda_L+m(\theta_L)} > \frac{(r+\lambda_H)\, m(\theta_H)}{r+\lambda_H+m(\theta_H)}\frac{\lambda_H}{\lambda_L}.$$

Given the assumption of $\lambda_L > \lambda_H$, a sufficient condition for this inequality to hold is that

$$\frac{(r+\lambda_L)\, m(\theta_L)}{r+\lambda_L+m(\theta_L)} > \frac{(r+\lambda_H)\, m(\theta_H)}{r+\lambda_H+m(\theta_H)},$$

which is always the case, because the function

$$f(r,\lambda,\theta) = \frac{(r+\lambda)\, m(\theta)}{r+\lambda+m(\theta)},$$

is increasing in both λ and θ, and we already know that $\lambda_L > \lambda_H$ and $\theta_L > \theta_H$ (from equation (1.28)).

1.8.6 Appendix F

In this Section, I derive the first order conditions of the social planner problem, equations (1.39) and (1.40), outlined in the main body of the text. Throughout this Section I will use that the matching function takes functional form described in (1.6). The Lagrangian of the social planner maximization problem is as follows:

$$
\begin{aligned}
\mathcal{L} \;&=\; \sum_{t=0}^{\infty} \beta^t \Bigg\{ c_t^L + \ln c_t^H + \eta_t^1 \left[(1-j_t)\left(1-s-u_t^H\right) y_H - c_t^H \right] \\
&+\; \eta_t^2 \left[j_t \left(1-s-u_t^H\right) y_L + \left(s-u_t^L\right) y_L + b\left(u_t^L + u_t^H\right) - v_t^L \psi_L - v_t^H \psi_H - c_t^L \right] \\
&+\; \eta_t^3 \left[u_t^L + \lambda_L \left(s-u_t^L\right) - m_L\left(\frac{v_t^L}{u_t^L + g_t u_t^H}\right) u_t^L - u_{t+1}^L \right] \\
&+\; \eta_t^4 \Bigg[u_t^H + \left(j_t \lambda_L + (1-j_t)\lambda_H\right)\left(1-s-u_t^H\right) \\
&-\; \left(g_t m_L \left(\frac{v_t^L}{u_t^L + g_t u_t^H}\right) + (1-g_t)\, m_H\left(\frac{v_t^H}{(1-g_t)\, u_t^H}\right)\right) u_t^H - u_{t+1}^H \Bigg] \\
&+\; \eta_t^5 \left[(1-\lambda_L)\, j_t \left(1-s-u_t^H\right) + m_L\left(\frac{v_t^L}{u_t^L + g_t u_t^H}\right) g_t u_t^H - j_{t+1}\left(1-s-u_{t+1}^H\right) \right] \Bigg\}
\end{aligned}
$$

I take first order conditions with respect to $\left\{c_t^L, c_t^H, v_t^L, v_t^H, u_{t+1}^L, u_{t+1}^H, j_t, g_t\right\}$ and, after that, impose steady state. The resulting set of first order conditions become:

$$\eta^1 = \frac{1}{c^H} \tag{1.60}$$

$$\eta^2 = 1 \tag{1.61}$$

$$(r+\lambda_L)\,\eta^3 = \eta^2 (b - y_L) - \left[\left(\eta^5 - \eta^4\right)(1-z)(1-\mu) - \eta^3 \left(z(1-\mu) - 1\right) \right] m^L(\theta_L) \tag{1.62}$$

$$
\begin{aligned}
&(r + j\lambda_L + (1-j)\lambda_H)\,\eta^4 - (r+\lambda_L)\,\eta^5 j = \eta^2 (b - j y_L) - \eta^1 (1-j)\, y_H \\
&- \left[\left(\eta^5 - \eta^4\right)\left((1-z)(1-\mu) - 1\right) - \eta^3 z (1-\mu) \right] g m_L\left(\theta^L\right) - \eta^4 (1-g)\, \mu m_H\left(\theta^H\right)
\end{aligned} \tag{1.63}
$$

$$z\eta^3 + (1-z)\left(\eta^4 - \eta^5\right) = -\eta^2 \frac{\psi_L}{(1-\mu)\, q_L\left(\theta^L\right)} \tag{1.64}$$

$$\eta^4 = -\eta^2 \frac{\psi_H}{(1-\mu)\, q_H\left(\theta^H\right)} \tag{1.65}$$

$$\left[\left(\eta^5 - \eta^4\right)\left((1-z)(1-\mu) - 1\right) - \eta^3 z (1-\mu) \right] m_L\left(\theta^L\right) = \eta^4 \mu m_H\left(\theta^H\right) \tag{1.66}$$

$$\eta^5 (r + \lambda_L) = \eta^2 y_L - \eta^1 y_H + \eta^4 (\lambda_L - \lambda_H) \tag{1.67}$$

where $z = \frac{u_L}{u_L + g u_H}$.

Substituting (1.66) into (1.63) and substituting (1.67) into the resulting equation I obtain

$$\left(r + \lambda_H + \mu m_H \left(\theta^H\right)\right) \eta^4 = \eta^2 b - \eta^1 y_H. \tag{1.68}$$

Substituting (1.65) into (1.68) we get the high skill market job creation condition (equation (1.39) for $i = H$):

$$(1 - \mu) \frac{\frac{\eta^1}{\eta^2} y_H - b}{r + \lambda_H + \mu m_H (\theta^H)} = \frac{\psi_H}{q_H (\theta^H)}. \tag{1.69}$$

Note that $\frac{\eta^1}{\eta^2}$ is the ratio of marginal utilities,

$$\frac{\eta^1}{\eta^2} = \frac{1}{c^H}.$$

To find the job creation condition for the low skill market take equation (1.66) and substitute it into (1.63) again, but this time substituting $\eta^4 \mu m_H \left(\theta^H\right)$ out instead. After this, substitute the term $\eta^1 y_H$ from the resulting equation using condition (1.67):

$$(r + \lambda_L) \left(\eta^4 - \eta^5\right) = \eta^2 (b - y_L) - \left[\left(\eta^5 - \eta^4\right) ((1 - z)(1 - \mu) - 1) - \eta^3 z (1 - \mu)\right] m_L \left(\theta^L\right).$$

Take this last equation and subtract condition (1.62) from it:

$$\eta^3 = \eta^4 - \eta^5. \tag{1.70}$$

I substitute equation (1.70) into equation (1.62) to get the job creation condition for the low skill market (equation (1.39) for $i = L$):

$$(1 - \mu) \frac{y_L - b}{r + \lambda_L + \mu m^L (\theta_L)} = \frac{\psi_L}{q^L (\theta_L)} \tag{1.71}$$

Finally, I can derive the equilibrium search condition (1.40) substituting condition (1.70) into condition (1.66) to get

$$\eta^4 - \eta^5 = \eta^4 \frac{m_H \left(\theta^H\right)}{m_L (\theta^L)},$$

which I then substitute, together with equation (1.65), into equation (1.64):

$$\theta^H \psi_H = \theta^L \psi_L.$$

Chapter 2

Fiscal Multipliers at the Zero Lower Bound in a Semi-Structural Model: A Comparison with the New Keynesian Framework

2.1 Introduction

The last decade has witnessed a long and sustained period of short-term nominal interest rates stuck at their lower bound.[1] Such a long spell of low, or even negative, nominal interest rates has rekindled interest on the impact of this constraint on the magnitude of fiscal multipliers. Most of the research in this topic has been carried out using New Keynesian type of models. These models incorporate agents with rational expectations, feature nominal rigidities and are dynamic in nature. However, for the sake of tractability, most of the analysis has been carried out using small scale versions of these type of models. The aim of this paper is twofold. First, I provide a succinct but comprehensive review of the literature that has been devoted to the analysis and quantification of the impact of the zero lower bound on the magnitude of fiscal multipliers. Second, I take a large scale global econometric semi-

[1] Although this is usually referred as the zero lower bound, this lower bound does not necessarily have to be equal to zero. Typically, central banks have stated that their lower bound was a small positive number in order to prevent central bank reserves becoming perfect substitutes with cash and to avoid putting too much pressure on profit margins of various financial institutions. However, some central banks have recently experimented using a small negative number as their lower bound.

structural model (NiGEM) and compare the predictions that emanate from this model with the predictions that the literature has produced using New Keynesian models.

The consensus in the literature is that when the nominal interest rate is stuck at the zero lower bound, fiscal expansionary shocks become much more powerful at stimulating the economy.[2] Underpinning this result is a rise of inflation expectations triggered by the fiscal impulse. Given a constant nominal interest rate, higher inflation expectations produce a fall in the real interest rate. Such decline crowds in private consumption and investment which magnifies the output response to the fiscal stimulus. The literature suggests that fiscal multipliers at the zero lower bound are well above one.

I use the National Institute Global Econometric Model (NiGEM) to evaluate the magnitude of fiscal multipliers when the zero lower bound holds. I define the fiscal multiplier as the percentage change in output that arises in response to a one per cent of GDP fiscal expansionary shock. NiGEM is an estimated semi-structural global model with forward-looking agents and built-in nominal rigidities. Semi-structural models such as NiGEM are widely used for policy making and economic analysis.[3] These models provide a much richer description of economies and fit the data better.[4] For instance, NiGEM is global in scope, featuring 44 different countries, including most OECD countries, and six regions. Countries in the model are linked through trade, competitiveness and financial markets and all main components of domestic demand, such as private consumption, investment and the public sector, are separately modelled. The main drawback is that some, although not all, sectors in the economy are modelled via reduced-form equations rather than being micro-founded. From this perspective, semi-structural models are less robust to the Lucas Critique than DSGE models, of which New Keynesian models are part.

Making use of NiGEM's capabilities, I report the magnitude of the fiscal multipliers that arise from several fiscal instruments. In particular, I consider three types of fiscal instruments: government consumption, government investment and direct tax rate shocks. Fiscal multipliers from government spending shocks are larger than those from taxes, as in the latter case, adjustments in savings mean that not all of the change in disposable income feeds into consumption and therefore output. For each fiscal instrument, I report the multi-

[2]Some authors have questioned this result, recently. See, for instance, Cochrane (2013), Mertens and Ravn (2014) and Kiley (2016).

[3]For example, NiGEM subscribers include the OECD, Bank of England, Banca di Italia and ECB.

[4]Semi-structural models may not necessarily fit well data in times where an economy enters a liquidity trap given that such episodes are rare and therefore are not overly present in the data used to estimate the model.

pliers that arise when I shock each country included in the analysis in isolation, those arising when I assume there is international coordination of fiscal policies and those arising when I adjust the model to proxy a scenario where economies are undergoing a period of "crisis times". There are several reasons why fiscal multipliers might be dependent on the phase of the business cycle. For example, in a recession the proportion of liquidity constrained agents may increase, the zero lower bound constraint may be binding or there may be an absence of supply constraints, see for instance Barrell et al. (2009b) and DeLong and Summers (2012). Auerbach and Gorodnichenko (2012) and Cugnasca and Rother (2015), among others, have found empirical evidence of fiscal multipliers being larger during downturns. In this paper, following Al-Eyd and Barrell (2005), I model "crisis times" as a period with a higher sensitivity of aggregate consumption and investment to short-term fluctuations in income to account for a larger proportion of liquidity constrained individuals and firms. I find that in most instances, except when there is international coordination of fiscal policies, most multipliers are below one.

Once I impose the zero lower bound constraint, I find that, as predicted by the literature that has made use of New Keynesian models to analyze the effectiveness of fiscal policy at the zero lower bound, multipliers increase. However, the magnitude of such increase is small. Most multipliers remain below one. This is in stark contrast to the results obtained in the literature, which usually predicts multipliers larger than unity and even above two. I find that all of the transmission mechanisms, highlighted by the literature, through which the zero lower bound operates to produce larger multipliers hold in the results produced by NiGEM, but one. In contrast with the results from open economy New Keynesian models, NiGEM fails to produce an improvement of the net trade position of a country following an expansionary fiscal shock when the zero lower bound holds.

I also find that the magnitude of the multipliers, in NiGEM, are sensitive to the degree of consumer and investment myopia. The less forward looking are the equations for consumption and investment, the lower the fiscal multipliers at the zero lower bound. New Keynesian models produce large fiscal multipliers when the zero lower bound holds because the increase in public expenditure generates an expectation of future inflation which makes the real interest rate fall. However, if agents are backward looking, they will not react to the expectation of future higher inflation nor to the decline in the real interest rate.

Once I modify NiGEM to reduce the degree of expectational myopia and produce a foreign demand crowd in effect, I find that fiscal multipliers at the zero lower bound are well above unity, a result in line with that of the literature. However, the model appears to struggle to produce multipliers larger than two. Part of this struggle may just reflect the difficulty to explore the whole parameter space of the model, given that NiGEM has more than 6.000 equations. Indeed, being able to explore the predictions of the model across the whole parameter space is one of the main advantages of using parsimonious New Keynesian models such as the ones used in the literature, where the number of equations rarely exceeds ten.

This paper adds to the body of work that has used large multi-country macroeconomic models to quantify the magnitude of fiscal multipliers. Papers in this literature include, among others, Cogan et al. (2010), Cwik and Wieland (2011) and in't Veld (2013). Thus, the main contribution of the paper is to compare the results of the theoretical literature with those that arise from a large-scale model whose aim is to provide a more accurate representation of reality at the expense of some of the ingredients that make a model fully structural.

The paper is organized as follows. Section 2.2 provides a review of the literature on fiscal multipliers at the zero lower bound. Section 2.3 describes the model I use to quantify fiscal multipliers at the zero lower bound, NiGEM. Section 2.4 provides the magnitudes of fiscal multipliers that arise in NiGEM under several possible scenarios as well as the impact that the zero lower bound has on the magnitude of the multipliers. Section 2.5 investigates why the results from the NiGEM model differ from the standard results of the literature and Section 2.6 concludes.

2.2 Fiscal multipliers at the zero lower bound

The literature has devoted a great deal of attention to the analysis of the mechanisms through which a fiscal impulse transmits throughout the economy as well as quantifying the magnitude of fiscal multipliers. For the remainder of the text I define the fiscal multiplier as the percentage change in output that arises in response to a one per cent of GDP fiscal expansionary shock.[5] As summarized by Ramey (2011), within the Neoclassical business cycle framework, fiscal shocks transmit throughout the economy via one of the following three channels: wealth effects, inter-temporal substitution effects and distortions to first-order

[5]Different types of government expenditure, such as for instance public sector wage payments or investment in infrastructure, can potentially deliver different multipliers. For the remainder of this Section I will abstract from this level of detail and assume all government instruments affect the economy in a similar way.

conditions.[6] However, fiscal multipliers are found to be small, usually below unity (see, for instance, Baxter and King (1993)).

Fiscal shocks fail to produce large multipliers because public expenditure crowds out private expenditure. Typically, following an increase in public sector expenditure, a negative wealth effect arises as the increase in the present discounted value of taxes required to pay for higher public expenditure triggers a decline in the expected discounted value of household's income. Such wealth effect induces workers to work more, to compensate for the loss of income, but also to consume less. Thus, the public expenditure elasticity of output is below unity. Including capital in the model does not alter the result: although the increase in labour supply increases the marginal return of capital, given that capital is fixed in the short-run, output cannot respond to the increased desire of investing.

The New Keynesian framework, being in its most simple form a Neoclassical model with nominal rigidities, faces the same considerations mentioned above. Thus, fiscal multipliers in New Keynesian models are also usually below one (see Galí et al. (2007) and Cogan et al. (2010)). There are, nevertheless, some important differences in the New Keynesian framework relative to the Neoclassical one that alter the results obtained within the latter: the presence of nominal rigidities and the presence of a monetary authority; both elements being intimately related. The direct effect of nominal rigidities, modelled as either sticky prices and/or wages, on fiscal multipliers is shown in Woodford (2011) in a simple New Keynesian model with no capital. Within the New Keynesian model there is an assumption of monopolistic competition that introduces a wedge, or a mark-up, between the marginal cost of production and the price charged by firms. This mark-up introduces an "efficiency wedge" within the labour demand condition of firms which makes the equilibrium outcome inefficient. However, following an increase in demand, say because of an expansion in public expenditure, the mark-up decreases as marginal costs of firms increase to meet higher demand while, at least, some firms find themselves unable to adjust the price accordingly. The decline in the mark-up reduces the source of inefficiency and increases the output response to the fiscal expansion.

Given that money neutrality does not hold within the New Keynesian framework, there can be a monetary authority (or central bank) who, in setting nominal interest rates and influencing future expectations of inflation, has an impact on the real side of the economy. As Woodford (2011) shows, the objective function of the central bank is key in shaping the

[6] For an exhaustive analysis of the propagation mechanisms of fiscal shocks within the context of the neoclassical growth model, see Barro and King (1984), Aiyagari et al. (1992) and Baxter and King (1993).

fiscal multiplier. For instance, the author finds that if the central bank targets a constant real interest rate, the fiscal multiplier becomes one, while if the central bank targets a constant inflation rate the fiscal multiplier becomes equal to the one that arises if prices were completely flexible. If the central bank follows a Taylor Rule then the fiscal multiplier lies between the two extremes.

If we introduce capital in the model, just like public expenditure may crowd out private consumption, it can also crowd out private investment (see, for instance, Cogan et al. (2010), Christiano et al. (2011) and Cwik and Wieland (2011)). Following an increase in demand, say because of higher public expenditure, there will be an expectation of future inflation, as those firms who are unable to raise prices today will do so in the future. If the central bank follows a Taylor Rule (and the Taylor condition holds, whereby monetary policy must react with sufficient strength to changes in expected inflation), the increase in the nominal interest rate required to curb the increase in expected inflation will result in an increase in the real interest rate. Such increase in the real interest rate will crowd out private investment, with the subsequent decline in the multiplier.

Christiano et al. (2011) provide a set of comparative statics. Fiscal multipliers in a New Keynesian framework are increasing in the degree of complementarities between consumption and hours worked, as the increase in labour supply triggered by the negative wealth effect derived from the increase in public expenditure increases the marginal utility of consumption. Fiscal multipliers are also increasing in the degree of price stickiness, as higher price rigidities triggers larger falls in mark-ups when activity rises. Multipliers are, instead, decreasing in the persistence of the public expenditure shock, as the longer the government sustains an increase in expenditure, the larger is the negative wealth effect on consumption. Finally, multipliers are decreasing in the sensitivity of the nominal interest rate to changes in expected inflation, as this triggers larger responses of the real interest rate following a rise in demand. Christiano et al. (2011) also finds that while it is possible to have multipliers larger than unity within the New Keynesian model, it is usually difficult, for plausible parameter values, to obtain multipliers above $1\frac{1}{4}$.

There is, nevertheless, one instance where the literature has found that the magnitude of fiscal multipliers may exceed unity within a range of plausible parameter values: the case where the economy enters a liquidity trap and the central bank finds itself constrained by the zero lower bound on nominal interest rates. Eggertsson (2001, 2011), Christiano et al. (2011) and Woodford (2011), among others, study the effects of fiscal policy at the zero lower bound.[7] To understand why fiscal policy may be more effective at the zero lower bound it is helpful to take a detour and review, briefly, why is the zero lower bound problematic.

As is standard in this strand of the literature, suppose there is a preference shock that increases the desire to save of consumers. Such shock, will trigger a decline in demand which will bring firms to lower their prices. Given price rigidities, firms cannot adjust their prices instantaneously, which gives rise to expectations of future deflation (or a deceleration of the inflation rate). If the central bank follows a standard Taylor Rule, whereby the bank adjusts the nominal rate to stabilize fluctuations in output or inflation, the preference shock should trigger a decline in nominal interest rates. Unfortunately, if the shock is large enough, the central bank desired nominal rate might be below zero, at which point the central bank finds itself constrained because it cannot set a nominal interest rate below zero. The problem with hitting the zero bound constraint lies in that further declines in activity trigger further expectations of price declines, which will translate into an increase in the real interest rate. As a result, consumers desire to save will increase, which will put further downward pressure on activity, and, in turn, on prices, which again will put upward pressure on the real interest rate and thus, a vicious loop begins. To counteract this spiralling desire to save is a temporary sharp drop in output, which will act on the inter-temporal consumption decision margin of households and will limit their desire to save: consumers, facing a temporary fall in income, will want to save less to limit the consumption dip in order to smooth consumption.

Increases in public expenditure, just like policies such as the central bank committing to future inflation (Eggertsson and Woodford (2003)), act to break the vicious loop originated by the zero lower bound. A rise in demand originated by higher government expenditure will act to curb deflation expectations and, as a consequence, the real interest rate will decline. Thus, in such a scenario, public expenditure crowds in private consumption. This channel turns out to be very powerful and may lead, under reasonable parameter values, to obtain fiscal multipliers above two.

Key to this analysis is an assumption that the fiscal impulse is temporary, a point made by Eggertsson (2011) in response to the findings in Cogan et al. (2010), where the authors find a fiscal multiplier of a magnitude smaller than unity even within the context of an economy stuck at the zero lower bound constraint. Suppose, for ease of exposition, that the increase

[7] These papers build upon a large strand of literature that analyses optimal monetary policy at the zero lower bound. Papers within this literature include, among others, Summers (1991), Fuhrer and Madigan (1997), Krugman et al. (1998), Reifschneider and Williams (2000), Eggertsson and Woodford (2003), Christiano (2004), Jung et al. (2005) and Wolman (2005). The list is not exhaustive. Svensson (2003) provides a summary of this literature.

in public expenditure were to be permanent. Heightened demand during the time when the zero lower bound holds would lead firms to set higher prices. However, once the economy returns to normality, a heightened level of public expenditure would lead the central bank to increase nominal interest rates, which in turn would put downward pressure on prices. Thus, given the forward-looking nature of firms in the model, the final effect on the price that firms want to set today is ambiguous, but at the very least it is possible to conclude that the immediate inflationary impact of the government stimulus is more muted than if the fiscal shock only lasted for as long as the economy remained stuck at the zero bound. On top of this, a permanent fiscal expansion produces a higher negative wealth effect than if it were to be temporary. Thus, labour supply, and consequently, aggregate supply, will increase by more. However, within the context of an economy stuck at the zero lower bound, expansions in supply are counterproductive, as they produce additional expectations of future deflation which triggers further increases of the real interest rate.

It makes sense to ask whether this set of conclusions holds once one expands the New Keynesian model to include open economies that trade with other economies. Just as in standard introductory economic textbooks, the presence of trade, in normal economic circumstances (*i.e.,* not at the zero bound), reduces the magnitude of the fiscal multiplier as part of the fiscal expansion is "leaked" away via an increase in imports from other countries (see, for instance, Cogan et al. (2010), Cook and Devereux (2011) and Cwik and Wieland (2011)). In their open economy New Keynesian model, Cook and Devereux (2011) show that the result that fiscal policy becomes much more powerful at the zero lower bound, not only holds when one considers a multi-country model, but becomes even stronger than in the closed economy version of the model. The intuition behind this result rests on the presence of an exchange rate. In an open economy, following the decline in the real interest rate that a temporary fiscal expansion triggers when the economy is stuck at the zero bound, the real exchange rate devaluates. As a consequence, on top of the crowding in effect of private consumption derived from lower real interest rates, there is a crowd in spending effect from the rest of the world as home goods become relatively cheaper compared to foreign goods. A necessary implication of this result is that a fiscal expansion at the zero lower bound generates a cross country negative spillover, as foreign spending is diverted from foreign goods to home goods. Cook and Devereux (2011) also find that these results are very sensitive to the monetary target of the foreign central bank. In their analysis, the authors assume that the foreign central bank follows a standard Taylor Rule. Were the foreign central bank have a different target, such as for instance, a constant real exchange target, this would limit the magnitude of the exchange rate depreciation. As a consequence, the home country fiscal multiplier would be reduced and the foreign fiscal multiplier would turn positive.

There is a recent strand of the literature that has challenged the view that fiscal policy might be more powerful at the zero lower bound. The starting point of this literature is the work by Benhabib et al. (2001a,b) who show that New Keynesian models that incorporate the zero lower bound constraint can move into a liquidity trap in two different ways. First, there is the standard way where the economy enters a liquidity trap because of a preference shock that drives up the desire to save of consumers. However, there is a second way which relies on the existence of multiple equilibria. More specifically, the authors show that if there exists an equilibrium in these models where monetary policy follows a Taylor rule and the coefficients of the Taylor rule satisfy the Taylor condition, then there always exists another equilibrium where the economy is in a liquidity trap. The corollary of this work is that the literature has been neglecting the analysis of an equilibrium that would arise because of self-fulfilling expectations and that could trigger the zero lower bound with no need of shocks to consumer preferences.

Mertens and Ravn (2014), building on Benhabib et al. (2001a,b), analyze the effects of increases in public expenditure once the economy enters a liquidity trap because of self-fulfilling expectations. The conclusions are completely at odds with the previous set of results from the literature on fiscal policy at the zero lower bound: fiscal expansions in an equilibrium where the zero lower bound holds because of self-fulfilling expectations produce fiscal multipliers smaller than one. The intuition behind this result is that in such equilibrium, consumers are very sensitive to changes in prices, which is reflected in an aggregate demand curve that becomes flatter than the aggregate supply curve. As a result, expansions in aggregate demand produce deflationary rather than inflationary pressure. Cochrane (2013) also contests the conventional result that fiscal policy at the zero lower bound is very effective. In his paper, Cochrane (2013) argues that while it is true that New Keynesian models have an equilibrium where fiscal policy is highly effective at the zero lower bound, there are other, actually, infinitely many other equilibria in which fiscal policy does not become more effective at the lower bound, even if one assumes that the central bank follows a monetary policy rule that satisfies the Taylor condition.

Finally, Kiley (2016) provides another argument to challenge the conventional result of the effects of fiscal policy at the zero lower bound. Key to the conventional result is the assumption of sticky prices and/or wages in the style of Rotemberg (1982) and Calvo (1983) which makes the price taking decision of firms a forward looking problem that depends on all future optimal prices. This mechanism links current prices with future desired prices and is the channel that links higher demand with higher inflation expectations. Instead, if one assumes, as Kiley (2016) shows, an alternative form of price slugginesh derived from a sticky-information set up in the style of Mankiw and Reis (2002), the link between current and future prices disappears and thus expansions in public expenditure fail to decrease the real interest rate when the economy is stuck at the zero lower bound.

2.3 NiGEM

Having reviewed the main results from the literature on fiscal policy at the zero lower bound, I will now present the model that I will use in the remainder of the paper. NiGEM is a semi-structural estimated model with a New-Keynesian framework in that agents are forward looking and there are nominal rigidities. The model is semi-structural because some parts of it are micro-founded while some others have been modelled in reduced form. For example, while each country model has a production function and factor demand schedules are derived from a profit maximizing firm, the model does not feature an explicit utility function so that aggregate consumption is modelled via a reduced form equation. Nominal rigidities are not modelled explicitly, using, for instance, a Calvo (1983) or Rotemberg (1982) framework as is standard in the New-Keynesian literature. Instead, nominal rigidities are embedded within the model through the error-correction (ECM) framework that underlies all of the equations of the model. Thus, variables have a long-run relationship that needs to be satisfied. However, external shocks may temporarily deviate those variables from their long-run path and the process of adjustment is slow-moving. The speed of adjustment is estimated and will be different across countries given data idiosyncrasies.

The main advantage of using one such semi-structural model as opposed to a New Keynesian model such as the ones used by the academic literature is that semi-structural models allow for a far richer description of reality. For example, an analyst could take government policy as announced in the latest spending envelope, break each item of the spending envelope across the various fiscal instruments present in the model, which typically would include several expenditure and revenue instruments, and analyze the impact of such announcement on the rest of the economy as well as the impact on other countries of the model. Obviously, this comes at a cost as many behavioural equations in a semi-structural model are modelled in reduced form rather than being derived from micro-founded behaviour. As a result, semi-structural models are less robust to the Lucas Critique than fully structural DSGE models, of which New Keynesian models are part.

The model is global in its scope. It has 44 separate country models, including most OECD economies, and six regional blocks.[8] Countries are linked via trade, competitiveness and financial flows. The model is closed in that at the global level, all exports are matched by imports, all liabilities are somebody else's assets, all income flows from assets are matched by flows on liabilities and current accounts add up across the world. Expectational terms are included to capture the forward-looking nature of agents. To solve for the current and future values of each variables the Extended Path Method (EPM) of Fair and Taylor (1983) is used. Given that NiGEM is, essentially, a linear model, the Certainty Equivalence assumption that the EPM uses remains of limited concern.[9]

NiGEM has well over 6.000 equations. As a result, a detailed exposition of the model falls outside the scope of this paper. I will instead focus on providing a broad picture of the main elements of the model and pay attention to some particular details that are relevant to this paper. The reader is referred to Barrell et al. (2004a) and the National Institute of Economic and Social Research website for a more comprehensive explanation of the model.[10]

I will begin the description of the model discussing how supply and demand interact within the model and their feedback into the price system. I will then move into a more detailed description of the supply and demand side and conclude with a description of trade linkages. All country models share the same economic structure and differences in their economic behaviour are the outcome of data idiosyncrasies. For the sake of brevity, I will omit country subscripts from all variables, although the reader should keep in mind that each country has its own set of variables. The model time period is quarterly.

2.3.1 Supply and demand

Each economy has a CES production function with labour augmenting technological progress (denoted by λ) nested within a Cobb-Douglas framework:

$$YCAP_t = \gamma \left[\left(sK_t^{-\rho} + (1-s) \left(L_t e^{\lambda t} \right)^{-\rho} \right)^{-\frac{1}{\rho}} \right]^{\alpha} M_t^{1-\alpha}. \tag{2.1}$$

[8] Regional blocks are simplifed country models that aggregate the data from several groups of countries.

[9] The presence of a zero lower bound on nominal interest rates is the main source of non-linearity of the model.

[10] Available at: http://www.niesr.ac.uk/

$YCAP$ is real output, K is total capital stock, L is total hours worked, M is oil input, t is a time subscript, ρ is the elasticity of substitution between capital and labour and α is the output elasticity of the non-oil sector of the economy. This production function constitutes potential output (or capacity output) in the economy. Output is composed of a homogeneous good that can be used for consumption or investment interchangeably.

In the short-run, output in a country is driven by demand. However, whenever a gap appears between demand and potential output, it feeds into the pricing system of the economy which gradually adjusts to reestablish the equality between actual and potential output. This gap is denoted as capacity utilization and is expressed as follows:

$$CU_t = \frac{Y_t}{YCAP_t}, \tag{2.2}$$

where Y_t represents actual output.

Thus, suppose that the modeller introduces a shock that increases total demand but has no effect on factors of production. While in the short-run demand, and thus actual output, will be larger than potential output, the gap between to two will create inflationary pressure which will gradually reduce total demand to the level of potential output.

Note that consumer prices are not the only mechanism that ensure demand and supply return to parity. Nominal interest rates, equity prices and exchange rates also play a role but I discuss each of these channels later in the paper.

2.3.2 Supply side

Profit maximization of the production function yields factor demands as a function of the user cost of capital ($user$), the real wage ($rwage$) and the elasticity of substitution between capital and labour $\left(\sigma = \frac{1}{1+\rho}\right)$:

$$\ln\left(\frac{K_t}{YCAP_t}\right) = a - \sigma \ln\left(user_t\right), \tag{2.3}$$

$$\ln\left(\frac{L_t e^{\lambda t}}{YCAP_t}\right) = b - (1-\sigma)\lambda t - \sigma \ln\left(rwage_t\right). \tag{2.4}$$

Where a and b denote constants. The user cost of capital, is, in turn, determined by a weighted average of the cost of debt and equity finance and is also influenced by corporate taxes:

$$user_t = \frac{\omega\left(lrr_t + iprem_t\right)\left(1 - ctax_t\right) + \left(1-\omega\right)\left(lrr_t + prem_t\right) + dep_t}{1 - ctax_t}, \tag{2.5}$$

where lrr denotes the long-run real rate and is the 40 period ahead forward convolution of short-term real rates, $iprem$ denotes the cost of debt over and above the risk-free rate, $prem$ the analogue for equity and $ctax$ is the corporate rate tax.[11] Note that the user cost of capital is a forward-looking variable as it is function of the long-run real interest rate. Expectations of future interest rate hikes will have an effect on today's user cost of capital.

The first order conditions (2.3) and (2.4) constitute the long-run relationships that capital and hours worked must satisfy. Nonetheless, NiGEM allows for short-run deviations from these relationships. Investment, for instance, is modelled as an adjustment towards a desired capital stock whose long-run path is given by equation (2.3). The evolution of the capital stock is described by the following error correction equation:

$$\begin{aligned}\Delta \ln\left(K_t\right) &= \delta_1 - \delta_2\left[\ln\left(K_{t-1}\right) - \ln\left(YCAP_{t+12}\right) + \sigma \ln\left(user_{t-1}\right)\right] + \\ &\quad \delta_3 \Delta \ln\left(K_{t-1}\right) + \delta_4 \Delta \ln\left(Y_t\right) + \delta_5 \Delta \ln\left(Y_{t-1}\right),\end{aligned} \tag{2.6}$$

where the term in brackets is the long-run equilibrium relationship, δ_2 is the speed of adjustment towards the long-run path, the remaining terms are short-run dynamics and $\{\delta_1, \delta_3, \delta_4, \delta_5\}$ are parameters. From this equation one can back-up investment using the following perpetual inventory equation:

$$I_t = K_t - \left(1 - dep_t\right) K_{t-1}, \tag{2.7}$$

where dep stands for the depreciation rate.

Thus, investment in the short-run is driven by fluctuations in demand, as captured by the terms in front of the coefficients $\{\delta_4, \delta_5\}$ in equation (2.6). However, supply side effects drive the long-run properties of investment.

Labour supply is exogenous in NiGEM. Thus, equilibrium in the labour market is described by a labour demand and a wage equation.[12] The long-run properties of labour demand are governed by equation (2.4), while the wage bargaining equation satisfies the following

[11] As this paper is not directly concerned with issues regarding the cost of finance, I will not provide further description of the way the user cost of capital is modelled.

[12] The labour market in NiGEM is a very stylised version of the bargaining framework of Layard et al. (2005), chapter 2.

long-run condition:

$$\ln(rwage_t) = c + \ln\left(\frac{YCAP_t}{L_t e^{\lambda t}}\right) - dU_t, \tag{2.8}$$

where U denotes the unemployment rate and $\{c, d\}$ are parameters. Thus, real wages are, in the long-run, function of productivity, as measured by output per capita, and the unemployment rate. The latter term is included to account for the fact that the bargaining power of workers fluctuates over the business cycle. The complete equation for nominal wages, in error correction format is:

$$\begin{aligned} \Delta\ln(wage_t) &= \omega_1 - \omega_2\left[\ln(rwage_{t-1}) - \ln\left(\tfrac{YCAP_{t-1}}{L_t e^{\lambda t-1}}\right)\right] + \\ &\quad \omega_3\Delta\ln(CED_t) + (1-\omega_3)\Delta\ln(CED_t^e) + \omega_4 U_{t-1}, \end{aligned} \tag{2.9}$$

where CED denotes the consumer expenditure deflator and CED^e is an expectational term for future inflation. Nominal wages react to expectations of future inflation but also incorporate a certain degree of myopia.

2.3.3 Demand side

Demand in NiGEM is succinctly summarized by the usual national account identity, whereby total output is split between private and public consumption, total investment and net trade.[13] Having already discussed investment, in this section I focus on discussing private and public consumption.

2.3.3.1 Private consumption expenditure

Absent a utility function, household expenditure in consumption goods is modelled via a reduced form equation that takes the following form:

$$\begin{aligned} \Delta\ln(C_t) &= \beta_0 - \beta_1\{\ln(C_{t-1}) - [\alpha_1 + \ln(HUW_{t-1})]\} + \\ &\quad \beta_2\Delta\ln(RPDI_t) + \beta_3\Delta\ln(RNW_t) + \beta_4\Delta\ln(RHW_t), \end{aligned} \tag{2.10}$$

where C denotes aggregate consumption and $RPDI$ is real personal disposable income which is computed by subtracting total tax receipts from total personal income and deflating the

[13]Stockbuilding is also a component of the accounting identity, but it is modelled as an exogenous random walk process.

resulting term by the consumer expenditure deflator (CED). RNW denotes real net financial wealth, which includes domestic and foreign assets and liabilities held by households, and RHW is real housing wealth, which depends on the stock and price of houses. $\{\beta_0, \beta_1, \beta_2, \beta_3, \beta_4\}$ are parameters, β_1 capturing the speed of adjustment of aggregate consumption to its long-run equilibrium relationship. HUW denotes the present discounted value of future real personal disposable income and is expressed as follows:

$$HUW_t = \sum_{t=1}^{T} \frac{RPDI_t}{(1 + rr_t)^{1/4}}, \tag{2.11}$$

where rr_t denotes the short-term real interest rate, which I will describe further below. rr_t has been exponentiated to transform it from annual to quarterly terms.

Equation (2.10) establishes that in the long-run, consumer expenditure grows in line with the present discounted value of real disposable income. If we had a household with a quadratic utility function, the resulting Euler equation would yield a consumption function very similar to the long-run relationship described within the term in brackets in equation (2.10).[14] Thus, such long-run relationship, conditional on the use of a quadratic utility function, is very similar to the New Keynesian IS equation, as the latter is essentially an Euler equation as well. However, equation (2.10) departs from the standard New Keynesian IS equation in that it embodies a certain degree of consumer myopia as captured by its short-run dynamics terms.

2.3.3.2 Public sector

NiGEM models both the revenue and expenditure side of the government. On the revenue side, NiGEM includes direct tax rates (composed of income tax and social transfers), the corporate tax rate and the indirect tax rate (VAT for European countries). On the expenditure side, NiGEM includes government consumption and investment, transfers to households and government interest payments. Government expenditure is assumed to grow in line with trend output.

While government consumption represents expenditure on final goods, government investment accumulates into a stock of public capital, which in turn enters the production function. Thus, total capital stock in the economy, K, is composed of the sum of private and public

[14] Assuming suitable terminal conditions.

capital stock. Although public investment adds to capital deepening, no further spillover is assumed.

More relevant to this paper is a solvency rule that ensures that the government deficit returns to sustainable levels after any shock. NiGEM does not feature a feedback effect between the stock of debt, or the budget deficit, and the premium charged on sovereign debt.[15] The modeller can set assumptions regarding such premium but there is no endogenous channel in operation. As a result, there is, in principle, no mechanism to ensure that governments return to budget balance. The solvency rule acts to ensure budget balance by linking deviations from a target deficit ratio into the level of the effective direct tax rate. Whenever the government deviates from its target, the direct tax rate adjusts to return, gradually, the actual deficit to the desired one.

2.3.4 The external sector

Exchange rates in NiGEM are formalized through a standard Uncovered Interest Parity (UIP) condition. This is possibly the most important weakness of the model as the empirical literature has consistently rejected the validity of such rule to explain exchange rate fluctuations.[16] However, given that the literature has not yet managed to offer a satisfactory theory of the determination of the exchange rate, the UIP condition is still used within NiGEM due to its tractability.

Thus, within NiGEM, the expected change in the exchange rate is given by nominal interest rate differentials between foreign and domestic assets. The condition can be written as follows:

$$e_t = e_{t+1}\left(\frac{1+r_t^*}{1+r_t}\right)(1+rp_t), \tag{2.12}$$

where e_t is the nominal bilateral exchange rate at time t (defined as domestic currency per unit of foreign currency), r_t is the short-term nominal interest rate at home, r_t^* is the foreign counterpart and rp_t is the exchange risk premium which is assumed to be exogenous. Note that all exchange rates are expressed against the US dollar. However, one can back out any bilateral exchange rate from those.

[15] This channel has recently been explored. However, it is still not part of the main model release.

[16] See the surveys by Froot and Thaler (1990), Taylor (1995), Lewis (1995), Engel (1996), Sarno (2005) and Isard (2006).

Export volumes are a function of a measure of price competitiveness and import demand from other countries:

$$\begin{aligned}\Delta \ln (XVOL_t) \quad = \quad & \gamma_0 - \gamma_1 \left[\ln (XVOL_{t-1}) - \ln (S_{t-1}) + \gamma_2 \ln \left(\frac{PXNCOM_{t-1}}{CPX_{t-1}} \right) \right] + \\ & \gamma_3 \Delta \ln \left(\frac{S_t}{S_{t-1}} \right) + \gamma_4 \Delta \ln \left(\frac{PXNCOM_t}{CPX_t} \right), \end{aligned} \tag{2.13}$$

where $XVOL$ denotes export volumes of goods and services, S denotes market size/demand and is derived from Armington matrices based on 2010 trade patterns, $PXNCOM$ is the domestic price of non-commodity exports and CPX is a weighted average of other countries export prices. Thus, it is assumed that in the long-run export volumes grow in line with demand correcting for relative price competitiveness.

Imports, in turn, are a function of domestic demand and real import prices. The equation for imports is as follows:

$$\begin{aligned}\Delta \ln (MVOL_t) \quad = \quad & \kappa_0 - \kappa_1 \left[\ln (MVOL_{t-1}) - 1.24 \ln (TFE_{t-1}) + \kappa_2 \ln (RPM_{t-1}) \right] + \\ & \kappa_3 \Delta \ln (RPM_t) + \kappa_4 \Delta \ln (TFE_t), \end{aligned} \tag{2.14}$$

where $MVOL$ denote import volumes of goods and services, TFE is total final expenditure and RPM is real import prices. A common long-run income elasticity across all countries of 1.24 is imposed, based on a panel estimation reported in Barrell and Dees (2005).

2.3.5 Prices

Prices are the main equilibrium force that operates to ensure any gap between supply and demand is closed in the long-run. Consumer prices (CED) are modelled as follows:

$$\begin{aligned}\Delta \ln (CED_t) \quad = \quad & \nu_0 - \nu_1 \left[\frac{\ln (CED_{t-1})}{1 + \frac{1}{2} itr_{t-1}} - \nu_2 \ln \left(P^M_{t-1} \right) - (1 - \nu_2) \ln UTC_{t-1} \right] + \\ & \nu_3 \Delta \ln \left(P^M_t \right) + \nu_4 \Delta \ln (UTC_t), \end{aligned} \tag{2.15}$$

where itr denotes the indirect tax rate, P^M is the price of imports and UTC is unit total costs. The remaining terms are parameters. Therefore, the consumer price deflator is a function of domestic inflationary pressures, captured by UTC, and foreign inflation via import prices. Unit total costs are, in turn, function of nominal wage growth, productivity and capacity utilization. Note that equation (2.15) is a function of expectations of future inflation via the dependence of unit total costs on nominal wages, which are function of the expected inflation rate as shown in equation (2.9).

Equation (2.15) is the NiGEM equivalent of the New Keynesian Phillips curve (NKPC). It resembles the NKPC in that it links current inflation with expected future inflation and the current output gap, which in NiGEM is captured via capacity utilization. However, equation (2.15) differs from the NKPC as unit total costs also depend to a certain degree on past inflation rates.

To close the model one then needs only to specify the monetary policy reaction function, that is, nominal interest rates. Interest rates are determined by policy rules adopted by monetary authorities as discussed in Barrell et al. (2006b). Nominal short term interest rates are set in relation to a standard forward looking feedback rule. The default rule follows a 'two-pillar' strategy, targeting a combination of inflation and a nominal aggregate. The 'two-pillar' strategy rule is expressed as follows:

$$r_t = \epsilon r_{t-1} + (1-\epsilon)\left[\varphi \ln\left(\frac{nom_t}{nom_t^*}\right) + (1-\varphi)\left(\pi_t^e - \pi_t^*\right)\right], \tag{2.16}$$

where r is the short-term nominal interest rate, nom is nominal GDP, nom^* is a nominal GDP target, π^e is inflation expectations and π^* is the inflation target. The expectational term for inflation can be set to look into one period ahead inflation, four periods ahead or eight periods ahead.

It is also assumed that equity markets are forward looking, with equity prices determined by the present discounted value of expected profits, adjusted by an equity risk premium.

2.3.6 Model assumptions

NiGEM incorporates a wide range of possible monetary and fiscal policy reaction functions. In order to evaluate the effects of fiscal shocks and to ensure a proper comparison across scenarios I need to be clear about the underlying assumptions that I impose as well as making sure that the policy reactions do not contaminate the immediate responses of the economy to the established shocks. The assumptions are listed below.

- NiGEM incorporates a feedback rule in the direct tax rate equation that ensures that the government deficit returns to the target deficit in the medium term. This is switched off for a year.

- The monetary authority in all countries follows a two-pillar rule, whereby it aims to stabilize both inflation and nominal output. Although all countries follow the same type of rule, the weights placed in each term of the reaction function differ across countries reflecting each country data idiosyncrasies.

2.4 Fiscal multipliers in NiGEM

In this section I present the magnitude of the fiscal multipliers that arise in NiGEM under several different scenarios. I define the fiscal multiplier as the first year percentage response of output to a one per cent of GDP fiscal expansionary shock. Although NiGEM comprises country models for 44 countries, I only report results for the Euro Area countries plus Canada, Japan, the UK and the US.[17]

I provide the multiplier for three of the main fiscal policy instruments included in NiGEM: government consumption, government investment and the direct tax rate. I calibrate the shocks on government consumption and investment to equal a one year increase in real GDP. Instead, for the direct tax rate I calibrate the shocks to generate a one per cent of GDP decline in tax receipts. Each instrument affects the economy through a different mechanism and, consequently, gives rise to different multipliers.[18] It is thus convenient to discuss each of the fiscal policy instruments briefly.

Both government consumption and investment affect final demand directly. Government consumption shocks only have a temporary effect on output as they do not impact factors of production directly. Instead, government investment accumulates into a stock of public sector capital which enters the production function. As a result, government investment shocks have an impact on output in the long-run. However, as capital accumulations occurs slowly, the short-run impact on output of government investment shocks are very similar to that of government consumption shocks. Instead, the direct tax rate affects output indirectly through households' real disposable income.

Fiscal multipliers arising from government spending shocks (government consumption and investment) are larger than the ones arising from a government revenue shock as the former

[17] Excluding Cyprus, Luxembourg and Malta as they are not modelled separately in NiGEM. Estonia, Latvia, Lithuania, Slovakia and Slovenia have their own country model in NiGEM but I do not include them in the present analysis as they do not have an explicit model for the government sector.

[18] Each instrument will also impact the economy in different ways beyond the first year impact. However, given the focus of this paper on short-term multipliers I will omit the results on the long-run dynamics.

impact output directly while part of the increase in real personal disposable income implied by the latter is channeled into savings. The reader is referred to Al-Eyd and Barrell (2005) for a more in-depth analysis of the relationship between each type of fiscal instrument and fiscal multipliers.

It is important to highlight that shocks to Euro Area countries trigger relatively smaller reactions of the monetary policy nominal interest rate than those that arise from shocks to non Euro Area countries. This is because of the common monetary policy area that defines the Euro Area: relative to the whole Euro Area economy, each country, even in the case of Germany, constitutes only a small fraction of the whole area. As a result, the European Central Bank will react to a lesser extent to shocks to any particular country.

Table 2.1 reports the first year fiscal multipliers that arise from a one per cent of GDP fiscal expansionary shock that lasts for one year using the set of assumptions described in Section 2.3.6. The multipliers reported in Table 2.1 constitute the benchmark case against which I will compare all the results reported in the remaining of the paper. Note that to produce Table 2.1, I have applied each fiscal impulse to each country in isolation, one at a time. I explore the impact of coordination of fiscal policies on the magnitude of the fiscal multiplier in Section 2.4.3.

As expected, fiscal multipliers from government spending shocks are larger than those from direct tax rate shocks. In addition, government investment shocks produce multipliers slightly higher than those of government consumption shocks, a result that emanates from the effect of investment on capital accumulation.

Table 2.1 also highlights that fiscal multipliers in NiGEM are generally small, usually below unity. This result is linked to several dimensions of the model. First, the presence of trade implies that part of the increase in total final expenditure derived from the fiscal shock is leaked away as imports from other countries. Second, several elements act to dampen the effect of the shock. One example is the reaction of the interest rate. Following the fiscal impulse, output increases which triggers a reaction of the monetary authority which will attempt to close the gap between actual and potential output. As a result, interest rates will increase which will act to depress consumption and investment. Another example is given by the exchange rate. Following an increase in the short-run interest rate, the exchange rate will appreciate immediately in order to produce the expected depreciation that the UIP condition requires. Such appreciation will also dampen the expansionary effect of the fiscal shock.

Table 2.1: First year multipliers from a 1% of GDP temporary fiscal expansion

	Government consumption	Government investment	Direct tax rate
Belgium	0.44	0.46	0.07
Canada	0.58	0.60	0.09
Finland	0.62	0.64	0.15
France	0.56	0.57	0.33
Germany	0.42	0.42	0.17
Greece	0.92	0.95	0.52
Ireland	0.21	0.22	0.04
Italy	0.52	0.53	0.07
Japan	0.83	0.85	0.17
Netherlands	0.54	0.54	0.10
Austria	0.48	0.50	0.09
Portugal	0.61	0.63	0.05
Spain	0.76	0.77	0.12
UK	0.51	0.53	0.09
US	0.83	0.84	0.12

Notes: No shift in the budget deficit target. Experiments conducted one country at a time.

Another important result that transpires from Table 2.1 is the heterogeneity in the magnitude of multipliers across countries. I devote Section 2.4.1 to a more careful analysis of the determinants of the magnitude of the multipliers.

2.4.1 Regression analysis

In this section I investigate what are the determinants of the observed heterogeneity in the magnitude of fiscal multipliers. To do so, I run OLS regressions of the fiscal multipliers onto a set of controls. The explanatory variables are: EA, which is a dummy variable that accounts for whether a country belongs to the Euro Area or not; ConsElas, which is the short-term aggregate consumption-income elasticity and is taken from NiGEM's aggregate consumption equation for each country (coefficient β_2 from equation (2.10)); TfeCont, which is the import content of total final expenditure taken from NiGEM's import equations (coefficient κ_4 from equation (2.14)); Openness, which is a measure of openness to trade and is defined as the average of the ratio between import volumes and real output between the 2010-2014 period and Size, which is the ratio of each country's GDP over the world's GDP measured in PPP terms.

The data series for import volumes and real output are taken from NiGEM's database which, in turn, draws from each country National Statistical office. The GDP series in PPP terms are taken from the IMF World Economic Outlook Database (2011). The estimation of NiGEM's import equations, from which I have taken the measure of import content of total final expenditure is discussed in Barrell et al. (2007). Al-Eyd and Barrell (2005) estimate NiGEM's aggregate consumption equations from where I have taken the estimates of the short-run aggregate consumption-income elasticities. Table 2.2 reports the results of the regression analysis.

Table 2.2: OLS results with fiscal multipliers as dependent variable

	Government consumption	Government investment	Direct tax rate
Constant	1.461***	1.505***	0.320
	(0.173)	(0.181)	(0.185)
EA	0.137	0.133	0.051
	(0.076)	(0.079)	(0.081)
ConsElas	-0.090	-0.099	0.461**
	(0.158)	(0.165)	(0.169)
TfeCont	-0.315***	-0.322***	-0.106
	(0.076)	(0.079)	(0.081)
Openness	-0.980***	-0.999***	-0.320*
	(0.161)	(0.168)	(0.171)
Size	0.011	0.010	-0.002
	(0.008)	(0.008)	(0.008)
Adj. R^2	0.761	0.748	0.412
F-test	0.002	0.002	0.075

Notes: a * indicates the coefficient is significantly different from zero at the 10 per cent significance level. A ** at 5 per cent and a *** at 1 per cent. Standard errors are reported in parenthesis.

The sign of the coefficients agrees with standard economic intuition. The coefficient in front of the dummy variable controlling for membership of the Euro Area (EA) has a positive sign, albeit is not statistically significant at the 10 per cent level by a very narrow margin. Euro Area countries share a common monetary policy. As a result, the reaction of the central bank will be relatively more muted to a shock to one particular Euro Area country than what it would have been had the country had its own monetary policy. Thus, following any of the expansionary shocks, the increase in interest rates and the subsequent appreciation of the domestic currency is relatively smaller in Euro Area than in non-Euro Area countries which results in larger reactions of output to the fiscal shocks.

The coefficient for the short-term aggregate consumption to income elasticity is not statistically different from zero for the case of government spending shocks but positive and significantly so for the case of the direct tax rate shocks. This is to be expected, as a direct tax rate shock affects household's disposable income directly, while government spending shocks only have an indirect effect on income. The positive sign captures that countries whose consumers have a higher marginal propensity to consume will experience larger multipliers following a rise in income derived from a decrease in income tax.

The signs for the regressors controlling for the import content of total final expenditure (TfeCont) and openness to trade (Openness) are also negative and significantly so. Countries whose total final expenditure has a higher import content experience lower multipliers as part of the increase in expenditure is leaked away via imports. Similarly, countries that are more open to trade also experience lower multipliers due to the "leakage" effect. Finally, the size of the economy does not appear to be statistically different from zero in any of the regressions.

The goodness of fit of the regressions is high, as shown by the adjusted R^2 measure and the F-test, although this is to be expected given that these regressions have no sample variation. In principle, it should be possible to obtain an R^2 equal to 1. However, given the size of the model and the large degree of feedback effects, there is no small set of variables that could produce such fit.

According to the results in Table 2.4.1, TfeCont and Openness appear to be the only relevant determinants of the magnitude of fiscal multipliers from government expenditure shocks, while ConsElas appears to the the only relevant one in determining that of a direct tax rate shock. One may then ask whether the regression model would fit the data equally well including only those controls. To this end, I re-run the regressions of table 2.4.1 but using only TfeCont and Openness as controls when I run the regression with the multipliers arising from government expenditure shocks and using only ConsElas as control when running the regression using the multipliers arising from a direct tax rate shock. The results are displayed in table 2.3.

Table 2.3 shows that the sign of the coefficients remains unchanged relative to those in table

Table 2.3: OLS results with fiscal multipliers as dependent variable: smaller subset of controls

	Government consumption	Government investment	Direct tax rate
Constant	1.445***	1.485***	0.014
	(0.172)	(0.175)	(0.046)
ConsElas			0.511***
			(0.153)
TfeCont	-0.270***	-0.280***	
	(0.074)	(0.075)	
Openness	-0.887***	-0.902***	
	(0.135)	(0.132)	
Adj. R^2	0.747	0.747	0.422
F-test	0.0001	0.0001	0.005

Notes: a * indicates the coefficient is significantly different from zero at the 10 per cent significance level. A ** at 5 per cent and a *** at 1 per cent. Standard errors are reported in parenthesis.

2.2 and the goodness of fit is at least as good as that in table 2.2.

2.4.2 Fiscal multipliers in crisis times

In a world where the assumption of perfect capital markets holds, agents' consumption and investment decisions can be decoupled from their income profile so long as the present discounted value of their spending profile equals that of their income.[19] Agents can simply borrow against their future income. However, the literature has found evidence that aggregate consumption correlates with measures of easiness of access to credit, see, for instance, Bacchetta and Gerlach (1997) and Ludvigson (1999), suggesting that some agents cannot gain access to credit even when they should be able to given their future stream of income. Following the literature, I call these agents credit or liquidity constrained individuals. Agents who cannot borrow against their future income rely much more on their current income stream, which implies that aggregate consumption will also be more sensitive to movements in income when the proportion of liquidity constrained agents increases.

The sensitivity of aggregate consumption to current income may fluctuate over the business cycle as the share of agents who face credit constraints changes. For instance, Barrell et al.

[19]This is a variation of Fisher separation theorem.

(2006a) suggest that the proportion of agents and firms with liquidity constraints increases over a financial crisis. Fiscal multipliers, in turn, will also be affected by the proportion of liquidity constrained agents, as increases in firms profits and household's disposable income triggered by the fiscal shock will translate into a stronger increase in consumption or investment.

In this section I look at how the magnitude of fiscal multipliers change when the share of liquidity constrained agents increases as it would happen during a recession. Unfortunately, NiGEM is a representative agent model. Thus, following Al-Eyd and Barrell (2005), I proxy the increase in the share of liquidity constrained agents by increasing the income elasticities of aggregate consumption and investment. Recall, the aggregate consumption equation in NiGEM is as follows:

$$\begin{aligned}\Delta \ln (C_t) &= \beta_0 - \beta_1 \{\ln (C_{t-1}) - [\alpha_1 + \ln (HUW_{t-1})]\} + \\ &\quad \beta_2 \Delta \ln (RPDI_t) + \beta_3 \Delta \ln (RNW_t) + \beta_4 \Delta \ln (RHW_t).\end{aligned}$$

For our purposes, β_2 is the parameter of interest as it represents the short-term income elasticity of aggregate consumption. To approximate an increase in the proportion of households facing liquidity constraints, I follow Al-Eyd and Barrell (2005) and increase the parameter β_2 by 25 per cent.

How can this increase be interpreted? Under a specific set of assumptions, a percentage increase of the short-run aggregate propensity to consume (β_2) could be interpreted as being exactly equal to the percentage increase in the proportion of households facing liquidity constraints. Suppose that there are two types of households in the economy: liquidity constrained agents, whose propensity to consume out of current income (β^c) equals 1, and agents who face no liquidity constraints, whose propensity to consume (β^u) equals 0. The latter case could be obtained from a utility maximization problem where the household has quadratic utility (as in Hall (1979)) and the interest rate limits zero. Aggregate consumption (C) can be expressed as follows:

$$C = wc_c + (1 - w) c_u,$$

where c_c and c_u denote consumption of constrained and unconstrained agents, respectively, and w denotes the proportion of constrained agents in the economy.

Under this set of assumptions, the aggregate propensity to consume out of current income equals w and the percentage change in w is equal to the percentage change in the aggregate propensity to consume.

Amidst a recession, not only households face difficulties to access credit. Firms may also be liquidity constrained just as households are. For consistency, I follow the same approach as with households and increase by 25 per cent the parameter in the aggregate investment equation that captures the sensitivity of aggregate investment to fluctuations in real income (parameters $\{\delta_4, \delta_5\}$ of equation 2.6).

Table 2.4 reports the percentage increase of the fiscal multipliers derived from increasing the income elasticity of aggregate consumption and investment relative to the multipliers displayed in Table 2.1.

Table 2.4: Crisis times: percentage increase of fiscal multipliers relative to the benchmark

	Government consumption	Government investment	Direct tax rate
Belgium	3.3	3.1	27.9
Canada	2.5	2.5	26.1
Finland	4.0	4.3	27.8
France	4.0	3.6	28.0
Germany	2.0	1.7	23.2
Greece	15.9	16.2	44.7
Ireland	1.2	1.6	23.7
Italy	3.3	3.4	25.6
Japan	8.2	8.3	27.3
Netherlands	2.8	3.3	25.0
Austria	3.6	3.7	28.9
Portugal	3.3	3.0	24.0
Spain	7.2	7.2	26.0
UK	3.8	3.9	25.2
US	20.5	20.4	48.2

Notes: No shift in the budget deficit target. Experiments conducted one country at a time.

The main feature that arises from Table 2.4 is that an increase in the proportion of liquidity constrained agents produces much larger increases, in proportional terms, of the multipliers arising from direct tax rate shocks than from government spending shocks. The average percentage increase of the multiplier for government spending shocks is of 5.7 per cent while that of the shock to the direct tax rate is 28.8 per cent.

The intuition behind this result has been already discussed in Section 2.4.1. Government spending shocks impact household's real disposable income only indirectly via general equilibrium effects, while the direct tax rate shock has a direct effect on disposable income. Thus, increasing the sensitivity of aggregate consumption to fluctuations in income will have a much larger impact to the multipliers arising from shocks that have a direct impact to household's income. This intuition is not valid for the case of private investment as the direct tax rate is not a tax on corporation profits. However, given the prominence of private consumption in total output compared to investment, the dynamics of the aggregate consumption equation dominate.

A question arises regarding the percentage increase of the fiscal multiplier for both Greece and the US. I conjecture that both countries experience a significantly larger percentage increase in fiscal multipliers relative to other countries because the proportion of private consumption out of total output is the largest in these two countries. To test this conjecture I run a regression of the percentage increase in fiscal multipliers as reported in Table 2.4 onto the average share of private consumption out of total output for each country between the years 2012 and 2015 (Cshare). The results are displayed in Table 2.5.

Table 2.5: Crisis times OLS results

	Government consumption	Government investment	Direct tax rate
Constant	-21.856**	-21.342**	-5.110
	(8.704)	(8.885)	(12.636)
Cshare	48.482***	47.613***	59.564**
	(15.181)	(15.497)	(22.040)
Adj. R^2	0.397	0.376	0.311
F-test	0.007	0.009	0.018

Notes: a * indicates the coefficient is significantly different from zero at the 10 per cent significance level. A ** at 5 per cent and a *** at 1 per cent. Standard errors are reported in parenthesis.

I find that, indeed, the coefficient in front of Cshare is positive and significant and the goodness of fit is not bad: Cshare alone explains around 35 per cent of the observed variation. This result makes sense, as it implies that the increase in private consumption derived from the fiscal impulse in times where a larger proportion of agents are liquidity constrained has a larger effect in those countries for which private expenditure represents a larger share of output. I also provide the scatter plot between the government consumption multipliers of Table 2.5 and Cshare in figure 2.8 in Appendix 2.7.2.

Thus, it would appear that both Greece and the US experience a larger percentage increase in the fiscal multipliers when the share of liquidity constrained agents increases because a larger fraction of their output depends on private consumption.

2.4.3 Fiscal multipliers under international coordination of fiscal policies

History shows that, on occasions, several countries find themselves synchronizing their fiscal policies, even if they had not intended to. The recent Euro Area sovereign crisis episode offers one such example where several governments across the Euro Area engaged, almost simultaneously, in fiscal consolidation programmes.

The literature has looked extensively into the impact of coordinating fiscal policies across several countries on the magnitude of fiscal multipliers. Examples include Gros and Hobza (2001), Beetsma et al. (2006), Benassy-Quere and Cimadomo (2007) and Ivanova and Weber (2011). From a theoretical point of view, a fiscal expansion coordinated across several countries has an ambiguous effect on the magnitude of fiscal multipliers due to the presence of two opposing forces. On the one hand, trade acts to increase the magnitude of the multiplier. If a country undertakes a fiscal expansion, their demand for imports will increase which will have a positive effect on neighbouring countries as their demand for exports increases.[20] On the other hand, higher demand at the international level should trigger larger reactions of the monetary policy authority. Interest rates adjust and damp the rise in demand to a larger extent than if the fiscal shock was implemented in one country alone.

In this section, I apply the same fiscal shocks that I applied to create Table 2.1, but run the simulations in all countries at the same time to capture an episode of international coordination of fiscal stances. I report the fiscal multipliers and, in parenthesis, the percentage increase relative to the multipliers in Table 2.1 in Table 2.6.

As it can be seen from Table 2.6, fiscal multipliers increase significantly when there is international coordination of fiscal policies. On average, government spending multipliers increase

[20] I use the term neighbouring from an economic perspective, where closeness is not only related to the geographical sense of the word but also to the degree of trade and financial linkages as well as migration flows between countries.

Table 2.6: Fiscal coordination: first year multipliers from a 1% of GDP temporary fiscal expansion

	Government consumption		Government investment		Direct tax rate	
Belgium	1.26	(182.2)	1.31	(184.9)	0.32	(355.1)
Canada	0.91	(58.0)	0.95	(57.5)	0.16	(72.8)
Finland	1.05	(68.1)	1.09	(69.7)	0.26	(74.6)
France	0.84	(51.1)	0.87	(52.0)	0.40	(20.1)
Germany	0.67	(58.2)	0.69	(63.7)	0.23	(37.9)
Greece	1.55	(68.4)	1.61	(70.0)	0.69	(30.9)
Ireland	0.41	(90.4)	0.43	(93.4)	0.09	(141.4)
Italy	0.73	(40.2)	0.75	(41.5)	0.14	(96.4)
Japan	1.03	(24.1)	1.06	(24.4)	0.21	(27.2)
Netherlands	1.36	(154.2)	1.42	(161.9)	0.34	(239.1)
Austria	0.84	(73.7)	0.87	(74.8)	0.21	(122.3)
Portugal	1.14	(85.9)	1.18	(88.7)	0.20	(343.2)
Spain	0.97	(28.9)	1.01	(31.0)	0.19	(60.2)
UK	0.81	(57.9)	0.84	(57.3)	0.17	(84.4)
US	0.93	(12.3)	0.95	(12.7)	0.15	(25.2)

Notes: No shift in the budget deficit target. Experiments conducted in all countries simultaneously. Numbers in parenthesis denote the percentage change compared to the multipliers in Table 2.1.

by 71.1 per cent while multipliers from direct tax rate shocks by 115.4 per cent. The increases are sufficiently strong to turn some of the multipliers larger than unity. It appears that in NiGEM, the positive spillovers derived from trade dominate the dampening effect coming from higher interest rates. Note, however, that the magnitude of the multipliers is a function of the number of countries that coordinate their fiscal stance as well as the trade linkages across the countries that coordinate the fiscal shocks. Had the number of countries implementing a fiscal expansionary shock been smaller, so would the increase in the multipliers.

A simple regression analysis (results displayed in Appendix 2.7.1) where I regress the percentage increase in the fiscal multipliers as displayed in Table 2.6 against the same set of controls described in Section 2.4.1 shows that the single most important factor that captures the increase in the multipliers is the degree of a country openness to trade.

2.4.4 Fiscal multipliers at the zero lower bound

In this section I look into how the magnitude of fiscal multipliers change when the zero lower bound holds. To do so, I re-run all the simulations of Sections 2.4 to 2.4.3 but forcing the short-term nominal interest rate to be constant for a year. I will also consider the case where the short-term nominal interest rate is held constant for two years. In keeping the short-term interest rate constant, I am still allowing the real interest rate to adjust given changes in expected future inflation/deflation. After a year (or two, depending on the simulation), I assume the monetary policy reaction function operates again as in normal times. Table 2.7 reports the multipliers that arise when the zero lower bound constraint binds for one year. In addition, in parenthesis, I provide the percentage increase of the magnitude of the multipliers compared to those reported in Table 2.1.

Table 2.7: First year multipliers from a 1% of GDP temporary fiscal expansion

	Nominal rate fixed 1 year					
	Government consumption		Government investment		Direct tax rate	
Belgium	0.45	(0.9)	0.46	(0.9)	0.07	(1.4)
Canada	0.61	(4.6)	0.63	(5.2)	0.10	(5.5)
Finland	0.63	(0.3)	0.64	(0.3)	0.15	(0.4)
France	0.57	(2.8)	0.59	(2.8)	0.34	(2.5)
Germany	0.45	(7.7)	0.46	(7.7)	0.18	(9.7)
Greece	0.92	(0.2)	0.95	(0.2)	0.53	(0.3)
Ireland	0.21	(0.5)	0.22	(0.4)	0.04	(0.6)
Italy	0.53	(2.2)	0.54	(2.1)	0.07	(2.4)
Japan	1.12	(35.2)	1.14	(34.5)	0.23	(36.7)
Netherlands	0.54	(0.8)	0.55	(1.8)	0.10	(2.5)
Austria	0.48	(0.5)	0.50	(0.6)	0.09	(0.9)
Portugal	0.62	(0.2)	0.63	(0.2)	0.05	(0.4)
Spain	0.77	(1.9)	0.79	(1.8)	0.12	(2.2)
UK	0.56	(9.4)	0.58	(9.0)	0.10	(10.1)
US	0.96	(16.9)	0.99	(16.9)	0.15	(20.0)

Notes: No shift in the budget deficit target. Experiments conducted one country at a time. Numbers in parenthesis denote the percentage change compared to the multipliers in Table 2.1.

The first element that stands out from the results in Table 2.7 is the differential impact of the zero lower bound on Euro Area countries against non-Euro Area countries. Given that the Euro Area interest rate moves little to a fiscal shock to any of its constituent countries, there is little effect coming from the presence of the zero lower bound constraint. When I consider a shock that forces the ECB to react with similar strength as those countries that do not belong to the Euro Area, then I do find that the percentage increases in the magnitude of the multipliers of Euro Area countries is in line with those of non-Euro Area countries. An example is provided in Table 2.8, where I evaluate the impact of the zero lower bound on fiscal multipliers when there is international coordination of fiscal policies. The shocks used to create Table 2.8 are the same as the ones used to create Table 2.6.

Table 2.8: Fiscal coordination: first year multipliers from a 1% of GDP temporary fiscal expansion

	Nominal rate fixed 1 year					
	Government consumption		Government investment		Direct tax rate	
Belgium	1.45	(15.5)	1.52	(15.5)	0.38	(18.2)
Canada	1.03	(12.1)	1.06	(12.6)	0.18	(14.3)
Finland	1.23	(17.7)	1.28	(17.8)	0.32	(20.9)
France	0.95	(13.1)	0.98	(13.1)	0.44	(8.5)
Germany	0.82	(23.8)	0.85	(23.3)	0.28	(21.6)
Greece	1.64	(5.7)	1.71	(5.8)	0.72	(4.9)
Ireland	0.45	(10.2)	0.47	(10.2)	0.11	(24.5)
Italy	0.81	(11.3)	0.84	(11.8)	0.17	(17.4)
Japan	1.44	(39.9)	1.48	(39.9)	0.31	(44.2)
Netherlands	1.66	(21.9)	1.73	(21.9)	0.43	(24.8)
Austria	0.95	(14.1)	0.99	(14.0)	0.25	(18.1)
Portugal	1.34	(17.2)	1.39	(17.5)	0.26	(25.6)
Spain	1.09	(12.0)	1.15	(13.2)	0.23	(21.6)
UK	0.94	(15.6)	0.97	(16.0)	0.20	(18.1)
US	1.13	(22.1)	1.16	(22.5)	0.19	(26.0)

Notes: No shift in the budget deficit target. Experiments conducted one country at a time. Numbers in parenthesis denote the percentage change compared to the multipliers used to produce Table 2.6.

Another result that arises from Table 2.7, is that, although multipliers increase when the zero lower bound constraint binds, it is not necessarily the case that multipliers become bigger than one. In fact, almost all of the multipliers remain below one. This is in stark contrast with the standard result from the literature on fiscal multipliers at the zero lower bound, see Section 2.2.

If one only focuses on non-Euro Area countries, openness to trade remains an important factor behind the percentage increase in the multipliers. This can be easily seen in Figure 2.9 in Appendix 2.7.2 where I plot the percentage increase in the government consumption multiplier for the four non-Euro Area countries included in the analysis against openness to trade as defined previously in the text.

I check how the magnitude of the multipliers change when I expand the length of time during which the zero lower bound constraint binds. Table 2.9 reports the percentage increase in the multipliers when the nominal interest rate is held constant for 2 years as opposed to only 1 year. I find that multipliers increase by more when I increase the length of time for which the zero lower bound holds. This is to be expected as, although the fiscal expansionary shocks last for one year only, their effect on inflation lasts for more than one year given the presence of nominal rigidities. As a result, if interest rates remain constant for a longer period of time, the long-run real interest rate falls by more as central banks would otherwise want to raise interest rates in the year following the end of the fiscal expansionary shock. This channel, however, would loose strength if I were to increase further the length of time at which the zero lower bound constraint binds relative to the length of the fiscal expansionary shock.

I also look into how multipliers respond when I expand the length of time that fiscal shocks last. I run this simulation to verify whether the claim by Eggertsson (2011), namely that fiscal multipliers decline if the fiscal shock is permanent even if the economy is stuck temporarily at the zero lower bound, in response to Cogan et al. (2010), holds in NiGEM. To this end, I run a simulation with the same set of shocks as those reported in Table 2.7, but where the expansionary fiscal shock is permanent rather than lasting for just one year.

One little caveat to this exercise that makes the results slightly less comparable is the assumption on the solvency rule: in all the simulations that I have considered so far, the solvency rule was switched off for a year and allowed to operate from there on. When the fiscal shock is of a permanent nature, this set-up for the solvency rule would give rise to a permanent increase in direct taxes, as the solvency rule would attempt to close the gap between the target deficit of a country and the permanently higher level of government spending. To avoid this, I allow the solvency rule to operate at all times but decrease the budget deficit target by one per cent to account for the permanent increase in government expenditure. I do, however, exclude the simulations for the government direct tax rate shocks. Given that the solvency

Table 2.9: First year multipliers from a 1% of GDP temporary fiscal expansion

	Nominal rate fixed 2 years					
	Government consumption		Government investment		Direct tax rate	
Belgium	0.45	(1.1)	0.47	(1.2)	0.07	(1.3)
Canada	0.64	(10.6)	0.66	(10.3)	0.10	(9.5)
Finland	0.63	(0.4)	0.64	(0.4)	0.15	(0.5)
France	0.58	(3.7)	0.59	(3.7)	0.34	(3.1)
Germany	0.46	(9.8)	0.45	(7.5)	0.17	(5.4)
Greece	0.92	(0.2)	0.95	(0.2)	0.53	(0.3)
Ireland	0.22	(0.7)	0.22	(0.7)	0.04	(0.9)
Italy	0.54	(3.1)	0.55	(2.9)	0.07	(3.2)
Japan	1.11	(33.5)	1.13	(33.6)	0.20	(18.8)
Netherlands	0.55	(2.3)	0.55	(2.1)	0.10	(1.8)
Austria	0.48	(0.7)	0.50	(0.8)	0.09	(0.9)
Portugal	0.62	(0.3)	0.63	(0.3)	0.05	(1.0)
Spain	0.77	(1.3)	0.79	(2.3)	0.12	(2.3)
UK	0.60	(17.4)	0.63	(18.0)	0.11	(16.6)
US	0.98	(18.4)	1.00	(18.5)	0.14	(18.9)

Notes: No shift in the budget deficit target. Experiments conducted one country at a time. Numbers in parenthesis denote the percentage change compared to the multipliers in Table 2.1.

rule operates via a feedback effect through the direct tax rate equation, a permanent shock to direct tax rate implies that the solvency rule must be switched off permanently, which then makes such simulation non-comparable to the remaining ones. Table 2.10 reports the results.

The simulations show that multipliers have decreased in most of the Euro Area and all of the non-Euro Area countries while they have increased for some of the Euro Area countries. The intuition behind the fall in the multiplier follows the argument made by Eggertsson (2011). Following the fiscal expansionary shock, the presence of the zero lower bound puts downward pressure on the real interest rate due to an expectation of future higher inflation. However, the fact that the fiscal expansion lasts for a long period of time implies that the inflationary impact of the shock will persist over and above the period of time in which the lower bound holds. As a result, fiscal multipliers may become smaller because there will be

Table 2.10: First year multipliers from a 1% of GDP permanent fiscal expansion

	Nominal rate fixed 1 year			
	Government consumption		Government investment	
Belgium	0.47	(4.8)	0.51	(10.1)
Canada	0.50	(-12.8)	0.57	(-5.8)
Finland	0.51	(-18.3)	0.85	(31.8)
France	0.52	(-6.3)	0.52	(-9.6)
Germany	0.33	(-21.9)	0.39	(-8.4)
Greece	1.02	(10.7)	1.08	(13.7)
Ireland	0.21	(-0.3)	0.32	(46.3)
Italy	0.56	(8.8)	0.58	(9.8)
Japan	0.67	(-19.2)	0.72	(-15.7)
Netherlands	0.43	(-20.1)	0.69	(26.9)
Austria	0.49	(2.2)	0.55	(9.5)
Portugal	0.64	(3.7)	0.44	(-30.6)
Spain	0.76	(0.2)	0.88	(14.3)
UK	0.40	(-22.5)	0.42	(-20.2)
US	0.77	(-7.2)	0.80	(-5.4)

Notes: there is a 1% shift in the budget deficit target. Experiments conducted one country at a time. Numbers in parenthesis denote the percentage change compared to the multipliers in Table 2.1.

nominal interest rate increases in the future that may result in the long-run real interest rate to increase, rather than decrease, at the onset of the shock.

For those countries that are part of the Euro Area block, given the muted response of the nominal interest rate, the previous channel looses strength and the increase in output derived from higher sustained demand may dominate. This becomes even more extreme when I consider a permanent government investment shock, which, on top of constituting an increase in demand, it accumulates and results in a significant increase of the capital stock of the economy.

Finally, I also look at the impact of the zero lower bound on fiscal multipliers when the share of agents facing liquidity constraints is higher; my proxy for “crisis times”. The results are displayed in Table 2.11 and show that the effect of the zero lower bound on fiscal multipliers is slightly larger when the share of liquidity constrained agents increases. However, the differential impact is small: across all countries, the average percentage increase of multipliers following a government spending shock when the zero lower bound holds, in "normal times", is 5.6 per cent, while the same figure when the share of liquidity constraint agents is increased is 6.6 per cent. For the direct tax rate shock, in the benchmark case displayed in Table 2.7, the average percentage increase is 6.4 per cent while in Table 2.11 is 7.5 per cent. In most instances, except the notable exceptions of Japan and the US, multipliers remain below unity.

Table 2.11: Crisis times: first year multipliers from a 1% of GDP temporary fiscal expansion

	Nominal rate fixed 1 year					
	Government consumption		Government investment		Direct tax rate	
Belgium	0.46	(1.0)	0.48	(1.0)	0.09	(1.2)
Canada	0.63	(5.5)	0.65	(5.6)	0.12	(6.2)
Finland	0.65	(0.4)	0.67	(0.3)	0.19	(0.6)
France	0.60	(3.0)	0.61	(3.1)	0.44	(3.4)
Germany	0.47	(8.5)	0.47	(8.5)	0.23	(11.1)
Greece	1.07	(0.3)	1.10	(0.3)	0.76	(0.3)
Ireland	0.22	(0.5)	0.23	(0.5)	0.05	(1.2)
Italy	0.55	(2.4)	0.56	(2.3)	0.09	(2.5)
Japan	1.26	(40.3)	1.29	(40.2)	0.31	(45.5)
Netherlands	0.56	(2.1)	0.57	(2.2)	0.13	(2.8)
Austria	0.50	(0.6)	0.52	(0.7)	0.12	(0.6)
Portugal	0.64	(0.3)	0.65	(0.3)	0.06	(0.6)
Spain	0.83	(2.1)	0.85	(2.2)	0.15	(2.7)
UK	0.59	(10.1)	0.60	(9.6)	0.13	(10.9)
US	1.21	(21.7)	1.24	(22.0)	0.22	(22.8)

Notes: No shift in the budget deficit target. Experiments conducted one country at a time. Numbers in parenthesis denote the percentage change compared to the multipliers used to produce Table 2.4.

In short, the results so far suggest that the impact of the zero lower bound on fiscal multipliers is not large enough so as to turn multipliers above unity. In only one instance most multipliers exceed the value of one: when there is fiscal coordination across all countries in the sample and, even then, the relevant channel is the fiscal coordination side of the shock rather than the impact of the zero lower bound constraint.

I devote Section 2.5 to analyze the propagation mechanisms of the shocks when the zero lower bound binds. The aim is to understand whether the result that the effect of the zero lower bound on multipliers is more muted in NiGEM compared to the standard New Keynesian model considered in the literature is a result of different propagation mechanisms or just simply that those propagation mechanisms are less powerful than otherwise thought.

2.5 Analysis

The literature has highlighted a number of channels through which fiscal stimulus may become highly effective when the economy is in a liquidity trap. Given that NiGEM does not appear to share the same predictions regarding the effectiveness of fiscal policy at the zero lower bound, in this section I check whether the same set of channels are at work in NiGEM, highlight a few potential explanations behind the difference in the results and analyze their quantitative implications.

2.5.1 Mechanisms

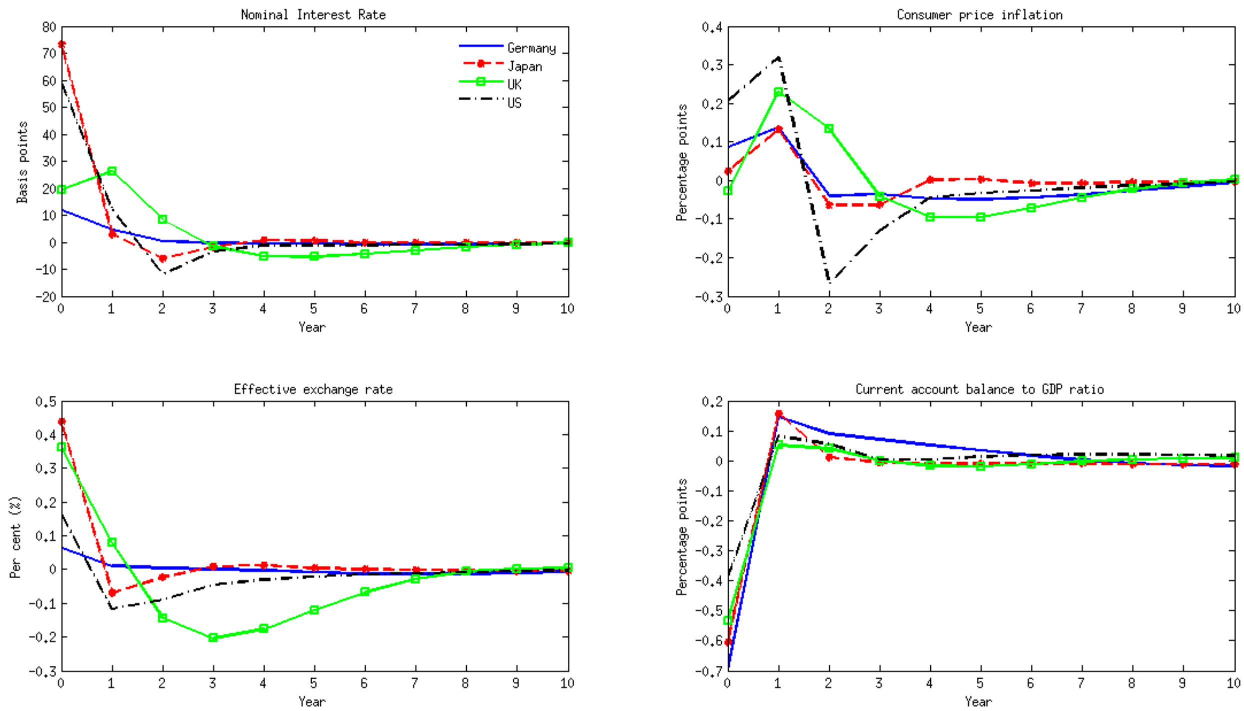
I begin presenting the effect of fiscal expansionary shocks on a set of variables of interest: nominal interest rates, inflation, the effective nominal exchange rate and the current account balance. The purpose is to let the reader obtain a clear picture of how the fiscal impulse transmits through the economy and to show that the model is reacting in the way that one would expect to. Throughout this Section, I will not attempt to explain why fiscal multipliers differ across countries as I already have done this in Section 2.4.1. For the sake of brevity I will focus on four countries only: Germany, Japan, the UK and the US. In addition, I will only present the results from the government consumption shock. Figure 2.1 provides the impulse responses of the aforementioned four variables to a temporary one per cent of GDP expansionary government consumption shock.[21]

As we have already seen from Table 2.1, a temporary government consumption shock raises output despite government consumption not being a factor of production. Given the presence of nominal rigidities embedded in the model, prices cannot fully react to the increase in demand and consequently output demanded rises.[22] The increase in output is accompanied

[21] It is the exact same set of shocks as the ones introduced to produce the first column of Table 2.1.

[22] In a structural model, the increase in government consumption affects labour supply. Higher public expenditure leads to a decline of households' present discounted value of income because of higher future taxes. As a result, a negative welfare effect appears that increases labour supply. NiGEM does not feature this channel as labour supply is exogenous in the model.

Figure 2.1: Temporary government consumption shock: impulse responses



Note: a positive value in the effective exchange rate panel denotes an appreciation of the currency against a basket of all the other currencies of the model.

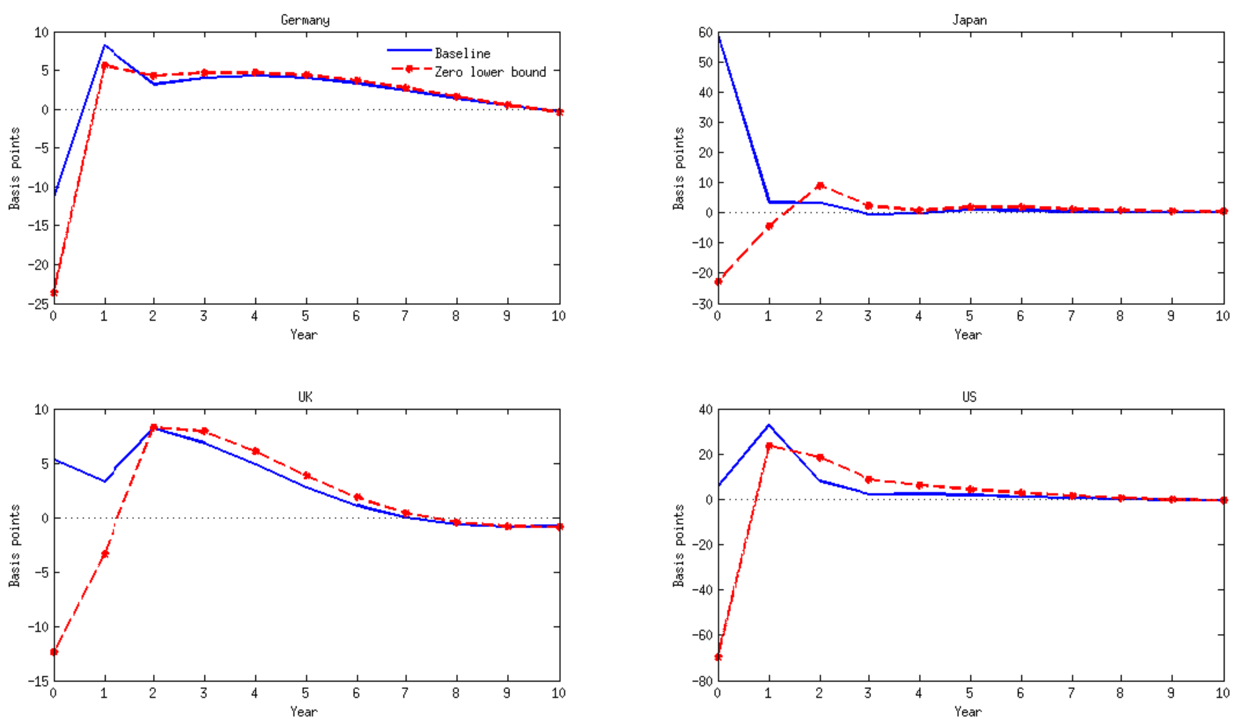
by a temporary increase in inflation, as can be seen in the upper-right hand panel of Figure 2.1. In addition, the increase in output combined with the increase in inflation, triggers a reaction by the central bank who increases the nominal interest rate to close the output and inflation gaps (upper-left hand panel of Figure 2.1). This increase in interest rates has an effect, through the Uncovered Interest Rate Parity (UIP) condition, on the nominal effective exchange rate as well (lower-left panel of Figure 2.1), which is defined as a weighted average of a basket of exchange rates in the model. Indeed, the increase in the interest rate generates an expectation of a future depreciation, which makes the exchange rate to jump on impact and appreciate. Finally, following the appreciation of the domestic currency, the current account balance worsens, as export volumes decrease and import volumes increase (lower-right hand panel of Figure 2.1).[23] In the long-run, as prices adjust and absent a long-term effect on factors of production, output returns to its baseline level.

[23] The Marshall-Lerner condition that states that for a currency devaluation to improve the current account balance one requires that the export and import price elasticities to be higher than one in absolute value holds in NiGEM.

We are now in a position to analyze the effects of introducing the zero lower bound constraint for one year. Recall that, according to the literature, the channel through which the zero lower bound gives rise to multipliers larger than unity in a closed economy model works as follows: higher public expenditure gives rise to inflationary expectations which decrease the short-term real interest rate given the constraint on the nominal rate. This, in turn, crowds in private consumption and investment. In addition, in an open economy model, the fall in the real interest rate produces a devaluation of the real exchange rate which acts to reinforce the increase in demand. Thus, I will focus on analyzing the differential impact of introducing the zero lower bound constraint on the short-run real interest rate, private consumption, private investment and the net trade balance, which I define as the difference between exports and imports over output.

Figure 2.2 provides the impulse response of the short-term real interest rate under two scenarios: the solid blue line denotes the simulation where the zero lower bound does not hold and the dashed red line is for the simulation where it does hold.

Figure 2.2: Short-term real interest rate



Focusing first on the solid blue line, which represents the benchmark simulation, Figure 2.2 highlights important differences in the magnitude and sign of the effect of the fiscal expansionary shock across the four reported countries on the short-term real rate. In particular, the impact reaction is positive in all countries except Germany. This is, of course, driven by the fact that Germany shares a common monetary policy with other countries. As a result, the impact effect on the nominal interest rate, as it can bee seen in the upper left hand corner of Figure 2.1, is much more muted than in the other countries. Thus, in Germany, the expectation of future inflation dominates the increase in the nominal interest rate and as a result, the real rate falls. The differences in the magnitude of the response of the real interest rate in the other countries are linked to data idiosyncrasies of each country which produce different coefficient estimates of the equations of each country model. For instance, from the upper right hand panel of Figure 2.1 we can see that inflation is more sensitive to a fiscal shock in the US than in Japan, which makes the short-term real interest rate increase in Japan much faster than in the US, on impact.

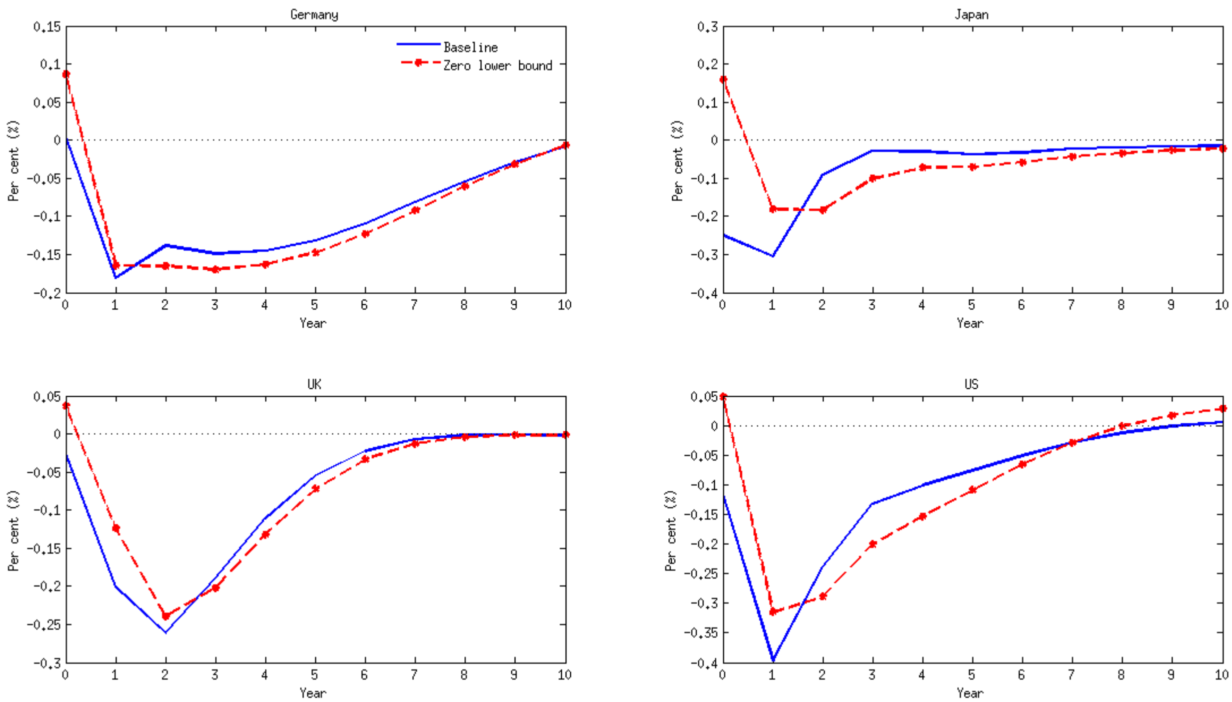
Instead, common to all countries is a fall of the short-term real interest rate, on impact, relative to the benchmark case following the introduction of the zero lower bound. This is to be expected, as the zero lower bound prevents the nominal rate to increase but expectations of future inflation, following an expansionary fiscal impulse, remain. This channel is in agreement with what has been suggested in the literature.

Moving onto the effects of such decline in the short-term real interest rate to other variables in the economy, Figures 2.3 and 2.4 report the impulse responses of private consumption and private investment. I will begin by focusing on the reaction of private consumption.

Figure 2.3 highlights several important features of the model. First, focusing on the benchmark case (solid blue line), an expansionary government consumption shock crowds out private consumption. The intuition follows the standard welfare effect channel: an increase in government consumption increases future taxation which results into a fall of the present discounted value of income (see the effective direct tax rate in the top panels of Figure 2.10 in Appendix 2.7.2). As a result, consumption falls on impact. Recall, from equation (2.10), that aggregate consumption depends on the present discounted value of future income. In addition, the increase of both inflation and nominal interest rates acts to compound the reduction of the value of future income.

Second, once the zero lower bound becomes binding, there is a consumption crowd in effect. For all countries, the impact effect of the fiscal shock on consumption turns from negative to positive. The decline in the short-term real rate acts to compensate the fall in the present discounted value of future income and, in addition, raises household's net wealth as asset

Figure 2.3: Private consumption

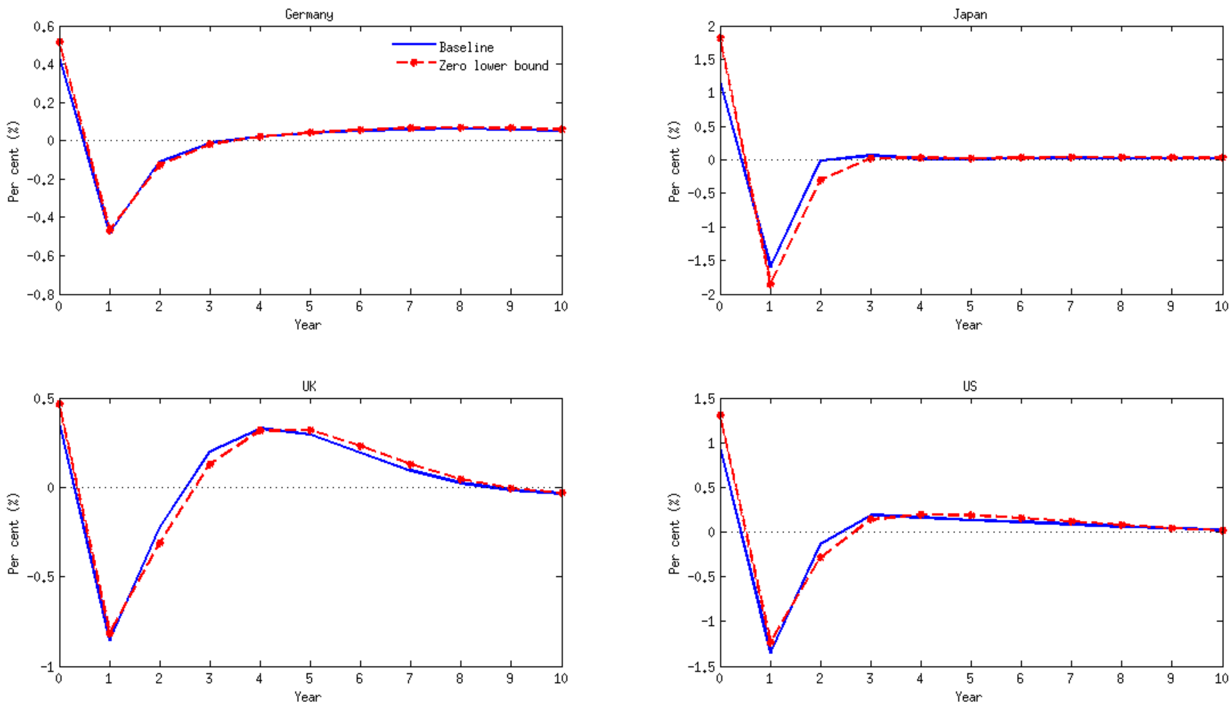


prices increase given a fall in the long-run rate.

Turning to the behaviour of private sector investment, Figure 2.4 shows that the introduction of the zero lower bound also increases the response of investment to the fiscal shock. The reader may be surprised to see that, in the benchmark case, despite the increase in nominal interest rates that occurs at the onset of the fiscal shock, there is a crowd in effect on investment. This behaviour emanates from the investment equation (equation (2.6)) which, while being function of the user cost of capital, also depends, in the short-run, on demand. As a result, on impact, higher activity pushes up investment, and as time goes by, investment falls in agreement with a heightened user cost of capital derived from higher nominal interest rates.

I also look at the response of the external sector to the fiscal shock. Figure 2.5 shows the impulse response of the net trade balance. Unsurprisingly, the net trade balance worsens following the fiscal shock for the benchmark case. Following the rise in government expenditure, imports increase. In addition, the nominal interest rate increases which, by the UIP condition, implies that the nominal exchange rate immediately appreciates in order to create an expectation of a depreciation (lower-left hand panel of Figure 2.1). The appreciation

Figure 2.4: Private investment

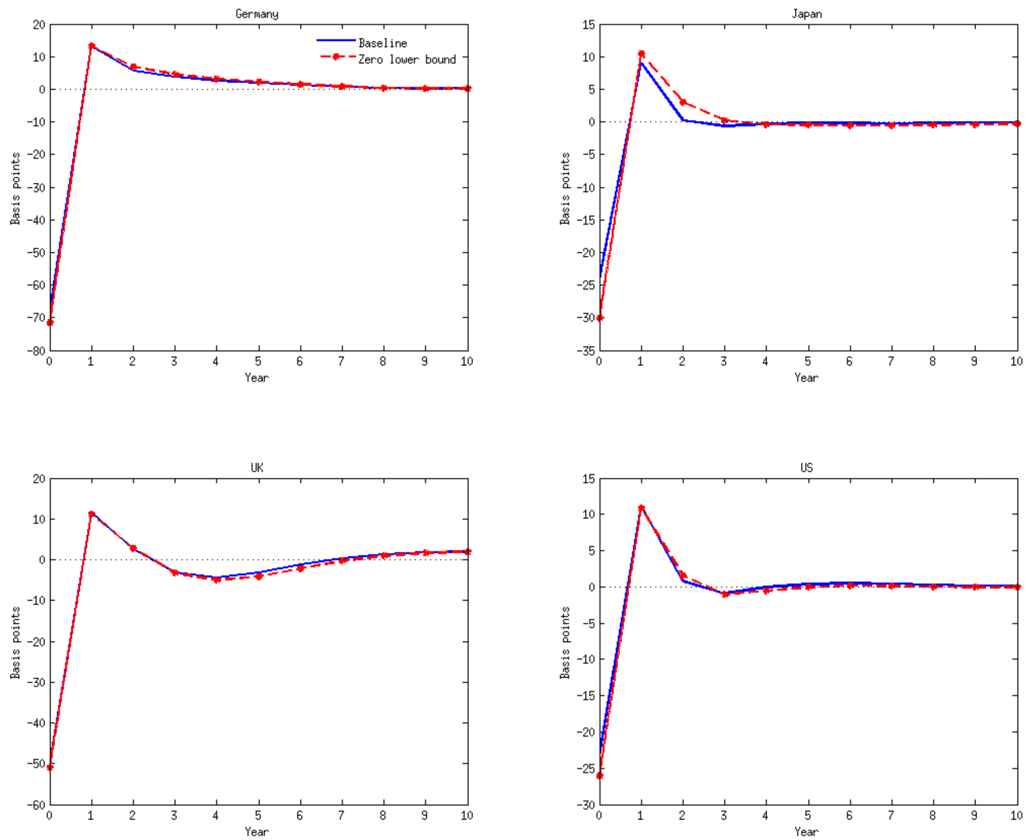


of the currency induces a decline in exports and a further increase in imports. However, and somewhat surprisingly, the fiscal impulse when the zero lower bound holds, rather than improving the net trade balance, as it does in the open economy New Keynesian framework, it makes it worse.

In the open economy New Keynesian model by Cook and Devereux (2011), fiscal policy at the zero lower bound produces larger multipliers than closed economy versions of the model. The mechanism works as follows: a fiscal expansion when the nominal interest rate is stuck at the lower bound produces a fall in the real interest rate. As a result, there is a crowd in effect from private consumption. On top of that, to satisfy interest rate parity, the fall in the real interest rate in the home country triggers a depreciation of the real exchange rate which crowds foreign demand in. According to figure 2.5, this channel does not appear to be in operation in NiGEM. In fact, the real exchange rate appreciates in almost all of the countries (see Figure 2.6).

Thus, it appears that NiGEM shares with the closed economy New Keynesian models the standard channel that produce fiscal multipliers larger than unity when the economy is

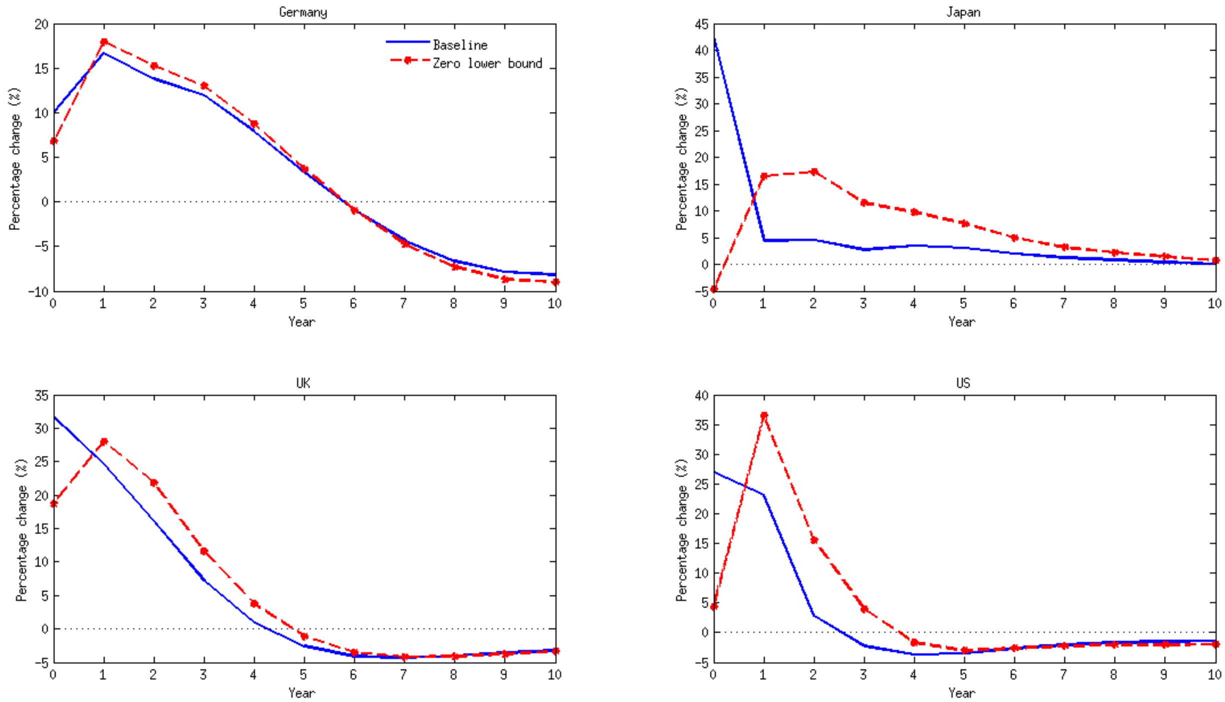
Figure 2.5: Net trade balance



stuck at the zero lower bound. This channel is, namely, the fall in the real interest rate that the fiscal expansionary shock produces which, in turn, crowds in private consumption and investment. However, NiGEM predicts multipliers smaller than unity in most instances. I have also shown that NiGEM does not share the mechanism of open economy New Keynesian models that deliver fiscal multipliers when the zero lower bound holds even larger to those of closed economy New Keynesian models. In NiGEM, a fiscal shock when the nominal interest rate is stuck at the zero lower bound, does not increase foreign demand for home goods.

There are two candidates that may explain the difference between the predictions of New-Keynesian type of models and NiGEM. First, NiGEM incorporates a degree of myopia in several of their behavioral equations. Consumer and investment myopia should reduce the impact of fiscal policy at the zero lower bound, as it implies that agents react to a lower extent to a fall in the real interest rate triggered by expectations of future inflation. Second,

Figure 2.6: Real effective exchange rate



in NiGEM, because of the UIP condition, differentials in the real interest rate do not affect the exchange rate, only differentials in the nominal interest rate. As a result, a fall in the real interest rate triggered by a rise in inflation expectations in an environment where the nominal interest rate is stuck at the zero lower bound, does not produce a depreciation of the home country real exchange rate, which is the key mechanism through which the open economy New Keynesian models produce fiscal multipliers at the zero lower bound in excess to those of closed economy New Keynesian models.

In order to disentangle the importance of each of the two candidates, I will begin analyzing the role of myopia in shaping fiscal multipliers at the zero lower bound in a closed economy version of NiGEM. Afterwards, I will consider the standard open economy version of NiGEM and allow for the real interest rate to have an effect on the terms of trade.

2.5.2 The role of myopia

Embedded into NiGEM's equations is a degree of myopia. Consumers respond to a higher degree to fluctuations in income than what would be implied in a fully rational expectations model. So does investment. Myopia is likely to limit the impact of fiscal policy at the zero lower bound. According to the New Keynesian framework, fiscal policy is highly effective at the zero lower bound because the expectations of future inflation triggered by the fiscal impulse create a fall of the real interest rate which crowds consumption and investment in. However, if agents are myopic, they do not factor in the fall in the real interest rate in their consumption and investment decisions and, as a consequence, fiscal policy at the zero lower bound looses traction.

I will consider a closed economy version of NiGEM in order to insulate to a better extent the effect of myopia on fiscal multipliers. The closed economy version of NiGEM is achieved by exogenising the paths of import and export volumes as well as the exchange rate. This means that I force exports, imports and the exchange rate to be held at their baseline level following the fiscal shock.

In order to investigate the role of myopia, I will consider the following two modifications to the model. First I will modify the investment equation with the aim of making it more forward looking. In the standard version of NiGEM, the evolution of the capital stock, from which one can derive investment, is described by the following equation:

$$\begin{aligned}\Delta \ln (K_t) &= \delta_1 - \delta_2 \left[\ln (K_{t-1}) - \ln (YCAP_{t+12}) + \sigma \ln (user_{t-1})\right] + \\ &\quad \delta_3 \Delta \ln (K_{t-1}) + \delta_4 \Delta \ln (Y_t) + \delta_5 \Delta \ln (Y_{t-1}) .\end{aligned}$$

Capital in the short-run only reacts to changes in current output. The user cost of capital ($user$), which is forward looking as it is function of the long-run real interest rate, comes with a lag and embedded within the long-term component of the error correction equation. Thus, I modify the equation in the following way:

$$\begin{aligned}\Delta \ln (K_t) &= \delta_1 - \delta_2 \left[\ln (K_{t-1}) - \ln (YCAP_{t+12}) + \sigma \ln (user_{t-1})\right] + \\ &\quad \delta_3 \Delta \ln (K_{t-1}) + \tilde{\delta}_4 \Delta \ln (user_t) + \delta_5 \Delta \ln (Y_{t-1}) .\end{aligned}$$

In essence, I remove the impact of fluctuations in current income on investment and replace it with a term that captures short-term fluctuations in the user cost of capital. As a result, if the long-run real interest rate declines following declines in the short-run real interest rates, this will have an immediate impact on investment. I have maintained the value of all the coefficient in the equation and calibrated the parameter $\tilde{\delta}_4 = -0.07$, so that a one percent increase in the value of the user cost of capital triggers a 0.07 per cent decline of the capital stock, all else equal. The calibration has been made for illustrative purposes.

I also modify the aggregate consumption equation. In particular, I take equation (2.10) and set the coefficients $\{\beta_2, \beta_3, \beta_4\}$ to zero and increase the coefficient $\beta_1 = 0.6$. These modifications make aggregate consumption less sensitive to fluctuations in current income and wealth and more sensitive to fluctuations in the present discounted value of real disposable income. Again, the calibration has been made for illustrative purposes.

Table 2.12 presents the results of a number of simulations. First, I consider a temporary expansionary shock to government consumption to the closed economy version of NiGEM. This is the Benchmark simulation. The fiscal shock is the same one as the one I used to produce the first column of Table 2.1. Under the label "No ZLB" is the fiscal multiplier that arises when the interest rate is free to adjust according to the monetary policy rule. Under the label "ZLB" is the fiscal multipliers that arises when the nominal interest rate is held constant for a period of two years. I then move to consider a case where I run the same two simulations (No ZLB and ZLB) but where I modify the investment equation in the fashion explained just above. These are the scenarios under the "Modification 1" label. Finally, I run the same set of simulations but modifying both the investment and the consumption equation. The results are shown under the label "Modification 2". In all three instances I also report, under the label $\Delta\%$, the percentage increase in the multiplier originated by introducing the zero lower bound constraint. Given that the response of the short-term nominal interest rate of the Euro Area countries is fairly muted, I have restricted myself to report the results for Japan, UK and the US.

Table 2.12: Closed economy: first year multipliers from a government consumption shock

	Benchmark			Modification 1			Modification 2		
	No ZLB	ZLB	$\Delta\%$	No ZLB	ZLB	$\Delta\%$	No ZLB	ZLB	$\Delta\%$
Japan	1.07	1.52	43.0	0.67	1.16	71.6	0.60	1.14	89.7
UK	1.14	1.35	18.6	0.83	1.14	37.9	0.68	1.24	82.2
US	1.15	1.39	21.0	0.77	1.25	62.5	0.64	1.21	89.6

Notes: No shift in the budget deficit target. Experiments conducted one country at a time. ZLB stands for "zero lower bound". Modification 1 denotes the case where I change the investment equation. Modification 2 denotes the case where I change the consumption and investment equation. $\Delta\%$ denotes the percentage change of moving from No ZLB to ZLB.

Table 2.12 highlights a number of results. First, as it can be seen in the first column, fiscal multipliers in a closed economy are of a larger magnitude than those reported in Table 2.1. In a closed economy, the fiscal impulse cannot be leaked away to other countries via imports.

However, contrary to the usual result in the New-Keynesian framework, the fiscal multiplier is above one. This result is due to the behaviour of investment, which, given that is driven by demand in the short-run, increases on impact despite the increase in the real interest rate (see, for instance, Figure 2.4). In short, private investment is being crowded in rather than out. As expected, the presence of the zero lower bound makes fiscal policy more effective, with fiscal multipliers becoming larger in all countries. Second, once I introduce the forward-looking version of the investment equation, fiscal multipliers in normal times become smaller than unity (Modification 1, column No ZLB). This is because the new specification makes investment much more sensitive to the reaction of the user cost of capital. Following an increase in the real interest rate triggered by the fiscal impulse, the long-run real interest rate increases and so does the user cost of capital. As a result, private investment falls. We are now capturing the crowding out effect on private investment that is typical of the New Keynesian models when nominal interest rates are allowed to follow a standard Taylor Rule. Notice as well that once we allow for a more forward-looking investment equation, the zero lower bound makes fiscal policy more effective. The percentage increase of the fiscal multiplier due to the presence of the zero lower bound constraint is higher in this case than in the Benchmark case. This can be attributed to the fact that investment is now more reactive to the change of the expected path of future real interest rates, which is the key mechanism through which the zero lower bound constraint makes fiscal policy more effective. Finally, once I modify the investment and consumption equations to make them less myopic, the percentage increase in fiscal multipliers becomes even larger. In all instances, the fiscal multiplier becomes greater than one and almost doubles relative to the one that originates when the economy is not at the zero lower bound.

Overall, it appears that consumer and investment myopia makes fiscal policy at the zero lower bound less effective than in a fully rational expectations model. How do these results compare to the standard results in the New Keynesian literature of fiscal multipliers at the zero lower bound? Woodford (2011) finds that, for reasonable parameter values, fiscal multipliers at the zero lower bound are usually above one but can also become larger than two. Christiano et al. (2011) confirm this result. The examples presented in table 2.12 suggest that once we reduce the degree of myopia in NiGEM's equations, fiscal multipliers at the zero lower bound become significantly larger than one. However, I did not find instances where they become larger than two. However, being NiGEM such a large model (it is composed of more than 6.000 equations), I cannot claim to have explored nowhere near the totality of the parameter space. The capacity to do so is one of the many advantages of using stylized models such as the ones used in the academic literature.

2.5.3 The role of the real interest rate on net trade

Myopia is not the only candidate that may explain the muted impact of fiscal policy when nominal interest rates are stuck at the zero lower bound in NiGEM. As we have seen in Figure 2.5, a key difference between the results in NiGEM and those from an open economy New Keynesian models such as the one by Cook and Devereux (2011), is the response of net trade to the fiscal shock. In the open economy model by Cook and Devereux (2011), fiscal policy at the zero lower bound becomes more powerful than in a closed economy New Keynesian model one as the fall in the real interest rate triggered by the fiscal impulse produces a real exchange rate depreciation. As a result, not only the fall in the real interest rate produces a crowd in effect of consumption, but it also crowds in demand from foreign countries. Implicitly, in the model by Cook and Devereux (2011), the fiscal shock generates an improvement of the net trade position of the home country. In NiGEM, a fiscal shock when the zero lower bound constraint holds does not produce an improvement of the net trade position. If anything, it makes it worse (see figure 2.5).

There are two reasons that can explain such behaviour of net trade in NiGEM. First, embedded in NiGEM's trade equations is an assumption that both export and import volumes are fairly, although not fully, price inelastic in the short-run. This is a robust finding in the empirical literature (see, for instance, Morin et al. (2014) or Lewis and De Schryder (2015)) and captures the fact that both exporters and importers may either insure themselves for a short period of time against exchange rate fluctuations or adjust their profit margins to maintain a competitive edge. As a result, even if the exchange rate were to depreciate significantly, one would not observe a significant change in the net trade position within the first year. Second, in NiGEM, it is differentials in nominal interest rates rather than in real interest rates what drives fluctuations in the nominal exchange rate. Thus, suppose the nominal interest rate is stuck at the zero lower bound. When the fiscal expansionary shock takes place, there is a rise in expected inflation. As a result, the real interest rate falls. However, as the nominal interest rate is constant, the nominal exchange rate does not move. Higher domestic inflation produces a rise in export prices, which means that there is a terms of trade appreciation as opposed to a depreciation as Cook and Devereux (2011) obtain in their model.

I modify NiGEM in two dimensions in order to produce an improvement of the net trade balance position following an expansionary fiscal shock when the economy is in a liquidity trap.

First, I increase the short-run price elasticities of export and import volumes (coefficients γ_4 and κ_3 in equations (2.13) and (2.14)). In the standard version of NiGEM, these are around -0.1 and -0.3, respectively. I decrease them both to -0.8. Second, for those simulations where the zero lower bound holds I introduce an additional shock to the nominal exchange rate. This shock is meant to capture that the fall in the real interest rate should trigger a depreciation of the currency. To calibrate the shock that I introduce to the nominal exchange rate, I run a separate simulation, for each country, where I shock the nominal interest rate to produce a fall that is equivalent to the fall that I observe in the real interest rate in those simulations where the zero lower bound holds. From this simulation I obtain a response of the nominal exchange rate which I use to calibrate the magnitude of the endogenous shock that I introduce to the nominal exchange rate in those simulations where the zero lower bound holds. By endogenous shock I refer to a shock that is introduced as a residual to an equation of the model, as opposed to an exogenous shock which consists in replacing the equation with a set of numbers.

Table 2.13 presents the magnitude of the fiscal multipliers that arise from a numbers of simulations. The names of the columns have the exact same meaning as those of Table 2.12: "Benchmark" denotes a case where no modification to the model is considered, "Modification 1" introduces a more forward looking investment equation and "Modification 2" introduces changes to both the investment and consumption equation as detailed in Section 2.5.2. For comparative purposes, Table 2.13 considers two sets of simulations. The first set, those that appear below the "No endogenous shock to the exchange rate" label, reports the fiscal multipliers when I use the standard version of the trade equations of NiGEM. The second set, those under the label "With endogenous shock to the exchange rate", reports the fiscal multipliers that arise when I modify the short-run price elasticities of exports and imports as well as introducing the endogenous shock to the nominal exchange rate, as explained above. I report the results for Japan and the UK only, as, in NiGEM, the nominal exchange rate of the US is constant and equal to unity, as the dollar is the benchmark currency against which all bilateral exchange rates compare to.[24]

Focusing first on the results from the simulations where neither the modification to the trade equations nor the shock on the exchange rate has been introduced, one can see that fiscal multipliers become smaller in the open economy version of NiGEM than in the close

[24]This feature has been modified in more recent versions of NiGEM, where it is now possible to shock the US nominal exchange rate. However, in the NiGEM version that I have used to produce these results this modification was still not available.

Table 2.13: Open economy: first year multipliers from a government consumption shock

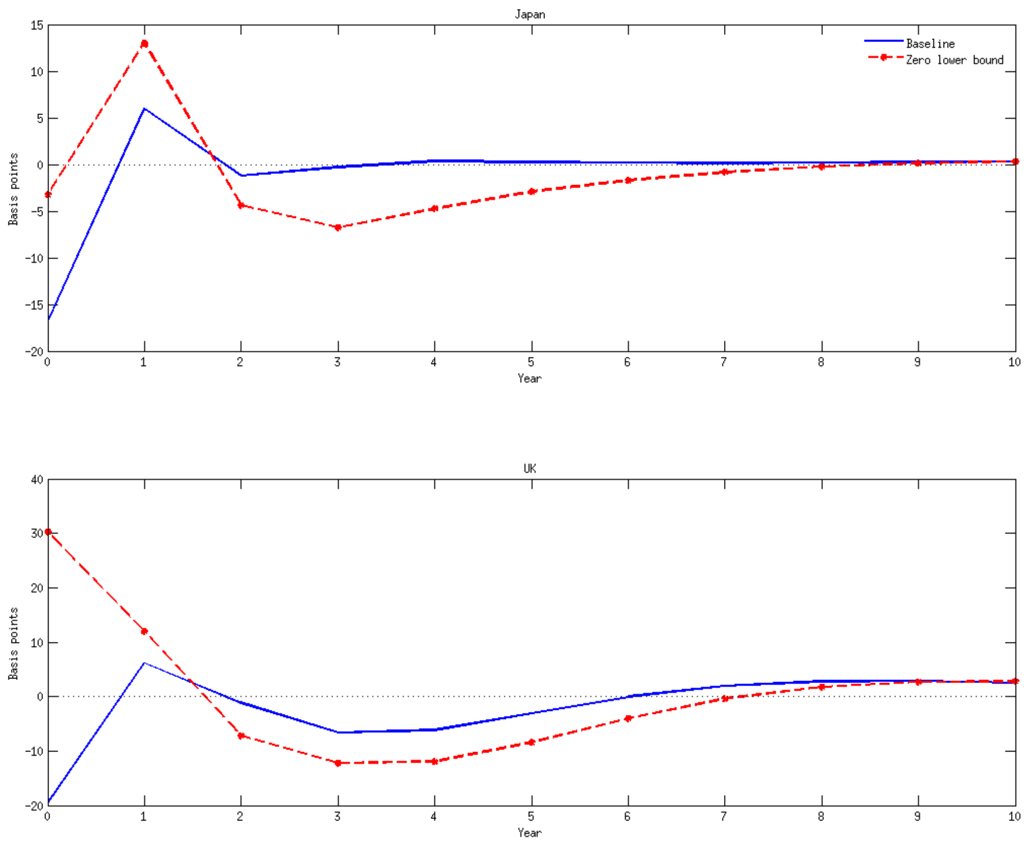
	Benchmark			Modification 1			Modification 2		
	No ZLB	ZLB	Δ%	No ZLB	ZLB	Δ%	No ZLB	ZLB	Δ%
No endogenous shock to exchange rate									
Japan	1.04	1.36	31.3	0.75	1.10	47.8	0.69	1.09	58.2
UK	0.99	1.14	15.1	0.86	1.06	23.9	0.78	1.09	39.6
With endogenous shock to exchange rate									
Japan	0.92	1.56	69.8	0.68	1.28	89.2	0.63	1.28	102.5
UK	0.87	1.61	84.6	0.76	1.49	97.3	0.71	1.53	116.5

Notes: No shift in the budget deficit target. Experiments conducted one country at a time. ZLB stands for "zero lower bound". Modification 1 denotes the case where I change the investment equation. Modification 2 denotes the case where I change the consumption and investment equation. Δ% denotes the percentage change of moving from No ZLB to ZLB.

economy one (see, for comparison, table 2.12). That fiscal multipliers are smaller in an open economy model than in a closed economy model when nominal interest rate is free to adjust is a standard result in the literature. As part of the fiscal shock is leaked away via imports, the increase in output is smaller. However, the open economy New Keynesian literature points out that fiscal multipliers at the zero lower bound can be larger than those in a closed economy, a result that I do not obtain here. This latter result is reversed once I consider the set of simulations that include a higher price elasticity of trade volumes as well as a shock to the nominal exchange rate. The last two rows of Table 2.13 show that fiscal multipliers at the zero lower bound become larger in this open economy version of NiGEM than in the closed economy version (see, for comparison, results in table 2.12).

The result is directly linked to the behaviour of net trade, which I plot in figure 2.7 expressed as the net trade to output ratio. Once I force the model to produce a depreciation of the currency following the fall in the real interest rate triggered by the fiscal shock when the economy is stuck at the zero lower bound, the net trade position improves. This would correspond to the mechanism layed out in Cook and Devereux (2011). Note however that, in figure 2.7, whereas the net trade position improves for the UK, once we account for the additional shock to the exchange rate, it doesn't for Japan, where it remains almost neutral. This can be attributed to the magnitude of the exchange rate shocks considered. While the outcome of the calibration delivered a fairly large exchange rate shock for the UK, it gave a fairly small shock for Japan instead. Were I to make it as large as the one for the UK, the outcome of the simulation for Japan would have delivered a positive net trade to output ratio response. The message, however, is unchanged. So long as the fall in the real interest rate triggers a depreciation of the currency, the net trade balance will improve relative to the case where the economy is not bound by the zero lower bound.

Figure 2.7: Net trade balance



It appears that the degree of myopia as well as the exchange rate rule are key in shaping the magnitude of fiscal multipliers at the zero lower bound. A lower degree of myopia and a higher sensitivity of the exchange rate to fluctuations in the real interest rate give rise to larger multipliers when the zero lower bound holds. However, the model appears to struggle to produce magnitudes like the ones reported by the New Keynesian framework, where multipliers above 2 are not uncommon in the presence of the zero lower bound. To a certain extent, part of the difference in the results may be attributed to the fact that NiGEM can not be made fully comparable to the New Keynesian framework. Given the semi-structural structure, a certain degree of myopia as well as rigidities in the adjustment process will always remain. The difficulties in exploring the predictions of the model across the whole parameter space may also be another part of the explanation.

2.6 Conclusions

This paper surveys the literature on the impact of the zero lower bound constraint on fiscal multipliers in New Keynesian models. It finds a general, although recently contested, consensus that fiscal multipliers at the zero lower bound are greater than one. The main channel behind this result is that a fiscal expansionary shock when the nominal interest rate is stuck at the zero lower bound, triggers a reduction in the real interest rate. Such decline in the real rate crowds in consumption and investment in closed economy models and foreign demand in open economy models.

Subsequently, I investigate whether these results hold within the context of a semi-structural large scale global economic model, NiGEM. Although similar in spirit to the New-Keynesian framework that underlies most of the literature of fiscal multipliers at the zero lower bound, I find that multipliers in NiGEM are, in most instances, below one and that the zero lower bound, although increasing the magnitude of such multipliers, falls short of bringing them above one. I find that most of the transmission mechanisms, highlighted by the literature, through which the zero lower bound operates to produce larger multipliers hold in the results produced by NiGEM, but one. In contrast with the results from open economy New Keynesian models, NiGEM fails to produce an improvement of the net trade position of a country following an expansionary fiscal shock when the zero lower bound holds. I also find that the magnitude of the multipliers, in NiGEM, are sensitive to the degree of consumer and investment myopia.

Once I modify NiGEM to reduce the degree of agent's myopia and produce a foreign demand crowd in effect following a decrease in the real interest rate, I find that fiscal multipliers at the zero lower bound become well above unity, a result in line with that of the literature. However, the model appears to struggle to produce multipliers larger than two. Part of this struggle may just reflect the difficulty to explore the predictions of the model across the whole parameter space, given that NiGEM has well above 6.000 equations.

2.7 Appendices

2.7.1 Appendix A

In this Appendix I report the results from regressing the percentage increase in the magnitude of fiscal multipliers derived from an international coordination of fiscal policies onto the same set of controls as the ones described in Section 2.4.1.

Table 2.14: OLS results with percentage increase of fiscal multipliers as dependent variable

	Government consumption	Government investment	Direct tax rate
Constant	64.95	65.29	215.04
	(49.89)	(50.88)	(150.21)
EA	6.41	8.97	76.86
	(21.77)	(22.20)	(65.54)
ConsElas	3.76	6.74	-297.54*
	(45.50)	(46.40)	(136.98)
TfeCont	-30.40	-31.89	-80.39
	(21.85)	(22.28)	(65.77)
Openness	141.60**	144.94**	165.22
	(46.27)	(47.19)	(139.29)
Size	-0.64	-0.47	0.69
	(2.22)	(2.26)	(6.68)
Adj. R^2	0.68	0.68	0.50
F-test	0.007	0.006	0.039

Notes: a * indicates the coefficient is significantly different from zero at the 10 per cent significance level. A ** at 5 per cent and a *** at 1 per cent. Standard errors are reported in parenthesis.

For government spending multipliers, only Openness is statistically significantly different from zero and comes with the expected positive sign: countries that are more open to trade benefit more from having other countries implementing a fiscal expansion. Also, the regressor that controls for the short-term income elasticity of aggregate consumption is weakly significant for the regression that uses the multipliers for direct tax rate shocks as dependent variable.

Most of the regressors in the regressions reported in Table 2.14 are not significantly different from zero. To gauge the importance of Openness to trade, I run the same regressions but using Openness as the one single control. The results are reported in Table 2.15.

Table 2.15: OLS results with percentage increase of fiscal multipliers as dependent variable: smaller subset of controls

	Government consumption	Government investment	Direct tax rate
Constant	-3.56	-3.82	-24.25
	(13.68)	(14.01)	(48.11)
Openness	182.50***	188.06***	345.34***
	(30.10)	(30.81)	(105.80)
Adj. R^2	0.72	0.72	0.41
F-test	0.000	0.000	0.006

Notes: a * indicates the coefficient is significantly different from zero at the 10 per cent significance level. A ** at 5 per cent and a *** at 1 per cent. Standard errors are reported in parenthesis.

Openness alone explains around 70 per cent of the observed variation in percentage increase in multipliers for government spending shocks, and 40 per cent for direct tax rate shocks.

2.7.2 Figures

Figure 2.8: Crisis times: percentage increase of government consumption multiplier against share of private consumption to total output

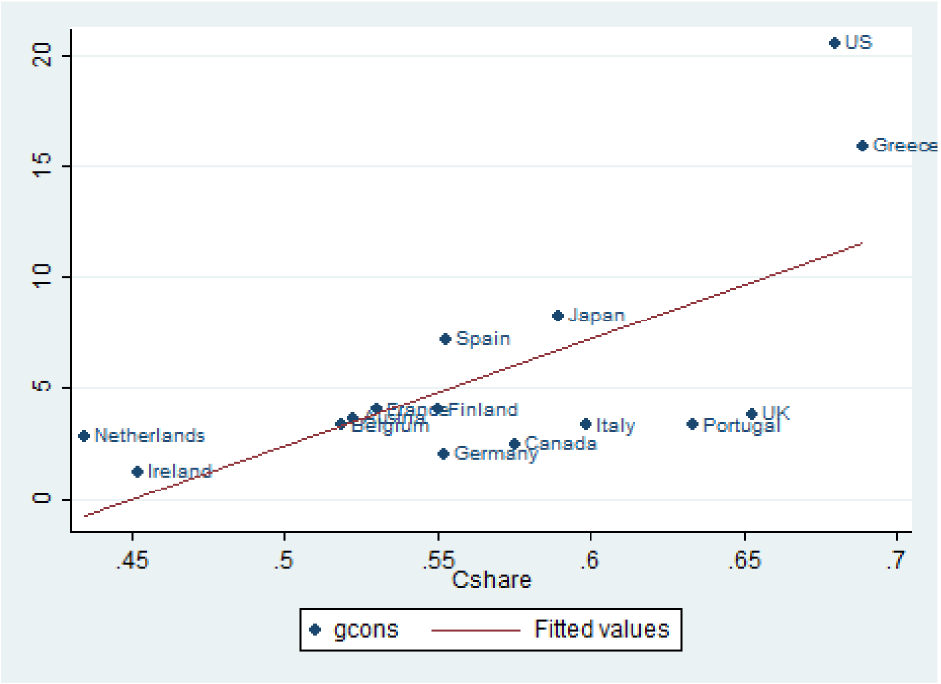


Figure 2.9: Government consumption multiplier against openness to trade

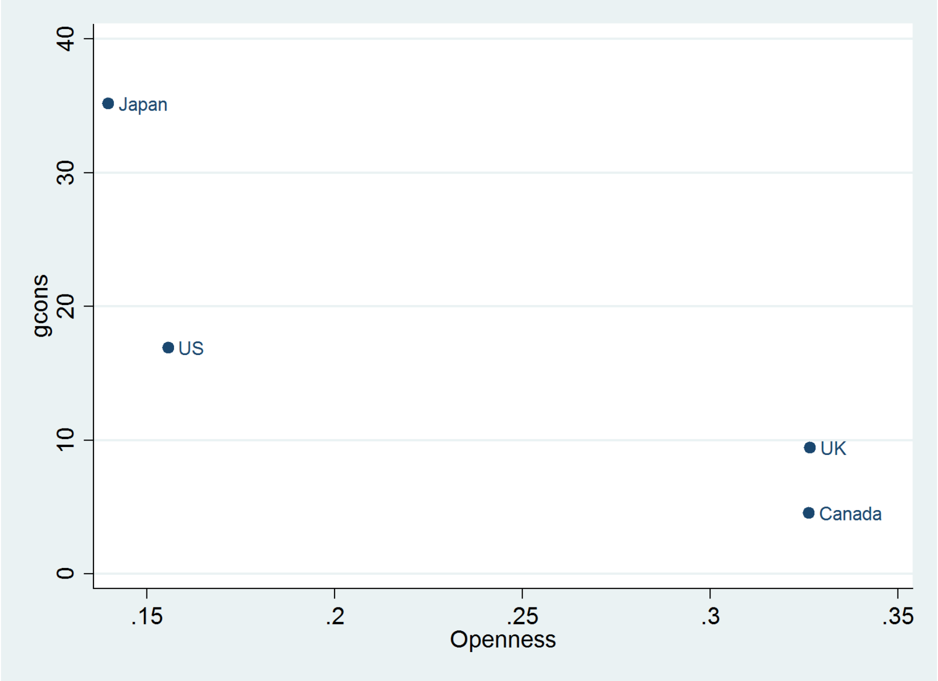
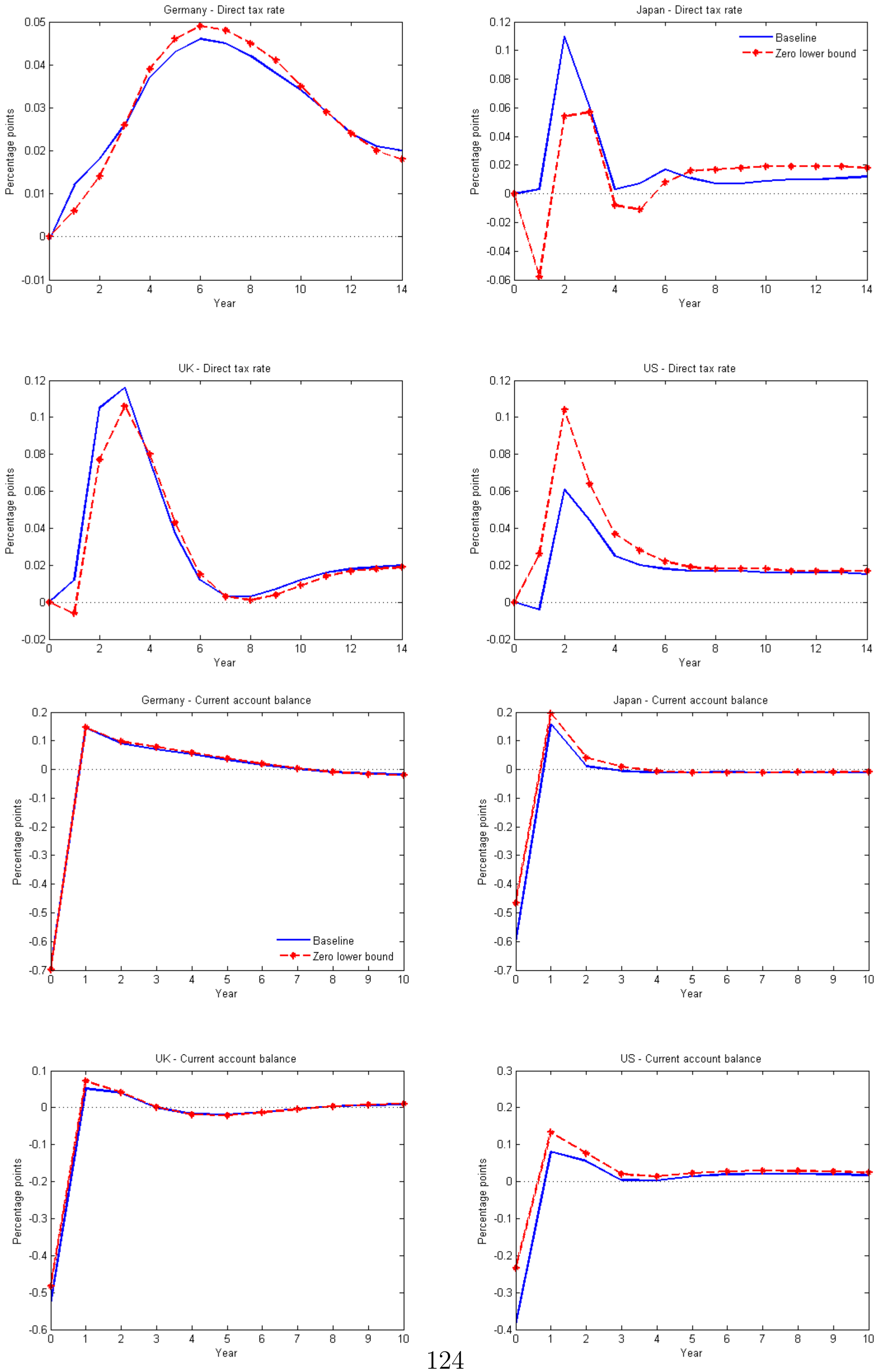


Figure 2.10: Effective direct tax rate and current account balance



Chapter 3

The Cyclical Behaviour of the Relative Price of Investment

3.1 Introduction

This paper provides a set of non-standard measures to characterize the comovement of the relative price of investment —defined as the ratio between the price of investment and the price of consumption— and output. Standard measures include correlations on detrended data or impulse response functions derived from structural VAR's. Here, following the methodology developed by Den Haan (2000) and Den Haan and Sumner (2004), I characterize the cyclical properties of the relative price of investment with correlations of VAR forecast errors and correlations of frequency-domain filtered data.

Investment —the most volatile component of output— has often been proposed as a key driver of business cycle fluctuations. The cyclical properties of the relative price of investment are of interest as they may provide indirect evidence of whether the main forces driving investment are of supply or demand side nature, thus providing additional means to test competing theories. Greenwood et al. (1988), Fisher (2006) and Justiniano et al. (2011), suggest that investment specific shocks can go a long way in explaining business cycle fluctuations, but one implication of their analysis is that the relative price of investment should be countercyclical, as the expansion of output would be driven by a surge in investment caused by an increase in the production efficiency of investment. Alternatively, a procyclical behaviour would point towards demand shocks being the dominant factor behind the move of investment. Recent examples in the literature advocating for the latter mechanism are Beaudry and Portier (2004, 2011) and Beaudry, Collard, and Portier (2011). In these papers, business cycle fluctuations arise from agents that receive news about the future profitability of investment goods. As investment increases at the time of the arrival of the news, rather than at the time when the technology shock occurs, a positive contemporaneous correlation between the price of investment and output arises.

A large body of the literature has found evidence in favor of characterizing the relative price of investment as countercyclical. For instance, Murphy et al. (1989), regress the prices of consumer durables and equipment goods deflated by the GDP price to the growth rate of unemployment and find a negative coefficient. Greenwood et al. (1997, 2000) define the relative price of investment as the ratio of the price of investment in equipment goods to the National Income and Product Accounts (NIPA) consumption price deflator of non-durable consumption goods and non-housing services and find it is counteryclical. Fisher (2006) also finds, using four different measures of investment, a negative correlation of the relative price of investment with output. All four measures use the consumption deflator for non-durable and service consumption, the service flow from consumer durables, and government consumption. As investment deflators, Fisher (2006) uses the equipment deflator from Gordon (2007) and Cummins and Violante (2002) (GCV), and a broader measure constructed with the GCV deflator and the NIPA deflators for nonresidential and residential structures, consumer durables and government investment. The remaining two deflators are the NIPA counterparts of the previous two measures. Justiniano et al. (2011) take NIPA data on consumption of non-durable goods and services as the consumption deflator, and the sum of consumption on durable goods and gross private domestic investment as the investment deflator to find that this measure of the relative price of investment has a negative correlation with real GDP per capita. However, in a recent paper, Beaudry et al. (2015) reach a different conclusion. In their paper, the authors use NIPA data detrended with an HP filter and report that, both on a large sample covering from 1960-2013 and in different sub-samples, the correlation between several measures of the relative price of investment, and two different measures of the business cycle -real output per capita and per capita hours worked in the private non-farm business sector- are not statistically significant different than zero.

The literature so far has relied mostly on two broad methodologies to describe cyclical patterns of variables. On the one hand, the researcher can use some of the many available filtering techniques to detrend a time series and then compute correlations between variables of interest. One drawback of this methodology is that it does not capture in a satisfactory manner the dynamic interrelations between those variables. Another important shortcoming, pointed out by Chadha and Prasad (1993) and Ball and Mankiw (1994), is that the correlations computed from the detrended data may be sensitive to the detrending procedure implemented on the original dataset. On the other hand, the researcher can estimate a VAR and, using a suitable identification strategy, back out the structural shocks driving the data to analyze the impulse response functions. This method has the beauty of providing the dynamic characterization of the variables as well as being very easy to interpret. The main drawback is precisely the need of an assumption to identify the structural shocks.

In this paper I extend the work of Beaudry et al. (2015) by looking at the cyclical behaviour of the relative price of several measures of investment using two alternative methodologies. The first methodology, developed by Den Haan (2000), computes correlations of VAR forecast errors. As explained in Den Haan (2000), the advantage of such methodology is that it allows to capture the dynamic interrelations between the variables of interest without the need to detrend the data or impose any identifying assumption. The disadvantage is that it does not identify the structural shocks driving the data. Nevertheless, it may provide sufficient information regarding the dynamics of the variables to test competing models. As Den Haan (2000) shows, competing models may produce, from a qualitative perspective, different sets of possible forecast error correlations.

The second methodology computes correlations on data filtered with a band pass filter. Band pass filters decompose any time series into a weighted sum of sine and cosine waves that are associated with different frequencies of the data and remove those elements related with the frequencies of our choosing. For each variable, one can construct several time series, each series comprising a different set of frequencies. Once the components of the series related with business cycle frequencies have been isolated, one can compute the correlations between the variables of interest. In this chapter, I will analyze the cyclical properties of variables that include cycles of at least one and a half to, at most, eight years. To provide a benchmark, the HP filter is almost equivalent to a band pass filter that removes all cycles associated with periodicities of more than eight years (see Gomez (2001)). From this perspective, by providing a means to isolate any range of frequencies of interest, the band pass filter allows to perform sensitivity analysis of the results obtained using the HP filter regarding the cyclical properties of the variables being analyzed.

I follow Beaudry et al. (2015) in that I use the same data sources and construct the same investment and consumption aggregates. The main investment aggregates are total private investment, business investment and household investment and the two consumption aggregates are non-durables and service consumption and the core counterpart obtained by excluding energy goods. To construct the relative price of investment I compute, separately, the price index of each investment and consumption aggregate and then take the ratio of the two.

I find that that different measures of business cycle properties produce different results. Instantaneous correlations on HP filtered data suggest that the relative price of total investment is acyclical in the full sample that covers data between 1960 and 2013 and procyclical in a reduced 1984-2013 sample. However, VAR forecast error correlations and correlations on frequency-domain filtered data suggest a countercyclical behaviour. Correlations on HP filtered data suggest that the relative price of household investment is procyclical, but VAR forecast error correlations suggest a countercyclical behaviour at short-run forecast horizons. Correlations that have been computed on frequency-domain filtered data also suggest a countercyclical behaviour if we include frequencies related with periods of up to 4 years. Correlations on HP filtered data suggest that the relative price of business investment is mildly countercyclical, but turns procyclical when using the reduced 1984-2013 sample. This is less clear when measuring the business cycle properties via VAR forecast error correlations. In almost all instances that I consider in the text, the relative price of business investment is countercyclical at all forecast horizons, except when using the 1984-2013 sample and the Core consumption price index. Even then, the positive correlation that I obtain is not statistically significantly different from zero.

The paper is structured in the following way. Section 3.2 describes the data. Section 3.3 reports the cyclical behaviour of the relative price of investment with instantaneous correlations on data filtered using the Hodrick-Prescott filter. Section 3.4 briefly describes how to compute the correlation of VAR forecast errors as well as some of its properties and then describes the empirical results. Section 3.5 reports the correlations of the relative price of investment and any of the two indicators of the business cycle using frequency-domain filtered data. Section 3.6 concludes.

3.2 Data and methodology

In this section I describe the data used in this paper and the methodology implemented to derive investment and consumption price series, which, in turn, are used to construct relative prices of investment. To ensure the results obtained by Beaudry et al. (2015) and mine are comparable, I use the same data source, apply the same methodology to aggregate categories of investment and define in the same way the investment and consumption aggregates[1].

The data comes from the Bureau of Economic Analysis (BEA) NIPA tables and runs from 1960 until 2013. I define total investment as the sum of fixed investment and consumer expenditures on durable goods, excluding changes in private inventories and government investment. I decompose total investment into business and household investment. Business investment captures nonresidential investment and includes investment on structures, equipment goods and intellectual property products. Household investment includes residential investment and consumer expenditure on durable goods. Table 3.1 below reports the share of each component of total nominal investment.

Table 3.1: Total nominal investment: component shares (per cent)

	1960-2013	1984-2013
Total private investment	100.0	100.0
Business investment	50.1	50.5
Structures	12.3	11.5
Equipment	24.7	23.9
Intellectual property rigths	13.1	15.1
Household investment	49.9	49.5
Durable goods	32.7	32.5
Residential	17.2	17.1

The relative price of investment is constructed dividing the price of each of the categories of investment by the price of consumption. I use two different measures for the price of consumption: the first one, which I call Benchmark, is the price index corresponding to consumer expenditure on non-durable goods and services; the second one, which I call Core, excludes gasoline and other energy goods from the first measure. BEA provides nominal, volume and price series for some of the aggregates. To construct the appropriate volume and price series for the remaining ones I follow BEA's chain aggregation method as described in Whelan (2002). Appendix 3.7 provides a more detailed explanation of the data and a brief example of the method used to aggregate components of investment and consumption.

The data described above is dominated by trends which, given my focus on cyclical dynamics, need to be removed. Following Beaudry et al. (2015) I first take logs of each series and then use a Hodrick-Prescott (HP) filter to estimate the trend of each variable and obtain the cyclical component by removing the aforementioned trend from each series. Finally, I need

[1]The data sets may differ slightly due to data revisions that have been introduced since Beaudry et al. (2015).

an indicator of the business cycle to correlate against each measure of the relative price of investment. Again, following Beaudry et al. (2015), I use as indicators the cyclical component of real GDP per-capita and per-capita hours worked in the private non-farm business sector. For the sake of brevity I will refer to the former measure as output and the latter as hours worked.

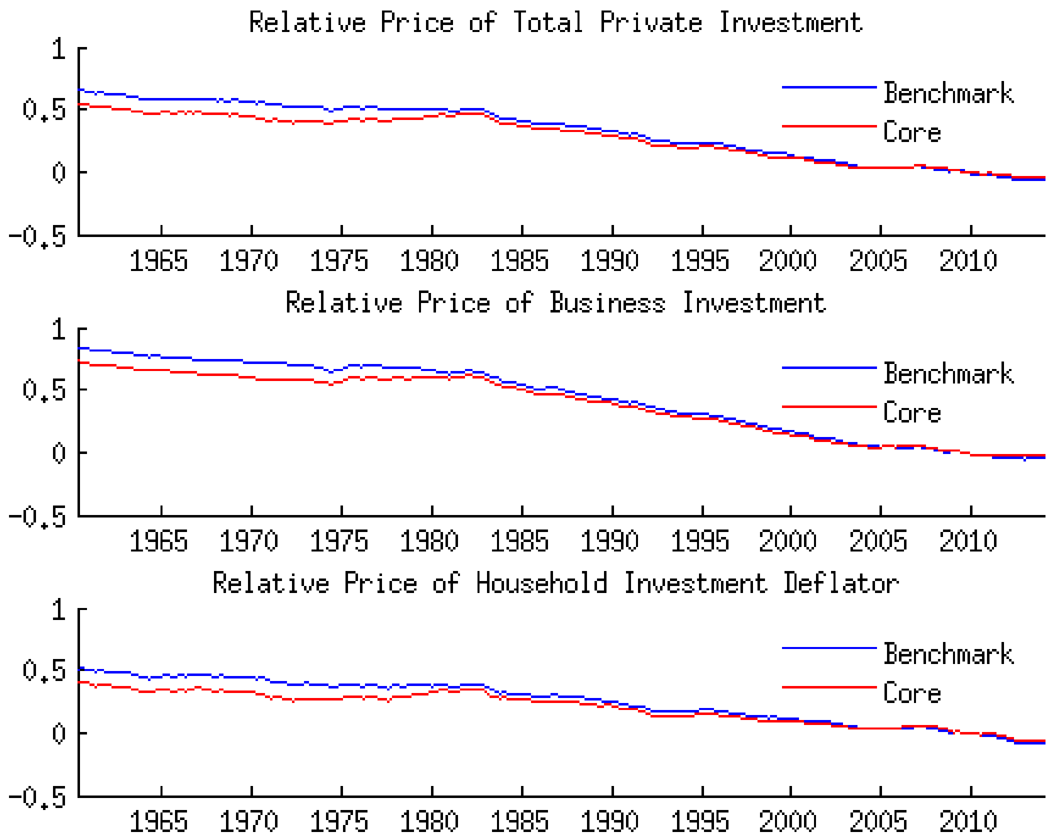
Figures 3.20 to 3.22 in Appendix 3.7.4 display the cyclical components of both business cycle indicators and of the price indices of the main investment and consumption aggregates. All measures, except perhaps per-capita hours worked, display a break in their time series properties: volatilities become smaller from the mid 80's, onwards. Of course, this observation is consistent with the literature on the Great Moderation. The case is most extreme when looking at the cyclical component of the price indices of investment, figure 3.21. Fisher (2006) showed that in the early 80's there was a significant change in the rate of decline of the relative price of investment; a fact that can easily be seen in figure 3.1 where I plot the log of the ratio of the price of the main investment aggregates to the price of the Benchmark and Core consumption aggregates. Thus, it could well be that the cyclical properties of the relative price of investment changed as well. In order to account for the presence of such break, I will run all the analysis using the whole sample as well as the sample starting from 1984 onwards[2].

3.3 Measuring comovement using traditional statistics

This section shows the business cycle properties of the relative price of our investment aggregates. A thorough analysis of the relative price of investment —the ratio of the price of investment to the price of consumption— requires an understanding of the cyclical properties of both the numerator and the denominator, separately. Thus, I will start presenting the cyclical properties of the price of investment and the price of consumption, and then move on to present the cyclical properties of the ratio of the two. The degree of comovement between data series is measured with instantaneous correlations. The data I have used, and the transformations implemented to estimate the cyclical component of each series, is described

[2]Small departures from the choice of the break date do not lead to significant changes in the reported results.

Figure 3.1: Relative Price of Investment



Note: To construct the relative price I use two different series for the price of consumption: a Benchmark legend entry denotes that the Benchmark consumption deflator has been used as the denominator and a Core entry denotes that the Core deflator has been used.

in Section 3.2.[3]

Table 3.2 describes the cyclical correlation of the price of several aggregates of investment against output and hours worked. Several elements stand out. First, when focusing on the whole sample columns, the price of total private and business investment are countercyclical with both measures of the business cycle, although the correlations are not statistically different from zero when using hours worked as the business cycle indicator. The price of household investment is countercyclical against output —albeit not significantly so— and acyclical against hours worked. Within business investment, the price of investment

[3]Throughout this section I will refer to the correlation between the cyclical component of two variables as the cyclical correlation.

Table 3.2: Cyclical correlation of price of investment and business cycle indicators

	Output		Hours	
	1960-2013	1984-2013	1960-2013	1984-2013
Total private investment	-0.38*	0.16	-0.12	0.46**
Business investment	-0.48**	0.10	-0.26	0.38**
Equipment	-0.58**	-0.29**	-0.48**	-0.10
Intellectual property rights	-0.40*	0.27	-0.17	0.35**
Structures	-0.13	0.38**	0.16	0.63**
Household investment	-0.29	0.20	-0.03	0.46**
Durable goods	-0.47**	0.00	-0.32	0.22
Residential	0.22	0.58**	0.45**	0.70**

Note: An * means the coefficient is significant at the 10 per cent significance level and ** means it is significant at the 5 per cent threshold. Variables are HP-filtered with a smoothing parameter of 1600.

in equipment goods is strongly countercyclical. Within household investment, the price of investment in durable goods is countercyclical, particularly when correlated against output, while the price of residential investment is procyclical, particularly when correlated against hours worked.

Second, all correlations become more positive when we restrict the sample to the period starting from 1984 onwards. Within this sub-sample, the price of investment becomes either acyclical or procyclical for all categories except for investment in equipment goods. The difference between the results obtained from the two sample periods may be explained by the oil price shocks that took place during the late 70's and early 80's. As oil price increased, output declined and the price of investment goods escalated as higher energy prices were transmitted through the production chain.

Table 3.3: Cyclical correlation of price of consumption and business cycle indicators

Business cycle measure	Sample	Benchmark	Core	Energy
Real per-capita GDP	1960-2013	-0.43**	-0.64**	0.06
	1984-2013	0.06	-0.34**	0.44**
Per-capita nonfarm business hours	1960-2013	-0.21	-0.44**	0.22
	1984-2013	0.17	-0.21*	0.46**

Note: An * means the coefficient is significant at the 10 per cent significance level and ** means it is significant at the 5 per cent threshold. Variables are HP-filtered with a smoothing parameter of 1600.

Table 3.3 presents the cyclical correlation of the price of two consumption aggregates (Benchmark and Core) against output and hours. I include a third category, the price for energy goods —the category that we remove from the Benchmark aggregate to create the Core one, to gain a better understanding of the magnitudes and signs of the price of the Benchmark and Core consumption series.[4] Both the price of the Benchmark and Core consumption aggregates are countercyclical in the full sample and the price of Core consumption more so than the Benchmark one. By contrast, the price of Energy goods is acyclical, if not mildly procyclical in the full sample and strongly procyclical in the reduced sample. As a result, after stripping out the procyclicality induced by energy prices, the price of our Core measure becomes more countercyclical. In addition, we can see that the price of the Benchmark consumption aggregate becomes either acyclical or even procyclical when I move from the full to the reduced sample. As Beaudry et al. (2015) suggest, the difference may be explained again by the oil price shocks of the 70's and 80's, as those shocks induced countercyclical movements of oil prices. Indeed, the price of Energy goods is more procyclical in the sample that excludes the oil price shocks when compared to the full one, which results in additional procyclicality for the price of the Benchmark aggregate. Given that the price of the Core consumption aggregate is more countercyclical than the price of the Benchmark aggregate, it will come as a no surprise that the relative price of investment will be more procyclical when using the Core aggregate for the price of consumption as the denominator rather than the Benchmark aggregate.

The cyclical properties of the relative price of the various categories of investment that I consider are shown in table 3.4 and 3.5. The former presents the results when the business cycle indicator is output, while the latter uses hours worked. P_I/P_C^B denotes the price of investment to the price of consumption ratio when I use the Benchmark aggregate for the consumption series, while P_I/P_C^C is the ratio for the case where I use the Core aggregate for the consumption series. There are small differences between the results reported here and the ones reported in Beaudry et al. (2015), but I view these differences as a product of small revisions introduced recently in the NIPA data that make their dataset and mine slightly different. These differences, however, do not alter the conclusions drawn.

The relative price of total private investment is acyclical in the full sample and, as expected from the previous discussion on the cyclical behaviour of the investment and consumption price indices, procyclical in the reduced one. Within total private investment, the relative price of business investment is mildly countercylical in the full sample, albeit the correlation is not statistically different from zero, and also turns significantly procyclical in the reduced sample. However, within this category, investment in equipment goods is countercyclical in the full sample, and significantly so, except where I use hours worked as the business

[4] Caution in interpreting the results is essential as correlations are not additive.

Table 3.4: Cyclical correlation of relative price of investment and output

	P_I/P_C^B		P_I/P_C^C	
	1960-2013	1984-2013	1960-2013	1984-2013
Total private investment	-0.09	0.18**	0.05	0.47**
Business investment	-0.19	0.10	-0.05	0.43**
Equipment	-0.32**	-0.29**	-0.24**	-0.02
Intellectual property rights	0.06	0.14*	0.24**	0.43**
Structures	0.10	0.44**	0.17	0.54**
Household investment	0.03	0.20**	0.14	0.44**
Durable goods	-0.04	-0.04	0.10	0.25**
Residential	0.50**	0.56**	0.54**	0.67**

Note: An * means the coefficient is significant at the 10 per cent significance level and ** means it is significant at the 5 per cent threshold. Variables are HP-filtered with a smoothing parameter of 1600. P_I denotes the log price of investment, P_C^B the log price of the benchmark consumption aggregate and P_C^C the log price of the core consumption aggregate.

cycle indicator in the reduced sample. The relative price of household investment is mildly procyclical, product of the acyclical behaviour of the relative price of investment in durable goods and the strong procyclicality of the relative price of residential investment. That the relative price of residential investment is procyclical does not come as a surprise given the tendency of the housing market to display sudden increases in demand which are usually associated with the expansionary phase of the business cycle. Consistent with the discussion around Table 3.3, I also find that the relative price of investment is more procyclical when using the price of the Core consumption aggregate as the denominator than when using the Benchmark one. To sum up, the evidence suggests that the relative price of investment is procyclical, if not acyclical, particularly from the mid 80's onwards. The only exception is the relative price of equipment goods that is clearly countercyclical.

While correlations are a useful measure to capture comovement between variables, they lag information regarding the volatility of the original series. It is possible to have two variables that invariably comove in opposite directions —the correlation would be -1, but where one is almost constant while the other displays large swings. The covariance coefficient, which is shown in table 3.6 for the case where the business cycle indicator is output, provides a sense of the magnitude of the fluctuations between two variables. Note that the covariance has been computed using the log of the relative price scaled by a 100 so that log differences become percentage changes. Under this scaling, the covariance coefficient is the average of the product of the percentage deviation from the mean of each series. So for instance,

Table 3.5: Cyclical correlation of relative price of investment and hours

	P_I/P_C^B		P_I/P_C^C	
	1960-2013	1984-2013	1960-2013	1984-2013
Total private investment	0.05	0.41**	0.23	0.67**
Business investment	-0.13	0.31**	0.06	0.63**
Equipment	-0.39**	-0.21**	-0.27	0.08
Intellectual property rights	0.07	0.25**	0.32**	0.52
Structures	0.32	0.66**	0.40*	0.75**
Household investment	0.16	0.37**	0.30*	0.59**
Durable goods	-0.11	0.03	0.08	0.31**
Residential	0.59**	0.62**	0.66**	0.72**

Note: An * means the coefficient is significant at the 10 per cent significance level and ** means it is significant at the 5 per cent threshold. Variables are HP-filtered with a smoothing parameter of 1600. P_I denotes the log price of investment, P_C^B the log price of the benchmark consumption aggregate and P_C^C the log price of the core consumption aggregate.

suppose that two variables have a correlation coefficient of 1 and both variables can either increase or decrease by x per cent. In this case, the covariance coefficient would equal x.

Table 3.6: Cyclical covariance of relative price of investment and output

	P_I/P_C^B		P_I/P_C^C	
	1960-2013	1984-2013	1960-2013	1984-2013
Total private investment	-0.13	0.12	0.07	0.40
Business investment	-0.27	0.05	-0.07	0.32
Equipment	-0.59	-0.33	-0.39	-0.06
Intellectual property rights	0.06	0.12	0.26	0.39
Structures	0.28	0.87	0.47	1.14
Household investment	0.04	0.17	0.24	0.44
Durable goods	-0.06	-0.05	0.14	0.23
Residential	1.19	1.02	1.39	1.29

Note: Variables are HP-filtered with a smoothing parameter of 1600. P_I denotes the log price of investment, P_C^B the log price of the benchmark consumption aggregate and P_C^C the log the price of the core consumption aggregate.

The relative price of investment in equipment, structures and residential goods display fluctuations against output of much larger magnitude than that of the remaining investment aggregates. Given that investment in equipment goods represents around a quarter of total investment in nominal terms and investment in structures and residential goods combined another quarter (see table 3.1), it comes as a no surprise, considering the cyclical properties of both aggregates, that the relative price of total private investment appears to be acyclical for the full sample.

Unfortunately, the sign of the correlation between two variables may be sensitive to the method used to detrend data; a point made by Chadha and Prasad (1993) and Ball and Mankiw (1994). Given this caveat, I revisit the current findings using an alternative methodology that does not rely on the method used to detrend the data.

3.4 Measuring comovement using correlations of VAR forecast errors

In the first part of this section I briefly describe the method developed by Den Haan (2000) to calculate correlations of VAR forecast errors at different time horizons and the relationship between these correlations and impulse response functions. The reader is referred to Den Haan (2000) for a more detailed explanation and proofs. The remainder of the section presents the results of applying this methodology to analyze the cyclical properties of the relative price of investment.

3.4.1 Methodology

Following the notation by Den Haan (2000), consider the following VAR specification:

$$X_t = \mu + Bt + Ct^2 + \sum_{l=1}^{L} A_l X_{t-l} + \varepsilon_t,$$

where subscript t denotes the time period, subscript l the lag order, X_t is a vector of N variables, possibly (co)integrated, μ, B and C are $N \times 1$ vector of constants, A_l are $N \times N$ matrices of coefficients, ε_t is a $N \times 1$ vector of innovations and L is the maximum lag order. In this paper, I will be considering two variables: P for the relative price of investment and Y for a measure of real activity. Once the VAR is estimated, I can denote the K-period ahead forecast of the variable Y_t as $Y^f_{t+K,t}$ and the K-period ahead forecast error as $Y^{fe}_{t+K,t}$. I denote the K-period ahead forecast and forecast error of P_t in the same way. I denote the covariance between the random variables $P^{fe}_{t+K,t}$ and $Y^{fe}_{t+K,t}$ as $COV(K)$ and the correlation as $COR(K)$. There are two ways to compute them: using the estimated VAR, one can compute the time series of forecast errors ($P^{fe}_{t+K,t}$ and $Y^{fe}_{t+K,t}$) at different forecast horizons and obtain the covariances and correlations. Den Haan (2000) uses this approach. One disadvantage of this method is that one has to throw away several observations, particularly at longer forecast horizons. An alternative approach, by Den Haan and Sumner (2004), uses the estimated VAR coefficients and the estimate of the variance-covariance matrix of the error term, ε_t, to compute the covariances and correlations at different forecast horizons. I use the latter approach in this paper.

The advantages of using this methodology include that one does not need to detrend the data, nor making any identifying assumption to isolate structural shocks. The latter is also the main drawback, as the methodology does not identify the structural shocks driving the variables of the system. One does also not need to make an assumption regarding the order of integration of the elements in X. The only important assumption is that the lag order of the VAR must be large enough to ensure that innovations are stationary[5].

There is a link between the covariance of forecast errors and the structural impulse response functions of the original variables. The K-period ahead forecast error of variable Y, $Y^{fe}_{t+K,t}$, can be rewritten as follows:

$$Y^{fe}_{t+K,t} = \left(Y_{t+K} - Y^{f}_{t+K,t+K-1}\right) + \left(Y^{f}_{t+K,t+K-1} - Y^{f}_{t+K,t+K-2}\right) + \cdots + \left(Y^{f}_{t+K,t+1} - Y^{f}_{t+K,t}\right),$$

where the first element of the right hand side of the equation is the one-period ahead forecast error realized at period $t+K$, the second element is the update of the two-period ahead forecast at period $t+K-1$ and the last term is the update of the K-period ahead forecast at period $t+1$. Let us denote the covariance between $\left(Y^{f}_{t+K,t+K-k+1} - Y^{f}_{t+K,t+K-k}\right)$ and $\left(P^{f}_{t+K,t+K-k+1} - P^{f}_{t+K,t+K-k}\right)$ by $COV^{\Delta}(k)$. Den Haan (2000) shows that one can write:

$$COV(K) = \sum_{k=1}^{K} COV^{\Delta}(k).$$

That is, the covariance of the K-period ahead forecast errors, $P^{fe}_{t+K,t}$ and $Y^{fe}_{t+K,t}$, is equal to the cumulative sum of the covariances of the k-step forecast updates. Notice that if $K = k = 1$, then the two covariances are identical. In addition, suppose $\varepsilon_t = DZ_t$, where D is an $N \times M$ matrix of coefficients, Z_t is an $M \times 1$ vector of (independent) structural shocks and define $Y^{imp,m}_{k}$ as the impulse response of output to a one standard deviation shock of the m'th element of Z_t, after k periods. It turns out that,

[5]However, imposing cointegration, if correct, would lead to efficiency gains in the estimation.

$$COV^{\Delta}(k) = \sum_{m=1}^{M} Y_k^{imp,m} P_k^{imp,m}.$$

The covariance between k-step forecast updates is equal to the sum of the products of the k-step impulse responses across all fundamental shocks. If $M = 1$, the expression boils down to the product between the impulse response of Y and P at forecast horizon k. $COV(K)$ would then be the cumulative sum of these products at all forecast horizons k. If, $Y_k^{imp,m}$ and $P_k^{imp,m}$ always had opposite signs, then $COV^{\Delta}(k)$ would be negative for every value of k, and so would $COV(K)$ for every value of K.

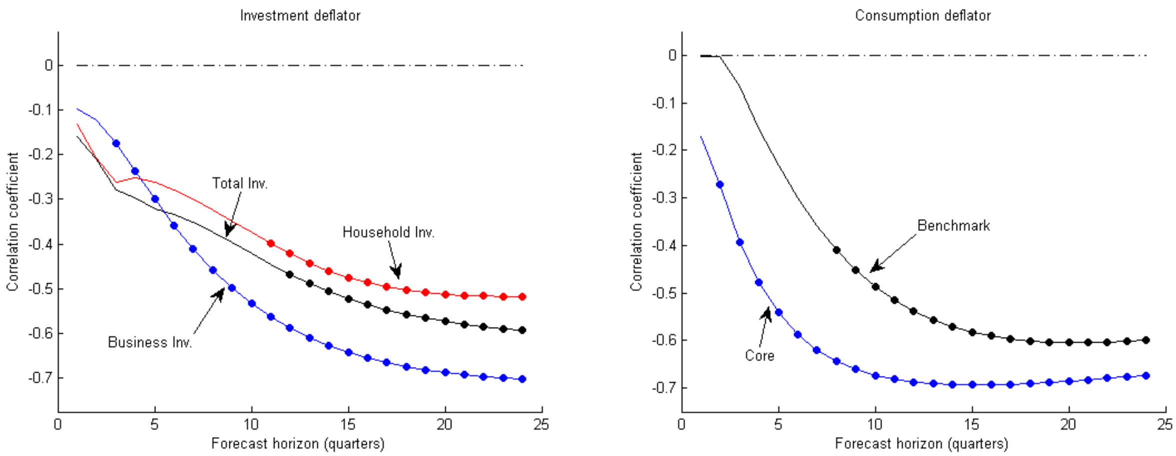
3.4.2 Description of results

This section presents the results obtained from computing VAR forecast error correlations between different sets of variables. In all figures, whenever a circle appears on top of a line it means that the correlation is significant at the 10 per cent confidence level on a two tailed test. The results are obtained using the whole 1960-2013 sample. I use the Akaike information criterion to determine the number of lags that each VAR should have as well as whether deterministic trends should be included. I report the specification of each VAR in a table in Appendix 3.7.3. All VAR's have been estimated in log levels. I perform some robustness checks in Section 3.4.3, including the case where I restrict the sample period to 1984-2013; a decision based on the results described in Section 3.3.

I start by looking at the VAR forecast error correlation of the price of investment and the price of consumption, separately, against output. For the sake of clarity, out of all the investment aggregates, I only report the results for total private investment —total investment henceforth— and its two main subcategories: business and household investment. The results are displayed in figure 3.2.

Compared to the results reported in Tables 3.2 and 3.3, the results in figure 3.2 are relatively similar in that both measures —instantaneous correlations on HP filtered data and VAR forecast error correlations— report that the price of the main investment and consumption aggregates are countercyclical, in the full sample. However, VAR forecast error correlations add additional information: at longer time horizons, the correlations become more negative, which could be indicative of low frequency supply side dynamics. However, the price of the total and household investment aggregates are only statistically different from zero at medium to long-run forecast horizons. The same holds for the Benchmark consumption price series. In addition, the Core consumption price series displays larger negative correlations than the benchmark deflator at all forecast horizons; a similar result to that reported in Section 3.3 which hinges on the cyclical behaviour of energy prices. As a result, I expect the correlations to be more procyclical when using the Core deflator.

Figure 3.2: VAR forecast error correlation between the price of investment and the price of consumption and output



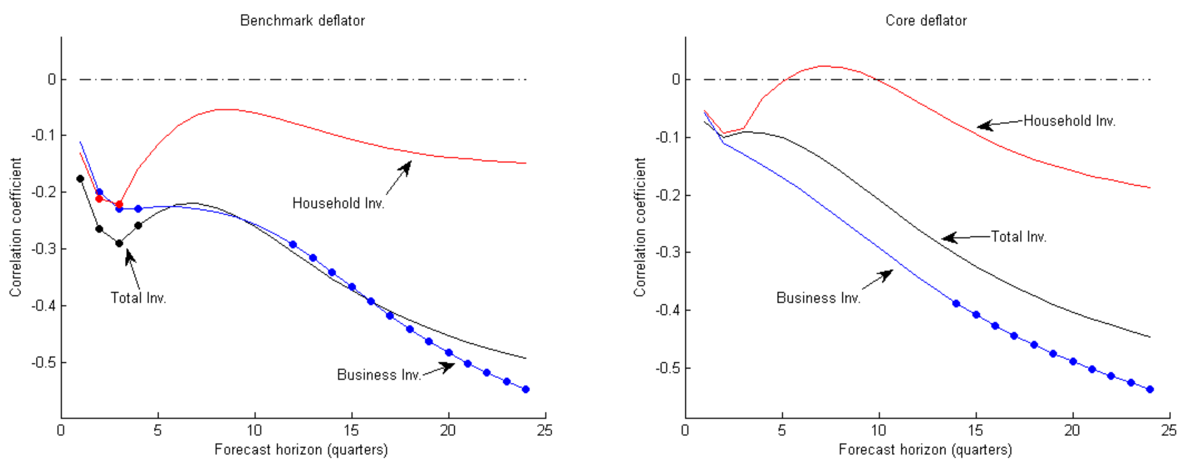
Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

Figures 3.3 and 3.4 plot the VAR forecast error correlation between the relative price of total, business and household investment and output or hours worked. Focusing on the correlations against output, both total and business investment are countercyclical at all forecast horizons. However, when using the Core consumption price index, the negative correlation of total investment and output becomes statistically no different from zero. Household investment is slightly countercyclical at all forecast horizons under the Benchmark consumption price index and acyclical at medium-run horizons under the Core consumption price index. In both cases, the correlations are not significantly different from zero. A similar picture arises when using hours worked as a business cycle indicator, except for the case where I use the Core price index, where the relative price of total investment becomes acyclical at medium-term horizons.

A comparison of the results obtained using VAR forecast error correlations against the results from Section 3.3 highlights some important differences. First, focusing on the cyclical properties using output as the business cycle indicator, the relative price of business investment is countercyclical according to both measures, but using VAR forecast error correlations I find that the negative correlations are at its smallest, in absolute value sense, at the short-run horizons, and become increasingly more negative, and significantly so from a statistical perspective, as the horizon expands. By contrast, the relative price of business investment, using instantaneous correlations on HP filtered data, is countercyclical but not significantly so. If productivity is the main force behind the movement in the relative price of business investment, and changes in productivity were to transmit throughout the economy in a slow manner as firms take time to incorporate the new blueprints, it could be that VAR forecast error correlations pick-up this low frequency dynamic that the instantaneous correlations fail to capture.

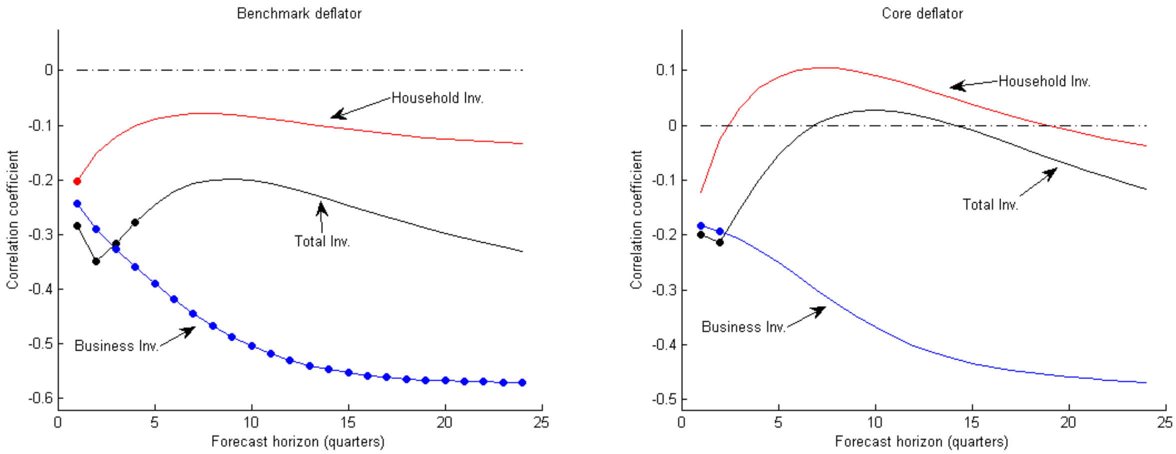
Second, the results obtained using the VAR forecast error correlations show that the relative price of household investment is countercyclical, and significantly so, at short-run horizons when using the Benchmark consumption price index. Instead, the results from Table 3.4 obtained using instantaneous correlations of HP filtered data suggested that the relative price of household investment was acyclical.

Figure 3.3: VAR forecast error correlation between relative price of investment and output



Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

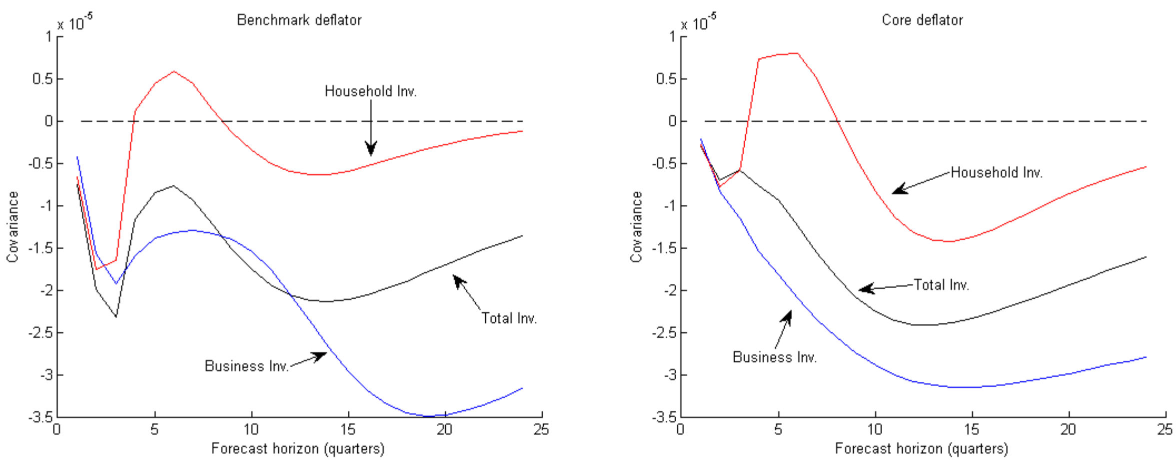
Figure 3.4: VAR forecast error correlation between relative price of investment and hours worked



Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

Similar correlations at different forecast horizons may hide differences in the magnitude of the fluctuations between the variables as the variance of the variables may change when the forecast horizon changes. To gain a sense of which time horizons are more important, in quantitative terms, I plot in figure 3.5 the covariance between the relative price of the three main aggregates of investment and output. To be clear, I plot the $COV^{\Delta}(k)$ elements, where k represents the forecast horizon, as described in Section 3.4.1.

Figure 3.5: VAR forecast error covariance of relative price of investment and output

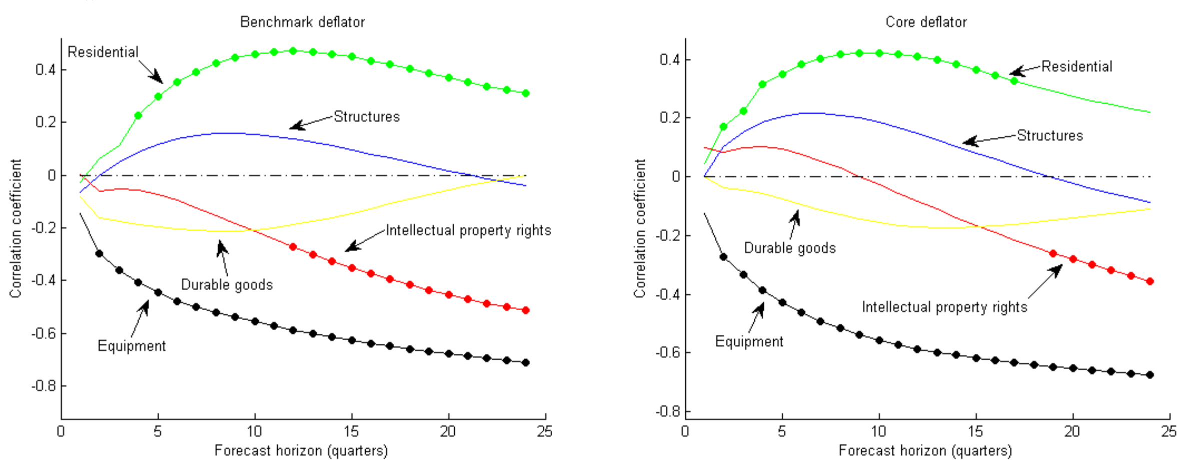


Note: Here I plot $COV^{\Delta}(k)$ for different values of k. Recall, $COV(K) = \sum_{k=1}^{K} COV^{\Delta}(k)$. Confidence intervals are not reported.

The covariances of long-run horizons, in the absolute value sense, are quantitatively more important than the short-run ones for the case of the relative price of business investment. This is not the case for total investment where the negative covariances are of similar magnitude across all forecast horizons. Under the Benchmark consumption deflator, the positive covariances that occur in the medium-term horizons for the relative price of household investment are small relative to the short-run negative covariances. The converse is true under the Core deflator.

To understand the behaviour of the relative price of the main investment aggregates I look into the behaviour of the relative price of each of their sub-components. Figures 3.6 and 3.7 show the correlations of the VAR forecast errors of each component of investment against output and hours worked. There is a pattern that can be observed across all instances: the relative price of investment in equipment goods is countercyclical at all forecast horizons and in a statistically significant manner, while the converse is true for the case of investment in residential goods (except in the very short-run). This cyclical pattern is in agreement with the results obtained using instantaneous correlations on HP filtered data (see Tables 3.4 and 3.5). Instead, and contrary to the results obtained using instantaneous correlations, the results from the VAR forecast error correlations suggest that the relative price of investment in intellectual property rights is countercyclical at long-run horizons, and significantly so when using output as the business cycle indicator.

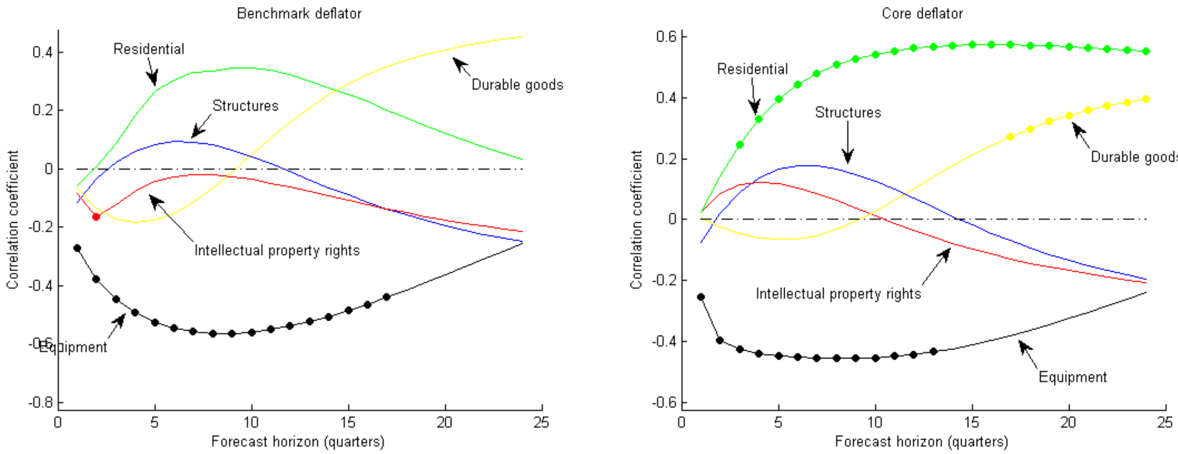
Figure 3.6: VAR forecast error correlation of relative price of subcomponents of investment and output



Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

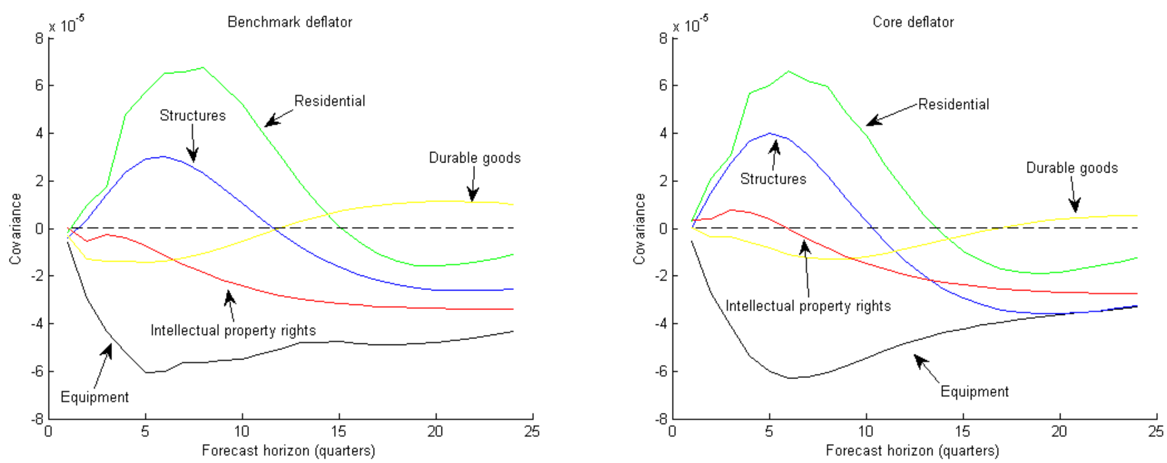
Figure 3.8 shows the forecast error covariances of the relative price of the sub-components of total investment and output. The short-term positive covariances of the relative price of

Figure 3.7: VAR forecast error correlations between relative price of subcomponents of investment and hours worked



residential goods are quantitatively much more important than the long-run covariances. For the case of equipment goods, the long-run negative covariances are of more relevance than the short-run ones and, in all instances, the magnitude of the covariances of the relative price of durable goods are much smaller compared to the covariances of all the other components of investment. Finally, the positive short-run covariances of the relative price of structures are of similar magnitude than the long-run negative ones.

Figure 3.8: VAR forecast error covariance of relative price of subcomponents of investment and output



Note: Here I plot $COV^{\Delta}(k)$ for different values of k. Recall, $COV(K) = \sum_{k=1}^{K} COV^{\Delta}(k)$. Confidence intervals are not reported.

It is clear that focusing on the aggregate categories of investment hides a high degree of heterogeneity in the cyclical behaviour of the relative price of each of the components of investment.

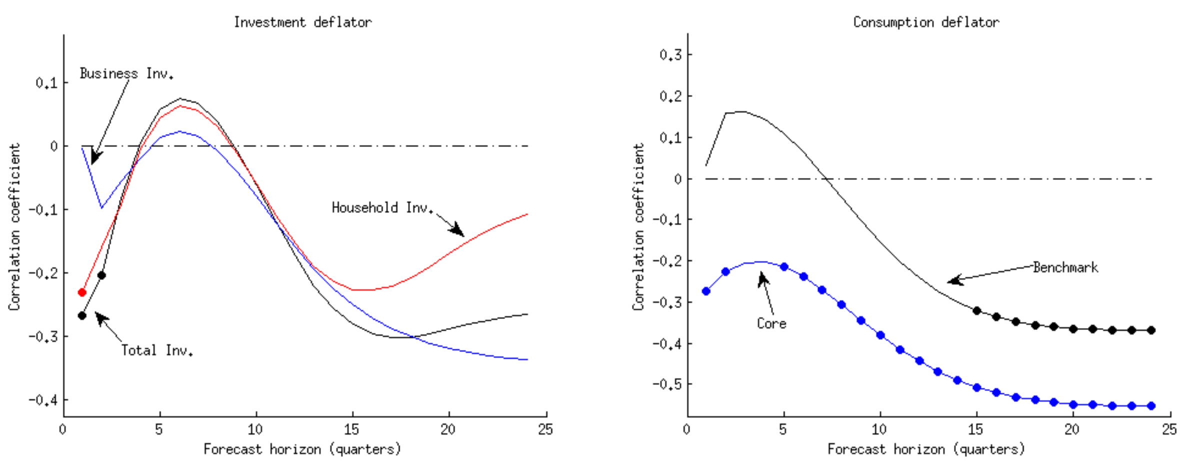
3.4.3 Robustness checks

In this section I check the sensitivity of the results to the use of a different time sub-sample as well as to modifications to the benchmark VAR specification structure.

3.4.3.1 1984-2013 sub-sample

As already mentioned in Section 3.2 and shown with traditional comovement measures in Section 3.3, there seems to be a change in the cyclical behaviour of the relative price of investment from 1984 onwards. That period coincides both with the end of the oil price shocks as well as the end of Paul Volcker's first tenure as chairman of the federal reserve. As a result, I look again at the short and long-run cyclical properties of the relative price of investment under the 1984-2013 sub-sample. As in Section 3.4.2, I first look at the cyclical properties of the price of investment and the price of consumption separately, figure 3.9. For the sake of brevity, I only report the results for the case where I use output as the business cycle indicator.

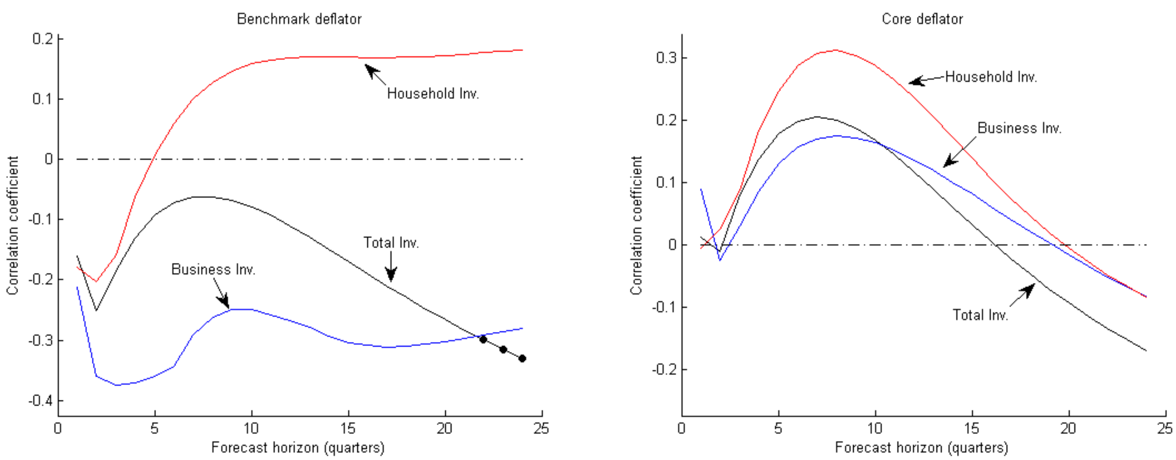
Figure 3.9: VAR forecast error correlation between the price of investment and the price of consumption and output



Consistent with the results displayed in Section 3.3, once I focus on the reduced sample I obtain that all correlations have become more positive, relative to the correlations that arise when using the full sample. However, as opposed to the slightly positive correlations on the price of investment series that I obtained using instantaneous correlations, the VAR forecast error correlations are still negative at most time horizons.

Figure 3.10 reports the VAR forecast error correlations of the relative price of the main aggregates of investment and output.[6] When using the Benchmark consumption price index both the relative price of total and business investment are countercyclical, although in this case the negative correlations become not statistically different than zero. The relative price of household investment remains slightly countercyclical in short-run horizons, but, in contrast to the case where I use the full sample, becomes procyclical in the medium to long-run forecast horizons although not in a statistical significant manner. Under the Core deflator the results change significantly. The relative price of all main aggregates of investment are acyclical in very short horizons and display procyclical correlations in a range of 0.5 to 4 year forecast horizons, but in all instances the correlations are not statistically significant.

Figure 3.10: VAR forecast error correlations of relative price of investment and output, 1984-2013



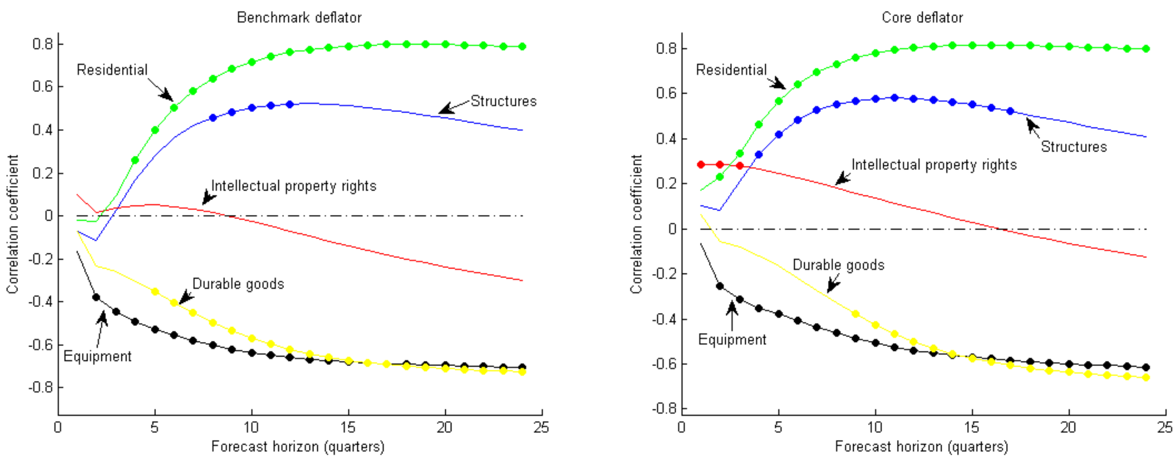
Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

These results are significantly different to those reported in Section 3.3. First, instantaneous correlations on HP filtered data on the reduced 1984-2013 sample suggested that the relative price of household investment was procyclical, and significantly so, with both consumption price indices. Instead, the results using VAR forecast error correlations does not find evidence, from a statistical perspective, that the relative price of household investment

[6]The results for the case where I use hours worked as a measure of the business cycle convey a similar message.

is procyclical, at any forecast horizon. Second, the relative price of business investment was procyclical when using the Core consumption price index on the reduced 1984-2013 sample according to the results in Table 3.4. Instead, while the results obtained with VAR forecast error correlations on the reduced 1984-2013 sample do become more positive compared to those obtained using the full sample in Section 3.4.2, none of them becomes procyclical and statistically different from zero at any time horizon. Again, it appears that instantaneous correlations fail to capture that the price of investment (the numerator) becomes more countercyclical at longer forecast horizons, which may be related with productivity developments in the economy that transmit with more of a lag.

Figure 3.11: VAR forecast error correlations of relative price of subcomponents of investment and output, 1984-2013

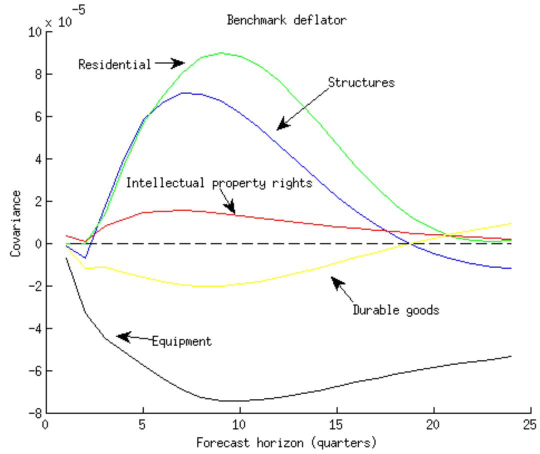


Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

That said, focusing only on the cyclical properties of the relative price of the main investment aggregates may lead to possibly incomplete conclusions. Figure 3.11 plots the VAR forecast correlation errors of the relative price of the sub-components of the investment aggregates and output. The cyclical properties of the relative price of each of the components of total investment have not changed much, in a qualitative sense, when compared to the results obtained in the full sample. The relative price of residential goods remains procyclical and that of equipment goods countercyclical. The main difference comes from the cyclical properties of investment in structures, whose relative price becomes procyclical, and significantly so in a statistical sense in medium-run forecast horizons, when compared to the full sample. It also appears that the relative price of durable goods has become more countercyclical.

Figure 3.12 shows the forecast error covariances of the relative price of the sub-components

Figure 3.12: VAR forecast error covariance of relative price of subcomponents of investment and output, 1984-2013



Note: Here I plot $COV^{\Delta}(k)$ for different values of k. Recall, $COV(K) = \sum_{k=1}^{K} COV^{\Delta}(k)$. Confidence intervals not reported.

of total investment and output. Comparing figure 3.12 and 3.8, the covariance profile of the relative price of residential and equipment goods has not changed much, in qualitative and quantitative terms. By contrast, that of investment in structures and, to a smaller extent, intellectual property rights, has become more procyclical. The covariance profile of the relative price of durable goods is also very similar to that in the full sample.

3.4.3.2 VAR specification

Table 3.7 in Appendix 3.7.3 contains the specification of each of the bivariate VAR's that I estimate and use to construct the VAR forecast error correlations. I will refer to the specifications described in table 3.7 as the baseline specification. In this section I look at how the results change when changing the specification of those VAR's. In particular, I look at the VAR forecast error correlations when I impose that all VAR's include 6 lags of each of the variables as well as a linear deterministic trend. My choice is motivated by the fact that most VAR's that I estimate in the previous sections have less than 6 lags and no trend.

Figures 3.16 to 3.19 in Section 3.7.4 of the Appendices report the VAR forecast correlation errors of the relative price of all categories of investment against output and hours worked, using the full 1960-2013 sample. The results portray a picture very similar to that of the results reported in Section 4.2, although there are some minor differences. For example, in all instances, as opposed to the case where I use the baseline VAR specifications, the relative price of household investment becomes procyclical in the long-run, although significantly so only when using hours worked as a proxy of the business cycle. When using hours worked as the business cycle indicator, the relative price of total investment switches from a negative correlation at short-run forecast horizons to a positive one at medium to long-run forecast horizons, but those positive correlations are not statistically significant. Focusing on the cyclical properties of the sub-components of the main aggregates of investment, I find very similar profiles to those reported in Section 4.2 albeit the magnitudes and statistical significance of some of the coefficients do change.

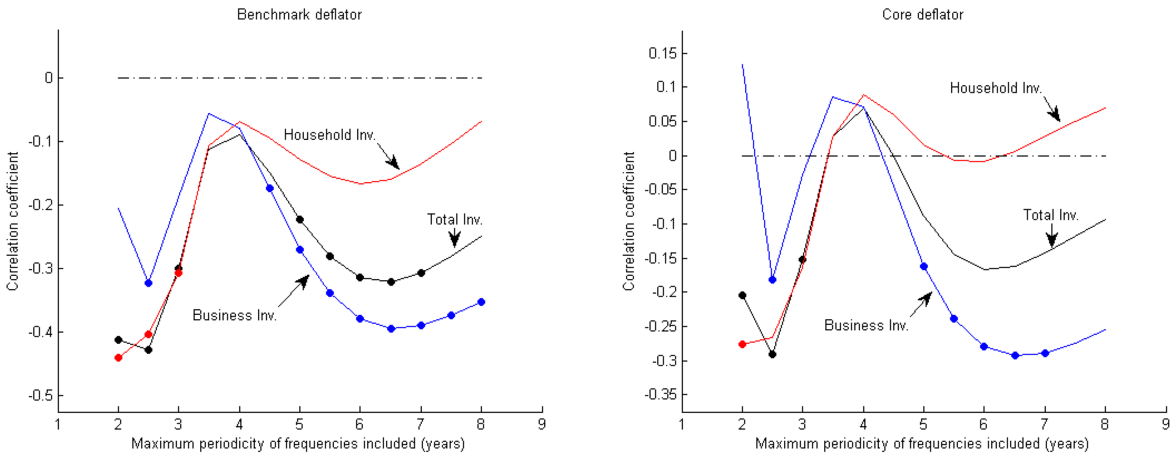
3.5 Measuring comovement using correlations on frequency domain filtered data

An alternative set of descriptive statistics to capture the business cycle behaviour of the relative price of investment can be obtained by means of band pass filters. Any stationary time series has a frequency-domain representation (see for instance Hamilton 1994, chapter 6), which means, informally, that the time series can be represented as a weighted sum of sine and cosine waves each of them related to a certain frequency ω. One can use this property to isolate and remove those components of a series that are related to certain particular frequencies. Band pass filters can remove both low and high frequencies. I refer the reader to Hamilton (1994) for a detailed exposition of the theory behind the frequency-domain representation of a time series, and to Baxter and King (1999) for an exposition on how to implement band pass filters.[7]

Figure 3.13 provides the correlation between the relative price of the main aggregates of investment and its components with real GDP per capita. Figure 3.14 reports the results for the case where I use hours worked as the business cycle indicator. Baxter and King (1999) specify that business cycles are cyclical components of at least six quarters and at most eight years. Therefore, the band pass filter that I apply removes all those frequencies related with periods of less than six quarters and more than the periodicities indicated in the horizontal axis, eight years being the maximum. To set a reference point, the widely used HP filter is approximately equal to a high pass filter that removes all cycles associated with periodicities of more than eight years (see Gomez 2001).

[7] Band pass filters are convenient, not only for their properties and the ease of interpretation of the outcome of the filter, but also because they can be applied onto integrated series (see Den Haan and Sumner 2004). However, if applied to an integrated series, the zero frequency needs to be removed.

Figure 3.13: Band pass filter: correlation between relative price of investment and output

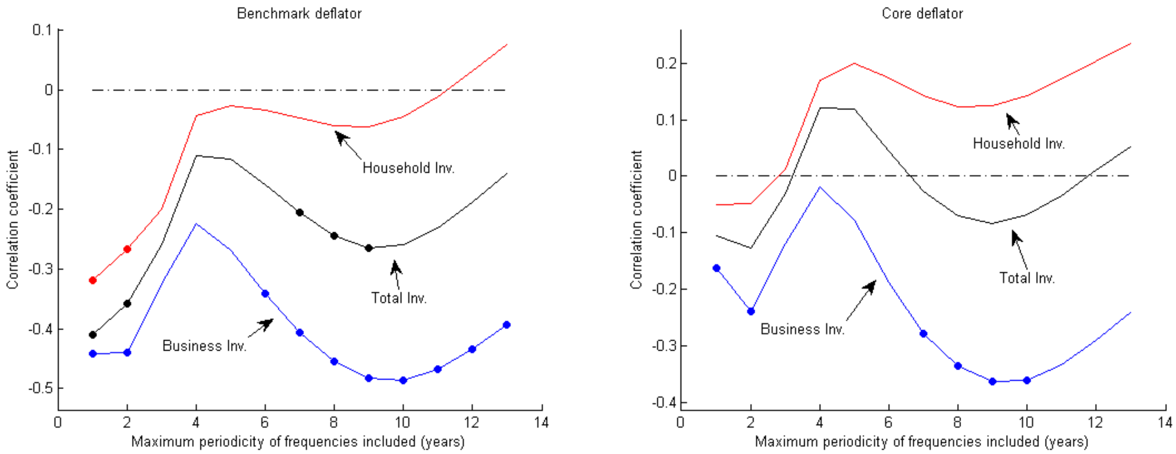


Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test. The band pass filter isolates that part of the series associated with cycles with periodicities between 6 quarters and the number of years indicated in the horizontal axis.

The results for the main investment aggregates are very similar to the ones reported in Section 3.4.2. The relative price of business investment is countercyclical and significantly so at almost all frequencies. The relative price of total investment is also, in almost all instances, countercyclical at almost periodicities. The relative price of household investment is countercyclical at almost all periodicities when using the Benchmark deflator, but turns slightly procyclical when we include lower frequencies and use the Core deflator, although not in a statistically significant sense.[8] The latter result is consistent with Band Pass filters that include periodicities between one and a half and eight years being similar to the HP filter. However, from this perspective, it becomes apparent that the cyclical properties of the relative price of household investment described in Section 3.3 are sensitive to the range of periodicities that ones uses to define the business cycle frequency.

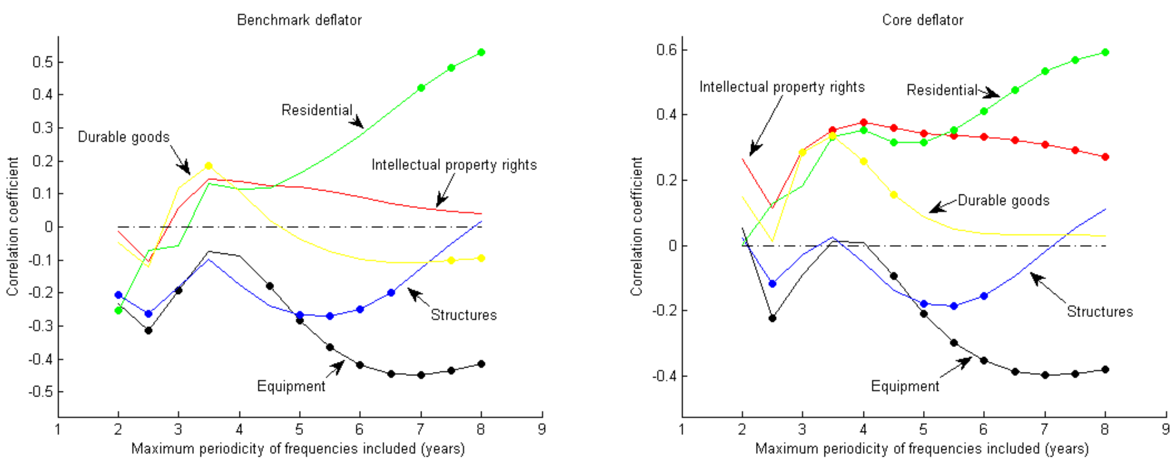
[8]Remember that the period of a wave is inversely related to the frequency.

Figure 3.14: Band pass filter: correlation between relative price of investment and hours worked



Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test. The band pass filter isolates that part of the series associated with cycles with periodicities between 6 quarters and the number of years indicated in the horizontal axis.

Figure 3.15: Band pass filter: correlation between relative price of subcomponents of investment and hours worked



Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test. The band pass filter isolates that part of the series associated with cycles with periodicities between 6 quarters and the number of years indicated in the horizontal axis.

Focusing on the cyclical behaviour of the relative price of the sub-components of investment against output, figure 3.15, we again obtain similar results to those in Section 3.4.2. The residential and equipment categories are procyclical and countercyclical, respectively. Interestingly, the correlations are of highest magnitude when the Band Pass filter is closest to the HP filter, that is, when frequencies in the range between 6 to 32 quarters are included. Note, in addition, that it makes economic sense that the relative price of residential investment is acyclical when only very high frequencies are included, as the process of building residential property is lengthy and takes time to appear in the national account statistics. The main differences compared to Section 3.4.2 appear to be the cyclical properties of the Structures and the Intellectual Property Rights category. The former appears to be slightly countercyclical at almost all frequencies when using correlations on frequency-domain filtered data whereas it appeared to be slightly procyclical when using the VAR forecast error methodology. The converse is true for the latter.

3.6 Conclusions

This paper uses a methodology developed by Den Haan (2000) and Den Haan and Sumner (2004) to analyze the business cycle behaviour of the relative price of investment. This methodology uses the correlation of VAR forecast errors to describe the dynamic behaviour of time series variables. The main advantages of this method include that it does not require to take a stance on a procedure to detrend the data, it does not requires to impose identifying assumption to single out structural shocks and allows to capture dynamic properties of the variables considered. The main drawback is, precisely, that it does not identify structural relationships between variables.

Different measures of business cycle properties produce different results. Instantaneous correlations on HP filtered data suggest that the relative price of total investment is acyclical in the full sample and procyclical in the reduced one. However, VAR forecast error correlations and correlations on frequency-domain filtered data suggest a countercyclical behaviour. Correlations on HP filtered data suggest that the relative price of household investment is procyclical, but VAR forecast error correlations suggest a countercyclical behaviour at short-run forecast horizons. Correlations that have been computed on frequency-domain filtered data also suggest a countercyclical behaviour if we include frequencies related with periods of up to 4 years. Correlations on HP filtered data suggest that the relative price of business investment is mildly countercyclical, but turns procyclical when using the reduced 1984-2013 sample. This is less clear when measuring the business cycle properties via VAR forecast error correlations. In almost all instances that I consider in the text, the relative price of business investment is countercyclical at all forecast horizons, except when using the 1984-2013 sample and the Core consumption price index. Even then, the positive correlation is not statistically significantly different from zero.

All three methodologies that I consider, namely instantaneous correlations on HP filtered data, VAR forecast error correlations and instantaneous correlations on Band Pass filtered data agree that the relative price of equipment goods is countercyclical and that of residential goods is procyclical.

3.7 Appendices

In this section I provide more details about the source of the data that I use and the method implemented to aggregate chain linked data.

3.7.1 Appendix A

The data source are the Bureau of Economic Analysis' NIPA tables[9]. More specifically, I use tables 1.1.3, 1.1.4 and 1.1.5 to obtain quantity, price and nominal series for Gross domestic product (line 1), Personal consumption expenditures on durable goods (line 4), Personal consumption expenditures on nondurable goods (line 5), Personal consumption expenditures on services (line 6), Nonresidential investment (line 9), Investment in structures (line 10), Equipment investment (line 11), Intellectual property products (line 12) and Residential investment (line 13). From tables 2.3.3, 2.3.4 and 2.3.5 I also get the quantity, price and nominal series for the subcomponents of Personal expenditure expenditure in non-durable goods (lines 9-12). These are used to construct the Core consumption deflator. Real GDP per capita is obtained by dividing the quantity series of Gross domestic product (line 1, table 1.1.3) by total population, which I obtain from table 7.1 (line 18). Finally, hours worked are the Bureau of Labour Statistics measure for non-farm business sector total hours, which I normalize by total population.

3.7.2 Appendix B

3.7.2.1 Investment series

From the BEA NIPA tables I get the following investment price series: Equipment, Intellectual property products, Structures, Durable goods and Residential investment. I also obtain

[9]http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1#reqid=9&step=1&isuri=1

the price series for Nonresidential Investment, which is the aggregate of the price series of investment in Equipment, Intellectual property products and Structures. I define the following three aggregates:

$$\begin{aligned}
\text{Business investment} &= \text{Nonresidential investment} \\
&= \text{Structures + Equipment + Intellectual property products,} \\
\text{Household investment} &= \text{Durable Goods + Residential Investment,} \\
\text{Total Private Investment} &= \text{Business Investment + Household Investment.}
\end{aligned}$$

The nominal series for these aggregates is computed by adding the nominal values of the subcomponents. To construct the price and quantity index I follow Whelan (2002). I provide a brief example here of how the method works by showing how to construct the quantity and price index of Household investment. Let D_t and R_t denote the quantity index on Durable and Residential goods, respectively and P_t^D and P_t^R denote the corresponding price indexes. Denote HI_t^N the nominal series of Household investment, obtained by adding up the nominal series of Durable goods and Residential goods. To construct the quantity index, HI_t, and price index, P_t^{HI} of Household investment I:

- Normalize $HI_T = 1$ for some reference data T. I follow the approach used in Beaudry et al. (2015) and set $T = 1$.
- For all the remaining dates,
$$HI_t = HI_{t-1} \times Q_t,$$
$$Q_t = \sqrt{\frac{P_{t-1}^D D_t + P_{t-1}^R R_t}{P_{t-1}^D D_{t-1} + P_{t-1}^R R_{t-1}} \times \frac{P_t^D D_t + P_t^R R_t}{P_t^D D_{t-1} + P_t^R R_{t-1}}}.$$
- Define the price index, P_t^{HI} as:
$$P_t^{HI} = \frac{HI_t^N}{HI_t}$$
- Finally, I normalize HI_t and P_t^{HI} by their respective average values and scale them up by a factor of a 100.

I thus construct the Total private investment quantity and price series by chaining the Business and Household investment series.

3.7.2.2 Consumption series

I define the following two consumption aggregates:

$$\begin{aligned}
\text{Benchmark} &= \text{Nondurable Goods + Services} \\
&= \text{Food and Beverages + Clothing and footwear +} \\
&\quad\ \text{Gasoline + Other + Services} \\
\text{Core} &= \text{Nondurable Goods + Services - Energy} \\
&= \text{Food and Beverages + Clothing and footwear +} \\
&\quad\ \text{Other + Services}
\end{aligned}$$

I construct the Benchmark quantity and price series by chaining the non-durable Goods and Services categories. By contrast, I construct the Core quantity and price series by chaining all the individual sub-components, excluding the Gasoline and other energy goods category.

Finally, I define the relative price of investment as

$$\text{Relative price of investment} = \frac{\text{Investment price index}}{\text{Consumption price index}}.$$

3.7.3 Appendix C

Table 3.7 describes the specification of each bivariate VAR that I run. I have used the Akaike information criterion to determine the number of lags that each VAR should have as well as whether deterministic trends should be imposed. The selection procedure could choose between imposing no trend, a linear trend and a quadratic trend. To prevent too much cluttering, I omit the specifications of the VAR's that use hours worked as a measure of the business cycle. However, the specifications are very similar to those reported here using real GDP per capita as the business cycle indicator.

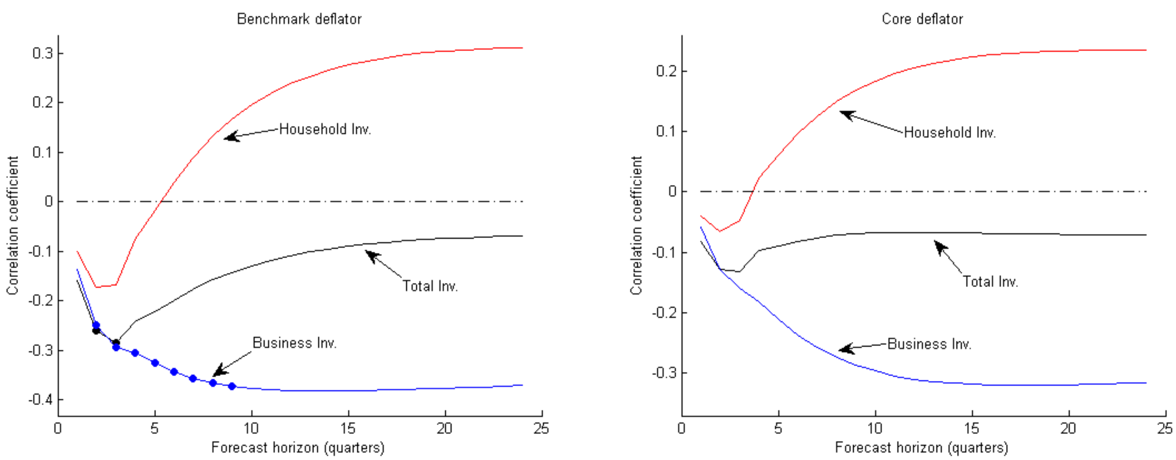
3.7.4 Figures

Table 3.7: VAR specification

Relative price of :	Consumption deflator	No. lags	Trend	
			None	Linear
Total private investment	Benchmark	3	Yes	No
	Core	3	Yes	No
Business investment	Benchmark	10	No	No
	Core	3	Yes	No
Equipment	Benchmark	3	Yes	No
	Core	3	Yes	No
Intellectual pr. rights	Benchmark	3	Yes	No
	Core	3	No	No
Structures	Benchmark	3	No	Yes
	Core	3	Yes	No
Household investment	Benchmark	4	Yes	No
	Core	3	Yes	No
Durable goods	Benchmark	3	No	No
	Core	3	No	No
Residential	Benchmark	4	Yes	No
	Core	3	No	No

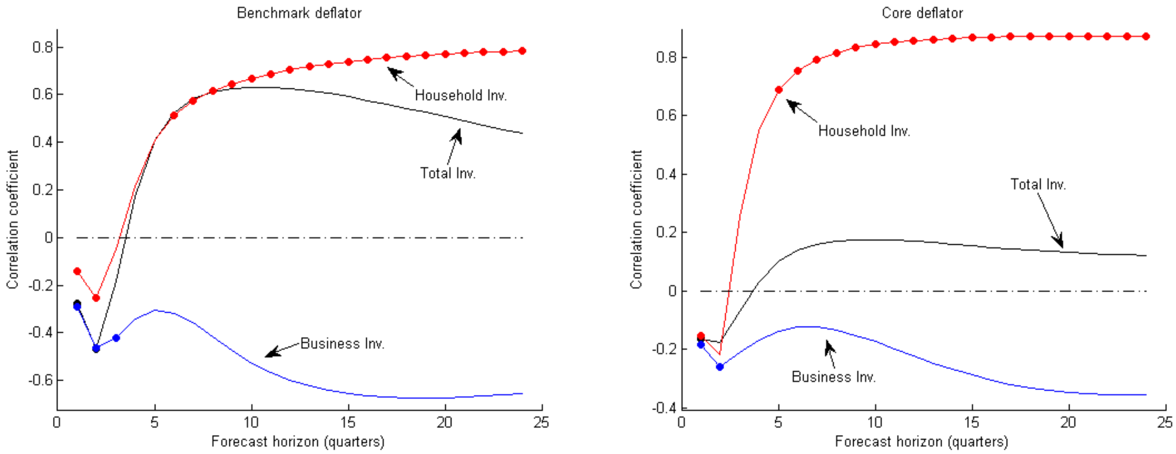
Note: all specifications are based on an estimation using the full 1960-2013 sample. All VAR's have been estimated in log levels. Sample period is quarterly. The selection procedure could choose between: no trend, linear trend and quadratic trend.

Figure 3.16: VAR forecast error correlation of relative price of investment and output



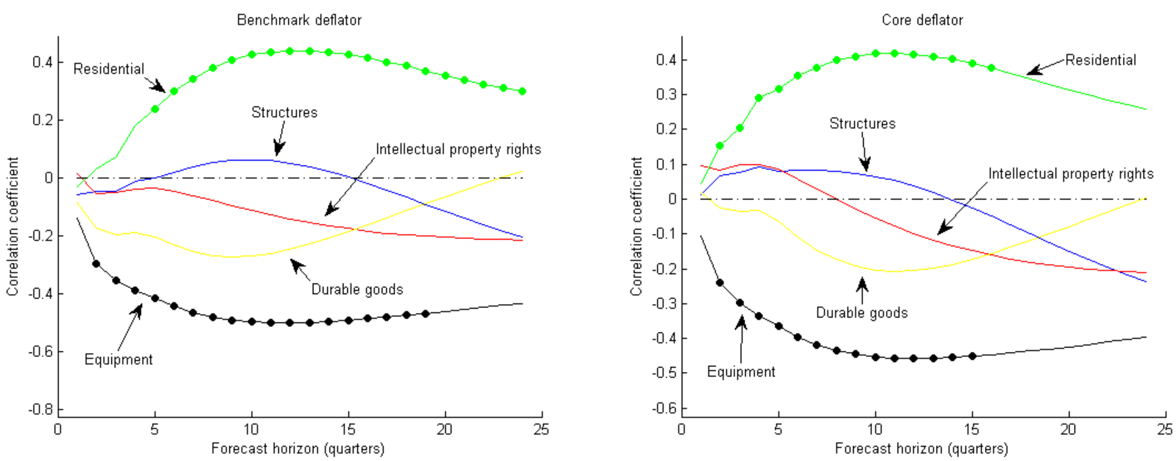
Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

Figure 3.17: VAR forecast error correlation of relative price of investment and hours worked



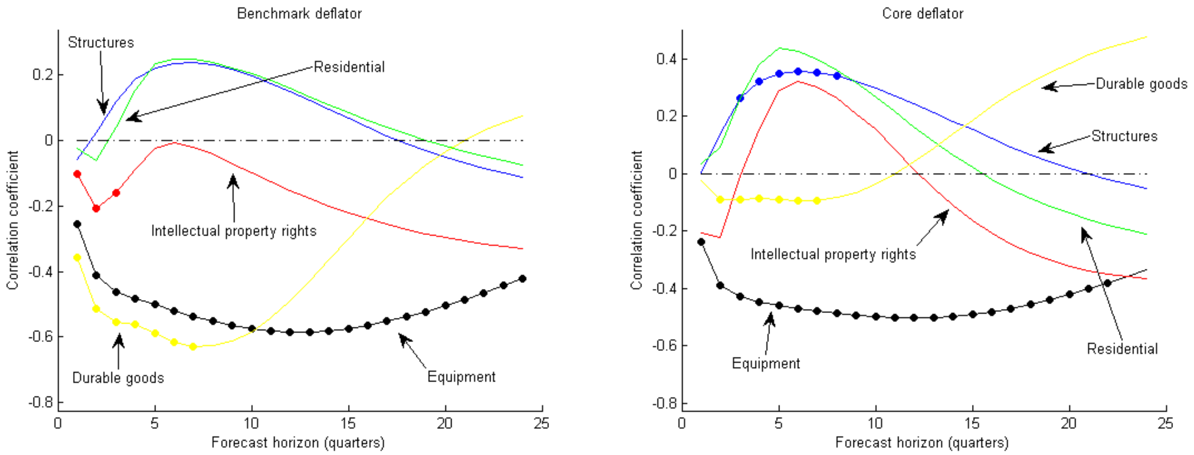
Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

Figure 3.18: VAR forecast error correlation of relative price of subcomponents of investment and output



Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

Figure 3.19: VAR forecast error correlation of relative price of subcomponents of investment and hours worked



Note: A circle indicates that the correlation is significant at the 10 per cent significance level on a two tailed test.

Figure 3.20: Cyclical component of business cycle indicators

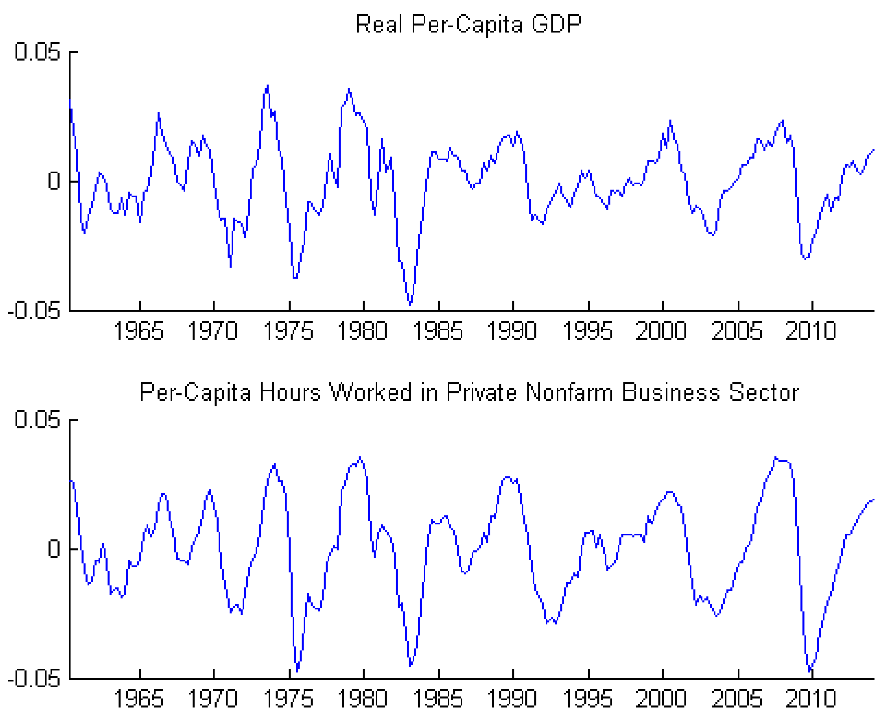


Figure 3.21: Cyclical component of price indices of investment

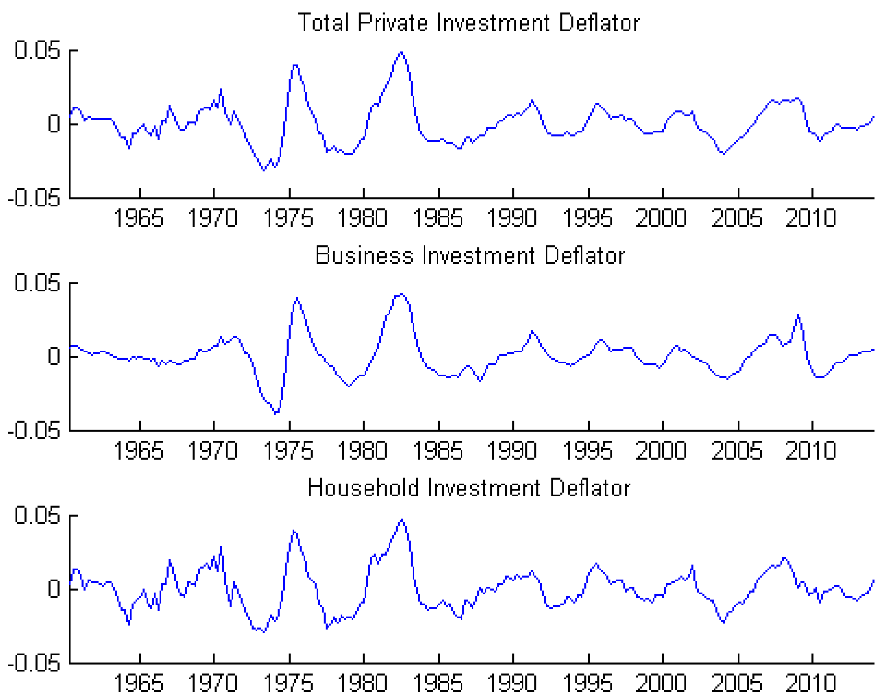
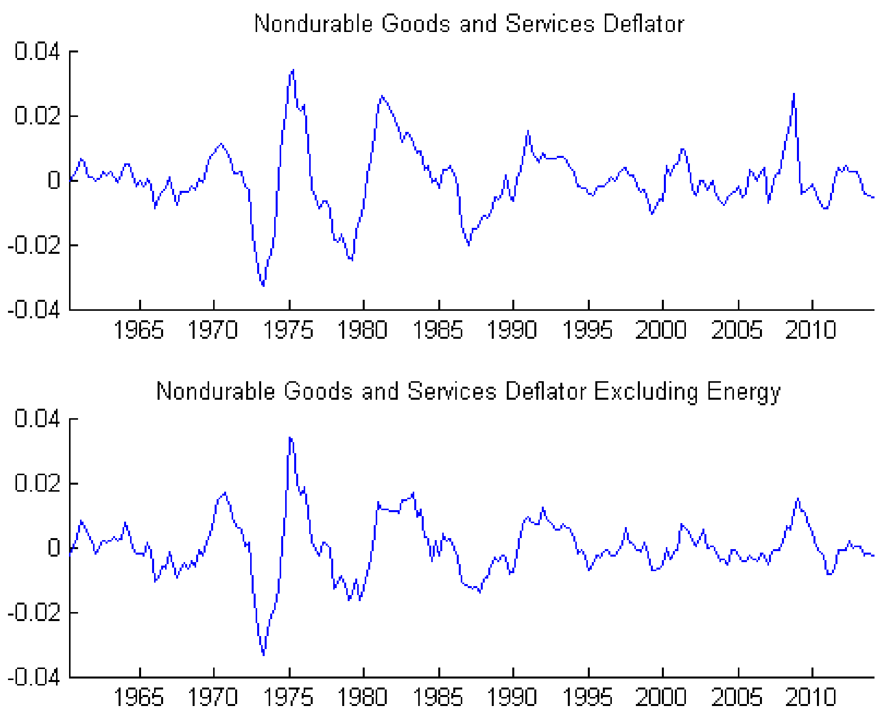


Figure 3.22: Cyclical component of price indices of consumption



Chapter 4

Macroprudential tools, Transmission and Modelling

4.1 Introduction

Macroprudential policy is focused on the financial system as a whole, with a view to limiting macroeconomic costs from financial distress (Crockett (2000)), with risk taken as endogenous to the behaviour of the financial system. However, as noted by Galati and Moessner (2014), "analysis is still needed about the appropriate macroprudential tools, their transmission mechanism and their effect". Theoretical models are in their infancy and empirical evidence on the effects of macroprudential tools is still scarce. Nor has a primary instrument for macroprudential policy emerged. Accordingly, in this paper we seek to address issues in the tools, transmission and modelling of macroprudential policy. The paper is structured as follows:

In Section 4.2, we look at general macroprudential instruments, notably capital or provisions held by institutions (either in time series or cross section) not specific to sectors they lend to. An example is the countercyclical buffer of 2.5 percentage points for banks, which rises when times are good and falls when they are bad, where the suggestion in Basel Committee (2010) is that such buffers should be calibrated to credit "gaps".[1] Dynamic provisioning across bank balance sheets also fits into this category. These are tools specifically developed

[1] Like the output gap, the credit gap measure is the distance between credit levels at time t and the long-run trend as (usually) derived using a Hodrick-Prescott filter.

to mitigate systemic risk.[2] There are additional tools that may be relevant at times such as capital controls and limits on system wide currency mismatches.

We also examine specific tools targeted to sectors such as housing. These were often not originally developed with systemic risk in mind, but can be modified to target systemic risk. Whereas macroprudential surveillance focused on house prices as a key indicator is common across many countries, attempts to regulate house purchase lending were historically less widespread, but is becoming more common in the light of the sub-prime crisis (Davis et al. (2011), CGFS (2010), Darbar and Wu (2015)).

In Section 4.3, we analyze the transmission of macroprudential tools and its effectiveness in reducing asset prices, credit growth and financial instability generally. We survey both the theoretical and empirical literature on the effectiveness of macroprudential policy and we present information on the main databases of macroprudential policy. Interestingly, from the literature it is often the sector specific tools that are shown to be most effective, although this may be because of longer experience of their use.

This then forms background to our own modelling exercise which is in Section 4.4. We seek to estimate panel error correction models for house prices and household sector credit, before testing the additional impact of macroprudential policies. We can use appropriate sets of variables in our equations given we focus on the OECD countries that offer comprehensive datasets. We contrast such results with those typical in the literature for global samples, which include mainly economic growth, policy rates and volatility. We find that a number of policies are shown to be effective for restraining house prices and credit.

We implement a seemingly unrelated regression procedure (SUR) in Section 4.5 to address a potential concern of weak cointegration underpinning the panel error correction regressions, particularly for house prices, in Section 4.4. While a country by country approach tackles successfully the concern of lack of cointegration, it has limited scope for econometric inference as the binary nature of the datasets used in this paper become a more taxing feature. Nevertheless, we still find evidence suggesting that macroprudential policies limit house price and credit growth.

[2] The Basel approach builds on the historically less interventionist approach of regulators and central banks in OECD countries, who have until recently taken the view that interest rates and individual bank capital regulation are all that is needed for both monetary and financial stability to be maintained.

4.2 Taxonomies and overview of macroprudential policies

4.2.1 Taxonomies

General versus specific is not the only possible taxonomy of macroprudential tools. There are also tools that focus on addressing the time dimension (procyclicality) versus the cross sectional dimension, within which there are tools to target capital, assets and liquidity, as shown below in Table 4.1

Table 4.1: The time and cross-sectional dimensions

	Time dimension	Cross-sectional dimension
Capital	- Countercyclical capital buffer - Dynamic provisioning - Sectoral capital requirements - Sectoral risk weights [- Countercyclical leverage ratio]	- G-SII and O-SII buffer - Systemic Risk buffer (SRB) [- Leverage ratio]
Assets	- Loan-to-value (LTV) caps - Loan-to-income (LTI) caps - Debt-to-income (DTI) caps	- Large exposure measures - Concentration limits
Liquidity	- Limits on loan-to-deposit ratio - [Time-varying] liquidity ratios - [Time-varying margin requirements]	- Systemic liquidity surcharge - Liquidity coverage ratio (LCR) - Net stable funding ratio (NSFR) - Minimum haircuts / margin floors - Reserve requirements

Source: Bennani et al. (2014)

The second taxonomy, Table 4.2, considers phases of the cycle. Some tools are for dampening the expansionary phase while others look at the contraction or at contagion between systemic institutions.

The third taxonomy looks at the market failures addressed by macroprudential policy that lead to systemic risk, which can be seen as justifying policy intervention. The three drivers of externalities are: first, strategic complementarities between firms that cause a build-up of

Table 4.2: The phases of the cycle

	Restrictions related to borrower, instrument, or activity	Restrictions on financial sector balance sheet (assets, liabilities)	Buffer based policies	Other	
				Taxation, levies	Other (including institutional infrastructure)
Expansionary phase	Time varying caps/limits/rules on: - DTI, LTI, LTV - margins, hair-cuts - lending to sectors - credit growth	Time varying caps/limits on: -mismatches (FX, interest rate) - reserve requirements	Countercyclical capital requirements, leverage restrictions, general (dynamic) provisioning	Levy/tax on specific assets and/or liabilities	- Accounting (e.g., varying rules on mark to market) -Changes to compensation, market discipline, governance
Contractionary phase: fire-sales, credit crunch	Adjustment to specific loan-loss provisioning, margins or hair-cuts (e.g., through the cycle, dynamic)	Liquidity limits (e.g., Net Stable Funding Ratio, Liquidity Coverage Ratio)	Countercyclical capital requirements, general (dynamic) provisioning	Levy/tax (e.g., on non-core liabilities)	-Standardized products -OTC vs. on exchange -Safety net (Central Bank/Treasury liquidity, fiscal support)
Contagion, or shock propagation from SIFIs or networks	Varying restrictions on asset composition, activities (e.g., Volcker, Vickers)	Institution- specific limits on (bilateral) financial exposures, other balance sheet measures	Capital surcharges linked to systemic risk	Tax/levy varying by externality (size, network)	- Institutional infrastructure (e.g., CCPs) - Resolution (e.g., living wills) - Varying information, disclosure

	Enhancing resilience
	Dampening the cycle
	Dispelling gestation of cycle

Source: Claessens et al. (2013)

vulnerabilities, second, fire sales that lead to collapses in asset prices and market liquidity, and third, interconnectedness and contagion. As shown in Table 4.3 policies may be effective against more than one externality, especially capital requirements.

4.2.2 General macroprudential tools

To quote from Basel Committee (2010), "the countercyclical buffer aims to ensure that banking sector capital requirements take account of the macro-financial environment in which banks operate. It will be deployed by national jurisdictions when excess aggregate credit growth is judged to be associated with a build-up of system-wide risk to ensure the banking system has a buffer of capital to protect it against future potential losses". The countercyclical buffer can thus be activated to increase the resilience of the system as a whole, while the release of the buffer will reduce credit crunch effects when banks seek to deleverage at times

Table 4.3: The risk dimension

Externalities due to:	Can be addressed by:			
	Capital Requirements (Surcharges)	Liquidity Requirements	Restrictions on activities, assets, or liabilities	Taxation
Strategic complementarities	X		X	
Fire sales	X	X		X
Interconnectedness	X		X	X

Source: De Nicoló et al. (2012)

of financial stress. But it may be slow to react to build up of risk in particular parts of the credit market and may not have an effect on credit growth when the banks already hold over the minimum capital level.

Dynamic provisioning is applied to overall credit expansion rather than that in the housing market, but would naturally bear on housing credit when this is a large proportion of total credit, as has been the case in Spain in recent years where dynamic provisioning has been applied since 2000. Banks set aside provisions during times when credit expansion is particularly rapid, which anticipates the losses to be realized when there is a downturn. The provisions are higher on riskier forms of lending. So, for example, at the end of 2007 the total accumulated provisions (close to 75 per cent were general provisions) covered 1.3 per cent of the total consolidated assets of Spanish deposit institutions, at a time that capital and reserves represented 5.8 per cent of those assets (Saurina et al. (2009)). Jiménez et al. (2012) find for the case of Spain that countercyclical macroprudential policies, such as dynamic provisioning, are useful in taming credit supply cycles, so Spain would have been even worse off in 2008/9 in the absence of such a policy. Dynamic provisioning helps smooth the downturn during recessions, upholding firm credit availability and performance.

The experience to date of this policy is that it has been more successful in the protection of the institutions than in limiting credit growth or the asset bubble, although the difficulties of the Cajas (savings banks in Spain) shows that even this effectiveness is limited. We note that the parameters of dynamic provisioning could be adjusted to penalize certain types of loan since they fall into 6 different risk buckets, but to our knowledge, the Spanish have chosen not to do this to date.

Liquidity tools such as the Basel III LCR and NSFR can be complemented by local tools such as the Macroprudential Stability Levy (Korea) and the Core Funding Ratio (New Zealand) and marginal reserve requirements. These may have a direct effect on loan growth as well as system stability since they limit the ability of banks to use wholesale funding to fund credit growth, becoming reliant, thereby, on more sluggish retail funding (IMF (2013)).

Cross sectional tools can contain structural risks from interconnectedness and contagion in the financial system (Arregui et al. (2013)), including higher capital charges on large and systemic firms, and tools to limit large exposures within the financial system. Payments and settlements systems can be adjusted to reduce the risk of a build-up of credit exposures within the financial system.

4.2.3 Housing market tools: loan-to-value limits

Historically, use of the loan-to-value (LTV) ratio has been most common in terms of macroprudential tools for the housing market. This has been used in particular in Asian and Eastern European countries (Borio and Shim (2007), Davis et al. (2011)). More recently they have been increasingly employed by EU countries. These limits tend to start from a typical "normal" level in the economy from a microprudential point of view, such as 80 per cent. Then they would impose a tightening beyond that of 10 or 20 percentage points. Such limits have historically tended to be chosen in economies that had a heavy exposure to financial cycles and housing markets that responded strongly to credit availability. Often fixed exchange rates would limit the use of monetary policy. LTVs might be complemented by other policies which seek to ensure prudent lending, such as limits on loan to income (these are preferred to LTV by Barrell et al. (2011)) and loan concentration, as discussed below. LTVs aim to enhance financial sector resilience and lean against build-ups of risk both at micro and macro levels. Authorities using them typically see them as both effective quantitatively and expressing a helpful signal of concern.

A risk with an LTV cap is to make the maximum level also a minimum and thus raise the LTVs on new lending. On the other hand, there is a risk that LTV limits are circumvented by strategies such as offshore borrowing, unsecured borrowing, financial engineering, falsification of asset valuation or other borrowing from outside the regulated financial system. Such problems could in principle be avoided by simply making the portion of loans above a regulatory limit non-enforceable in the case of default (Weale et al. (2008)) – a policy that has not been tried, to our knowledge, at present.

As for other macroprudential policies, effectiveness of LTV policies is not easy to distinguish from the effects of monetary policy, confidence and income growth expectations upon changes in borrowing and house prices, although the panel econometrics reported in this paper and other studies seeks to overcome this problem. Writing at an early stage, CGFS (2010) seems to suggest that the success in generating resilience has been greater than in restraining credit expansion. In addition, it should be noted that LTV limits are not strictly countercyclical since the ratio depends on an endogenous variable (house prices). Structural features of the financial markets may also limit lending via LTVs, for example in Germany via Pfandbriefe which can only be used to securitise if they have LTVs of less than 80 per cent.

4.2.4 Other sector-specific macroprudential tools

LTV limits are not the only form of regulation of the terms of credit that can be applied to the housing market. Debt service/income caps have also been tried in a number of countries, notably in East Asia. Such limits require there to be sufficient information exchange between banks and/or the existence of a central credit register.

Some countries have explicitly varied capital weights to allow for concerns regarding the housing market. This enables banks to choose whether or not to lend to the sector judged to be growing too rapidly in the light of the amended cost of lending. They could react by absorbing the cost, raising more capital, and raising the cost of lending to the sector. At a macroeconomic level, it could be seen as widening the spread of mortgage loans over the deposit rate in the housing market, as the deposit margin can also be adjusted when capital requirements are raised (see Barrell et al. (2009a)).

However, Acharya (2013) finds that risk weights imposed to achieve macroprudential goals can instead lead to the build-up of financial risks because risk weights on certain asset classes such as mortgages encourage the build-up of exposure to other assets that are not deemed as risky, but that can contribute to vulnerability with concentrated exposure.

Implicit taxation of credit growth via reserve requirements was applied widely in the pre-liberalisation policies in countries such as the UK and France, where rapid growth in lending attracted higher reserve requirements on the funding side. In Finland in the late 1980s there was a threshold set on loan growth with lending above that level attracting higher reserve requirements. This was considered successful in restraining lending growth relative to that in Sweden (Berg et al. (1993)), although it did not prevent the occurrence of a banking crisis in Finland. Such policies are at times applied to the housing market. Banks with access to securities borrowing or foreign bank credit could avoid such restrictions if imposed on purely domestic lending growth. A response may be direct limits on growth of domestic and/or foreign currency loans.

Loan concentration limits at a sectoral level were applied in Ireland in the late 1990s, which meant that only up to 200 per cent of own-funds could be lent to a given industrial sector, while only up to 250 per cent could be lent to two sectors, which shared the economic risks of an asymmetric shock, such as property and construction. But these evidently did not prevent sufficiently large exposures to lead to economic and financial difficulties in that country. Such limits may also be applied to interbank lending.

4.3 Literature survey on modelling the impact and transmission mechanism of macroprudential policy

4.3.1 Theoretical research papers on macroprudential policy

We note there are rather few papers that have sought to look at monetary and macroprudential policy together. These are typically in stylised calibrated models rather than estimated ones. And a comment from one such paper is relevant "within a standard macroeconomic framework, it is very difficult to derive a satisfactory way of modelling macroprudential objectives" (Angelini et al. (2010)).

Galati and Moessner (2014) give a helpful breakdown of progress in macroprudential modelling, into three areas: banking/finance models, three-period banking or DSGE models, and infinite horizon general equilibrium models, which we follow in this paper.

Banking/finance models, in the tradition of Diamond and Dybvig (1983) highlight how financial contracts are affected by various incentive problems related to information asymmetry and commitment that can entail default. Then, there can be self-fulfilling equilibria generated by shocks, leading to systemic financial instability. They accordingly seek to explain the interaction of borrowers and lenders. For example, Perotti and Suarez (2011) look at price based and quantity based regulation of systemic externalities arising from banks' short term funding. Accordingly, current liquidity regulation could be justified, together with a Pigovian tax on short term funding. However, such models tend to be cross section and omit the time series dimension and thus cannot be used to address procyclicality. Furthermore, they tend to be partial equilibrium and thus omit key general equilibrium effects.

Such effects are included in three period general equilibrium models of the interaction of asset prices and non-financial and financial sector systemic risk. Such models assess risk taking by heterogeneous agents in an economy vulnerable to such systemic risks. For example there may be financial amplification during booms and busts that have external effects as in Goodhart et al. (2012) and Gersbach and Rochet (2012a and b). Individual agents take decisions without allowing for the general equilibrium effects of their actions, in particular the effects of asset sales caused by excessive borrowing on asset prices. Accordingly, they generate patterns of feedback loops entailing falling asset prices, financial constraints and fire sales. Then, macroprudential tools can be shown as helpful in preventing fire sales and credit crunches, including LTV, capital requirements, liquidity coverage rations, dynamic loss provisioning and margin limits on repos by shadow banks (Goodhart et al. (2013)).

Further results of interest are provided by models that focus on the functions of banks in the economy such as improving liquidity insurance, risk sharing and raising funding, which as shown by Kashyap et al. (2014) can then be used to analyze weaknesses underlying the global financial crisis, notably excessive risk taking by underfunded banks relying on short term funding and exploiting the safety net. Horváth and Wagner (2013) meanwhile show that new regulations can lead savers and banks to alter other portfolio choices. Countercyclical regulation can worsen cross sectional risk for example, although tools to reduce cross sectional risk may reduce procyclicality.

Infinite horizon DSGE models with financial frictions build on the insights of papers such as Bernanke et al. (1999) on the financial accelerator. Such models (e.g. Goodfriend and McCallum (2007)) were traditionally linear, so found it hard to deal with non-linearities implicit in systemic risk and changes in regulation. They tended to assume complete markets and that defaults either do not occur or are exogenous. And furthermore they tended to ignore endogenous leverage. So a crisis is modelled as a big negative shock that gets amplified rather than a credit boom that gets out of control (Boissay et al. (2013)).

More recent models have sought to overcome these problems, with multiple equilibria, non-linearity, externalities and amplification mechanisms being more sophisticated. Hence macro-prudential policies can be better assessed, although the models have to remain small due to the difficulty of the solution methods (Galati and Moessner (2014)). Borrowers may, for example, face occasional binding endogenous borrowing constraints in times of crisis as in

Fisher (1933) debt deflation paradigm, linked to falling asset prices and declining net worth. See for example Benigno et al. (2013). Meanwhile models such as Brunnermeier and Sannikov (2014) look at global dynamics in continuous time models with financial frictions. The financial sector does not internalize the costs associated with excessive risks, so there is high leverage and maturity mismatch. Securitisation allows risk to be offloaded by the financial sector but raises overall risk taking. The economy has low volatility and adequate growth in steady state but the steady state is unstable due to large shocks provoking endogenous leverage and risk taking with feedback loops from the financial to the real economy. The model features a pattern of rising leverage and amplification when aggregate risk declines, as in the great moderation.

He and Krishnamurthy (2014) have developed a quantitative model to assess the different dynamics in tranquil times and times of stress. Benes et al. (2014) provide a simulation model where parameters are calibrated to the features of financial cycles.

In general, such models highlight the transmission mechanism of real and financial factors, with the combination of macroeconomic boom, credit boom and low interest rates being dangerous, with consumption smoothing and precautionary saving being key underlying factors in financial imbalances' build-up. Model calibrations can help with understanding how macroprudential regulation can reduce the risk of crisis. State contingent taxes can also play a role, as can Pigovian taxes and an optimal mix of macroprudential policy and bailouts.

4.3.2 Datasets for macroprudential research

There are three publicly available datasets for research in this area, one from the BIS and two from the IMF, which are widely used in the research cited below, and which we employ in our own research detailed in Section 4.4.

The BIS dataset is focused on policy actions for housing markets, covering 60 economies worldwide from 1990-2012, Table 4.4. The database covers policy actions by central banks and financial authorities, including monetary policy measures and also prudential measures (both microprudential and macroprudential). The focus is on the direction of change of such measures. For monetary policy measures, this includes reserve requirements, credit growth limits and liquidity requirements. These have a general effect on lending for the private sector in general, including for housing. As regards prudential measures, these include

LTV limits and loan prohibitions (e.g. to second home purchase); DSTI and other lending criteria; adjustable risk weights on housing loans; specific and general loan loss provisioning on housing loans; and limits on bank exposures to the housing sector. Each measure is then classified as tightening, loosening or neutral. The dataset incorporates 590 monetary policy type measures and 246 prudential policy measures. The dataset is purely qualitative but can be made quantitative by attaching values of 1 for measures of tightening and -1 for measures of loosening, then cumulating across time to obtain a measure of monetary and prudential stance.

Table 4.4: 2013 BIS dataset

Variable	Description
MON	Non-interest monetary policy measures affecting housing, cumulated
PRU	Prudential measures affecting housing, cumulated

Source: Shim et al. (2013).
Note: each variable is a cumulation of dummies that take three values: 1, 0 and -1. 1 stands for tightening in policy, -1 for loosening and 0 for no change. The database covers a sample from 1990 to 2012.

According to the database, the Asia Pacific countries have been most active in terms of prudential measures and Latin America in terms of monetary policy measures. There has been a shift over time from monetary to prudential measures as countries focused on macro-prudential policy after the crisis, having earlier adjusted monetary policy towards inflation targeting.

The first IMF dataset is set out in Cerutti et al. (2015) and the variables are described in Table 4.5. It covers 119 economies over 2000- 2013. It draws on the IMFs Global Macro-prudential Policy Instruments (GMPI) survey. There are 12 instruments in the publicly available dataset, as follows:

- General Countercyclical Capital Buffer/Requirement (CTC);
- Leverage Ratio for banks (LEV);
- Time-Varying/Dynamic Loan-Loss Provisioning (DP);
- Loan-to-Value Ratio (LTV);
- Debt-to-Income Ratio (DTI);
- Limits on Domestic Currency Loans (CG);

- Limits on Foreign Currency Loans (FC);
- Reserve Requirement Ratios (RR);
- Levy/Tax on Financial Institutions (TAX);
- Capital Surcharges on SIFIs (SIFI);
- Limits on Interbank Exposures (INTER);
- Concentration Limits (CONC).

Table 4.5: 2015 IMF dataset

Variable	Description
CTC	General Countercyclical Capital Buffer/Requirement
LEV	Leverage Ratio for banks
DP	Time-Varying/Dynamic Loan-Loss Provisioning
LTV	Loan-to-Value Ratio
DTI	Debt-to-Income Ratio
CG	Limits on Domestic Currency Loans
FC	Limits on Foreign Currency Loans
RR	Reserve Requirement Ratios (RR)
TAX	Levy/Tax on Financial Institutions
SIFI	Capital Surcharges on SIFIs
INTER	Limits on Interbank Exposures
CONC	Concentration Limits
LTV_CAP	Subset of LTV measures used as a strict cap on new loans
RR_REV	Subset of RR measures that impose a specific wedge on foreign currency deposits or are adjusted countercyclically
MPI	All variables aggregated in total and then in two subgroups:
MPIB	Borrower related (LTV_CAP and DTI)
MPIF	Those others which are aimed at financial institutions assets or liabilities

Source: Cerutti et al. (2015)
Note: each variable is a dummy that takes on two values: 0 for no policy and 1 for policy in effect. The database covers a sample from 2000 to 2013.

They also employ LTV_CAP as the subset of LTV measures used as a strict cap on new loans; and RR_REV as the subset of reserve ratio (RR) measures that impose a specific wedge on foreign currency deposits or are adjusted countercyclically. These are aggregated in total and then in two subgroups, borrower related (LTV_CAP and DTI) and those others which are aimed at financial institutions assets or liabilities. The dataset covers the period the policy operates but with no judgement of intensity or whether they are binding. Finally there is an index for 2013 whether the policy is applied by the central bank.

The database shows that it is emerging markets that use macroprudential policies most, followed by developing and finally advanced countries. Among instruments and over the whole time period, CONC, INTER, and LEV, have been consistently used by advanced, emerging and developing countries alike. LTV is most used by advanced countries and RR_REV and FC by emerging markets and DP and CG by developing countries.

The second IMF dataset (Cerutti et al. (2016)) focuses on changes in the intensity in the usage of several widely used prudential tools by cumulation of policy actions, taking into account both macro-prudential and micro-prudential objectives, see Table 4.6. The database covers 64 countries, and has quarterly data for the period 2000Q1-2014Q4. The five types of prudential instruments in the database are: capital buffers, interbank exposure limits, concentration limits, loan to value (LTV) ratio limits, and reserve requirements. A total of nine prudential tools are then constructed since some further decompositions are presented, with capital buffers divided into four sub-indices: general capital requirements, real estate credit specific capital buffers, consumer credit specific capital buffers, and other specific capital buffers; and with reserve requirements divided into two sub-indices: domestic currency reserve requirements and foreign currency reserve requirements. However, it does omit some of the tools included in the earlier database, not least taxes on financial institutions.

4.3.3 Empirical research papers on macroprudential policy using global samples

As noted by Galati and Moessner (2014), empirical analysis of macroprudential policy is difficult because of lack of established models of real and financial interactions and lack of data (although the datasets above are a major advance). Furthermore, distinguishing correlation and causation is a major problem.

One approach is the event study as for example, Crowe et al. (2013) assess the effects of policies like LTVs on real estate market volatility. Policies such as maximum LTV adjusted in line with the real estate cycle can curb a boom most effectively. It is suggested that the focus on a narrow range of lending of such tools reduces the costs they impose on the wider economy. They also argue that measures aimed at strengthening the banking system (such as dynamic provisioning), help to cope well with the bust even if they are unable to arrest

Table 4.6: 2016 IMF dataset

Variable	Description
Changes in prudential instruments	
sscb_res	Change in sector specific capital buffer: Real estate credit. Requires banks to finance a larger fraction of these exposures with capital
sscb_cons	Change in sector specific capital buffer: Consumer credit Requires banks to finance a larger fraction of these exposures with capital
sscb_oth	Change in sector specific capital buffer: Other sectors. Requires banks to finance a larger fraction of these exposures with capital
cap_req	Change in capital requirements. Implementation of Basel capital agreements
Concrat	Change in concentration limit. Limits banks' exposures to specific borrowers or sectors
Ibex	Change in interbank exposure limit. Limits banks exposures to other banks
ltv_cap	Change in the loan-to-value ratio cap. Limits on loans to residential borrowers
rr_foreign	Change in reserve requirements on foreign currency-denominated accounts
rr_local	Change in reserve requirements on local currency-denominated accounts
Aggregate indexes	
Sscb	Sum of changes in sector-specific capital buffers across the residential, consumer, and other sectors
PruC	Country index by time t and country c, equal to 1 if the sum of the 9 instruments is >=1 and -1 if the sum of the instruments is <=-1, 0 otherwise
PruC2	Country index by time t and country c, equal to 1 if the sum of the 9 instruments is >=1 and -1 if the sum of the instruments is <=-1, 0 otherwise. In this case, all individual instruments are adjusted to have maximum and minimum changes of 1 and -1
Cumulative indexes (relative to 2001q1)	
cum_sscb_res	Cumulative change in sector specific capital buffer: Real estate credit
cum_sscb_cons	Cumulative change in sector specific capital buffer: Consumer credit
cum_sscb_oth	Cumulative change in sector specific capital buffer: Other sectors
cum_cap_req	Cumulative change in capital requirements
cum_concrat	Cumulative change in concentration limit
cum_ibex	Cumulative change in interbank exposure limit
cum_ltv_cap	Cumulative change in the loan-to-value cap
cum_rr_foreign	Cumulative change in reserve requirements on foreign currency-denominated accounts
cum_rr_local	Cumulative change in reserve requirements on local currency-denominated accounts
cum_sscb	Cumulative change in the aggregate sector-specific capital buffer instrument
cum_PruC	Sum of the cumulative version of the 9 instruments by country c and time t
cum_PruC2	Sum of the cumulative version of the 9 instruments by country c and time t. In this case, all individual instruments are adjusted to have maximum and minimum changes of 1 and -1

Source: Cerutti et al. (2016)
Note: Database covers a sample from 2000q1 to 2014q4.

the boom (see also Jiménez et al. (2012) on the Spanish experience).

A second approach is assessment of authorities or outside observers on effectiveness of macroprudential instruments. Borio and Shim (2007) for example sought to evaluate the impact of macroprudential policies on credit and asset price growth. They found that there was rapid growth in both these variables at the time the measures were introduced. They found that there were reductions in both credit growth (of 4-6 per cent) and house price growth (3-5 per cent) after the measures, although it is not always easy to divide the impact of such measures from that of monetary policy or economic growth and to assess what would have happened in the absence of such policies.

A third approach is of reduced form regressions, often using panel data. Here the weaknesses are that such regressions may not capture well the interaction of policy, real and financial sectors; there is little experience of macroprudential policy to assess the effect and transmission mechanism; and there is again a difficulty in isolating effects from those of monetary policy.

In an early study, Wong et al. (2011) look into the effectiveness of LTV limits in a panel of 13 countries over 1991-2010. They find that economies with LTV policy are estimated to have a lower sensitivity of mortgage delinquency ratios to property prices than those without LTV policy, taking into account other determinants of default (property prices, GDP growth, mortgage debt/GDP and interest rates). On the other hand, their model can be criticized as not being empirically robust, notably due to omitted variation in regulations.

Kuttner and Shim (2013) assess the effectiveness of nine non-interest rate policy tools, including macro- prudential measures, in stabilizing housing market prices and related lending in 57 countries over 1980- 2011. They use panel regressions, with controls for the short rate and the growth in real GNI per capita. Housing credit growth is slower significantly by adjustments in the maximum debt-service-to-income (DSTI) ratio, the maximum LTV, limits on banks' exposure to the housing sector and housing-related taxes. However, when using mean group and panel event study methods, only the DSTI ratio limit has a significant effect on housing credit growth. Furthermore, only a change in housing-related taxes significantly affects house price inflation.

Vandenbussche et al. (2015) assess the relation between macro-prudential policies and house price inflation in Central, Eastern, and South-eastern European countries, using panel data techniques. Capital ratio requirements and non-standard liquidity measures (marginal reserve ratio on foreign funding or linked to credit growth) reduce house price inflation, according to their results.

Akinci and Olmstead-Rumsey (2015) construct an index of domestic macroprudential policies in 57 advanced and emerging economies covering 2000-2013. Effectiveness of policies in curbing bank credit and house prices is assessed using a dynamic panel data model where control variables include real GDP growth, change in nominal monetary policy rates and the VIX, a measure of the implied volatility of S&P 500 index options. Findings of the paper are that usage has become more active since the global financial crisis, in both advanced countries and EMEs; the main target is the housing market, and they are often related to bank reserve requirements, capital controls and monetary policy. Macroprudential tightening is associated with lower bank credit growth, housing credit growth, and house price inflation and targeted policies are more effective. In EMEs capital inflow restrictions targeting the banking sector are also associated with lower credit growth, although portfolio flow restrictions are not. Without the measures, credit and asset price growth would have been much greater.

Cerutti et al. (2015) use a 2013 IMF survey (see Section 4.3.2) of annual macroprudential measures in 119 countries, with a panel GMM regression for macroprudential indicators with independent variables including GDP growth, the policy rate level and banking crises and country fixed effects as well as the macroprudential variables. An index summing all types of policy is correlated with lower credit growth, especially in EMEs. Borrower based policies like LTV and DSTI limits, as well as financial institutions based policies like limits on leverage and dynamic provisioning are shown to be particularly effective in reducing growth in real credit and house prices. Policies work best in the upturn but are less effective in a bust period. Macroprudential policy is weaker in more open and financially deeper economies, suggesting there is evasion cross border or in shadow banking. Countries with more cross border borrowing use macroprudential policies more.

Bruno et al. (2016) provide a comparative assessment of the effectiveness of macro-prudential policies in 12 Asia-Pacific economies, using databases of both domestic macroprudential policies and capital flow management (CFM) policies over 2004-13, with 152 CFM measures and 177 domestic macroprudential measures. Estimation is by dynamic GMM to allow for endogeneity. They find that banking sector CFM polices and bond market CFM policies are effective in slowing down banking inflows and bond inflows, respectively and also there are spillover effects of these policies on the "other" type of inflows. Macroprudential policies tend to be introduced along with monetary tightening, and are most successful when they complement monetary policy by reinforcing monetary tightening.

Zhang and Zoli (2016) look at macroprudential and capital flow measures in 13 Asian and 33 other economies since 2000. Measures did help to limit growth in house prices, credit, equity prices and bank leverage with LTV, tax and foreign currency linked measures being most effective.

Lim et al. (2011) again using panel approaches assess links between macroprudential policies, credit and leverage. They show some policies are effective in reducing the procyclicality of credit and leverage, notably tools such as LTV and DTI caps, ceilings on credit growth, reserve requirements, and dynamic provisioning rules.

Dell'Ariccia et al. (2011) assess the use of macroprudential policies in diminishing credit booms and busts, both in terms of risk of a boom and its adverse effect on the economy. They find a reduction in the probability of a bad boom from such policies, in particular for those that culminate in a financial crisis, although they do not much affect the probability of adverse economic consequences. On balance, it is suggested that macroprudential policies can reduce the risk of a bust, as well as adverse effect on the rest of the economy of financial system difficulties.

IMF (2013) assesses how changes in macroprudential policies affect financial vulnerabilities (credit growth, house prices, and portfolio capital inflows) as well as the impact on the real economy (output growth and the share of residential investment), and whether the effects of policies are more effective in the upturn or downturn. Their findings are that both time-varying capital requirements and reserve requirements affect credit growth; LTV limits and capital requirements have sizable effects on house price rises, and that reserve requirements reduce portfolio inflows in emerging markets whose exchange rate regime is flexible. However, only limits on LTV impact output growth, with the suggestion that this works through a reduction in investment in buildings and dwellings.

Macro stress tests can be used to assess responses of the financial system to large shocks see Drehmann (2009). For the most part, however, such studies do not allow for the potential large impact of small shocks, and omit feedback from the financial system to the macro economy. However, Aikman et al. (2009) in their Risk Assessment Model for Systemic Institutions capture feedback effects from liquidity risk and procyclicality. Hence regulatory changes such as capital tightening can affect systemic risks. Bank of Canada work (Gauthier et al. (2012)) looks at interbank spillover effects across major Canadian banks, entailing solvency, market and funding liquidity risks.

Counterfactual analysis seeks to assess what would have happened if macroprudential; policies had been applied to past events. Antipa et al. (2010) use a DSGE model of the US with a modified Taylor rule where the short rate responds to credit growth as well as inflation and authorities can influence the short term credit spread. Such a policy could have mitigated the last credit cycle and the succeeding recession. Catte et al. (2011) use the National Institute Global Econometric Model (NiGEM) for the US over 2002-7 and assume a policy was feasible that would influence spreads on mortgages.[3] This would again have mitigated the housing cycle. Barrell et al. (2010b) use a well-founded logit estimate of the determinants of banking crises in OECD countries (based on Barrell et al. (2010a)) and were able to provide estimates of the degree of macroprudential regulatory tightening needed to reduce crisis probabilities in the subprime crisis and over earlier non-crisis periods to acceptable levels, as well as providing a useful tool for macroprudential surveillance able to predict crises sensitively without changes in specification over 1998-2008. They show that an international consensus on regulatory changes will generate "winners" and "losers" in terms of capital and liquidity adjustments, and that raising capital and liquidity standards by 3.7 percentage points across the board will reduce the annual average probability of a financial crisis to around 1 per cent. In Barrell et al. (2009a) assessment is also made of costs as opposed to benefits of since higher capital and liquidity requirements induce banks to raise lending margins, hence adversely affecting the user cost of capital, investment and the capital stock.

Barrell et al. (2010b) also looked at how house prices should impact on macroprudential regulation generally. Against the background of their logit model predicting banking crises cited above, as well as arguments that credit growth should guide countercyclical provisioning, they suggest that the appropriate adjustment for procyclicality requires the country to calculate the trade-off between house prices, current account balances and regulatory variables over time. Since there is nonlinearity in a logit equation, there is not a simple rule that can be derived. Undertaking a scenario with house prices 5 percentage points higher, they showed that the regulatory adjustment is greater, as would be expected, with higher lagged house price growth, but the relationship is not one-to-one – it depends also on the other regulatory and non- regulatory variables in the model. A given growth rate of house prices is more threatening to financial stability when there is also low capital and liquidity as well as a current account deficit.

Davis et al. (2011) again run NiGEM simulations for the Swedish economy following estimation of a house price equation for that country. Results suggest that macroprudential policies can have a distinctive impact on the economy, focused on the housing market, which

[3] https://nimodel.niesr.ac.uk/

could helpfully complement monetary policy at most points in the cycle. A generalised rise in capital adequacy is shown to have a quite marked impact in GDP, mainly via investment rather than consumption. However, a more focused capital adequacy rise for mortgage lending only or an LTV policy appear to have scope to reduce house prices with less effect on the rest of the economy than other options, although it may of course be more subject than capital adequacy based policies to disintermediation. Capital adequacy for mortgage lending affects GDP more than the LTV policy since it impacts more on personal income and hence consumption. Monetary policy does of course also affect housing market variables but also has a greater effect on the wider economy, as do generalized rises in capital ratios affecting all lending.

Whatever the context, it is clear that the correct modelling of house prices and credit is crucial and is likely to receive increasing attention in the wake of the sub-prime crisis and policy developments; it is this issue we turn to in the next section. The determinants of house prices and credit may either capture directly the impact of policy, or identifies key driving variables which would otherwise bias the results of estimation – and which may in any case be indirectly affected by policy in a macroeconomic context.

Finally, micro data has been rather little used in the debate to date. Using Korean survey data, Igan and Kang (2011) find beneficial effects of LTV and DTI limits on mortgage credit growth in Korea. Gauthier et al. (2012) find that macroprudential capital requirements reduce probabilities of crises and of individual bank failures in Canada by around 25 per cent. In the UK over the period 1998-2007, Aiyar et al. (2014) find that bank-specific higher capital adequacy requirements dampened lending by individual banks (whereas tighter monetary policy did not affect the supply of lending). On the other hand, bank capital requirements were ineffective due to increased lending from the branches of foreign banks.

Claessens et al. (2013) seek to analyze the impact of macroprudential policies in limiting vulnerability of individual banks' balance sheets. They assess 48 countries, 25 advanced and 23 EMEs, with 2820 banks and 18000 observations. They group the macro-prudential policies according to whether they are aimed at borrowers (caps on debt-to-income (DTI) and loan-to-value (LTV) ratios), banks' assets or liabilities (limits on credit growth (CG), foreign currency credit growth (FC) and reserve requirements (RR)), policies that encourage counter-cyclical buffers (counter-cyclical capital (CTC), dynamic provisioning (DP) and profits distribution restrictions (PRD)) and a final group of miscellaneous policies (which have some overlap with the first three groups). They perform panel, GMM regressions relating these policies to changes in individual banks' assets. They find that policies aimed at borrowers are effective in (indirectly) reducing the build-up of banking system vulnerabilities. Measures aimed at banks' assets and liabilities are very effective, but counter-cyclical buffers as a group show less promise. The category "other" is also very effective. In upturns, all the measures except buffers reduce bank asset growth. Whereas borrower based measures are also relatively less effective, they do appear to limit "credit crunches" in contractionary periods. Between advanced countries and EMEs the main difference is the greater effectiveness of borrower based measures in advanced countries. A package of measures appears to work best in EMEs, perhaps as their financial systems are less liberalized. But no policy seems to be effective in counteracting a "credit crunch" in the downturn.

4.4 Modelling the impact of macroprudential policies

Our starting point is that many studies cited above have sought to cover global samples, but at a cost of having a rather limited set of control variables for macroprudential. We are focusing here on OECD countries, notably in Europe, and accordingly can use a better and more precise set of controls. Our chosen target variables, in line with much of the literature, are real house prices and real household sector credit. The macroprudential instrument datasets used are the first and second IMF dataset and summary measures derived from the BIS dataset as outlined in Section 4.3.2.

Typical estimates for determination of house prices are in error correction format. There is first a cointegrating levels equation which forms an inverted demand function for housing but also includes a supply effect such as the stock of housing which determines the long-run price of housing (Meen (2002), Barrell and Kirby (2004, 2011), Adams and Füss (2012), Igan and Loungini (2012), Muellbauer and Murphy (2008), Capozza et al. (2002)). This first stage equation constitutes the relationship that drives the long-run properties of the dependent variable and can be written as the following regression equation:

$$Y_t^c = X_t^c \beta^c + \varepsilon_t^c,$$

where Y is a $T \times 1$ vector containing the dependent variable in log levels, t denotes the time period, c is a country index, X is an $T \times N$ matrix of N regressors in log levels including a constant, β is an $N \times 1$ vector of coefficients and ε is the residual term.

This first stage equation is incorporated into an expanded equation that recognises that actual house prices deviate from their fundamental values in the short-run and typically includes a set of controls in first differences to allow for these dynamics. For the error correction equation to be meaningful there has to be a cointegrating relationship between the long-run variables (the first stage regression step) and the elements capturing the short-term dynamics must be stationary. This set up allows the examination of factors that drive house price dynamics. The second stage can be written as:

$$\Delta Y_t^c = \alpha^c + \lambda^c \left(Y_t^c - X_t^c \beta^c\right) + \Delta Z_t^c + \epsilon_t^c,$$

where α denotes a constant, Z is a set of regressors aimed at capturing short-term deviations of the dependent variable from the long-run relationship and ϵ is the error term. The two stages may be combined, as in our work shown below, in a single stage error correction estimation. A similar approach is adopted for credit.

Variables used are as follows: log real house prices (LRPH), log real personal disposable income (LRPDI), the real long rate (LRR), log real household liabilities (LRLIABS), log real gross financial wealth (LRGW), unemployment rate (U) and log real housing capital stock (LRKH). The Im-Pesaran-Shin panel unit root tests for the main variables (not illustrated) show most variables, being trended, are I(1) thus justifying an error correction model based approach to estimation. Changes in real house prices were regressed on contemporaneous changes in explanatory variables, and lagged dependent and explanatory variables (both in levels) as well. This error-correction specification is able to deal with non-stationarity in the data, and at the same time distinguishing short- and long-run influences, and differences between cycles. The significance of the coefficients for lagged non-stationary variables (in levels) and their magnitude reveal the long-term relationship among those variables.

Following the bulk of the literature, our panel modelling started from the panel error-correction approach of Davis et al. (2011), also employed in Armstrong and Davis (2014), with an extended house price equation including real house prices, real personal disposable income and the long term real interest rate (proxying the user cost) as well as the rate of unemployment, real gross financial wealth (as a portfolio balance effect), housing stock (lag only), household credit (lag only) and dummies for financial crises. We estimated corresponding equations for mortgage credit, viewing this as a further portfolio balance equation, albeit closely linked to housing.

We used data from 2000Q1-2015Q4 with quarterly observations for up to 18 advanced OECD countries from the NiGEM database, the short estimation period being necessitated by the short period covered by the macroprudential databases. The countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Austria, Portugal, Sweden, Spain, the UK and the US.

We undertake panel regression that treats all countries as equally important, while the country fixed effects take account of heterogeneity, and we impose cross section weights. In each case we eliminated insignificant variables. The initial estimates are tabulated in Table 4.7 below. To confirm the existence of the long-term relationship, we also implement the panel cointegration test proposed by Kao (1999) among those variables with significant lagged level terms in a simple levels equation (i.e. the first step of an Engle and Granger (1987) two-step estimation). As shown in the table, the test rejects comfortably the null of no cointegration for the panel regressions on real household credit growth, while it barely rejects the null at the 10 per cent significance threshold for real house price growth.

Table 4.7: Baseline equations (2000Q1-2015Q4)

Variable	Real house price growth (DLRPH)	Real household credit growth (DLRLIABS)
C	0.185*** (2.9)	0.373*** (6.0)
DLRPDI	0.129*** (4.8)	0.108*** (4.2)
DLRR	-0.0033** (2.4)	
DLRPH(-1)	0.397*** (14.6)	
DLRLIABS (-1)		0.097*** (3.4)
DLRLIABS (-2)	0.065*** (2.7)	
DLRLIABS (-3)	0.082*** (3.5)	
LRLIABS (-1)		-0.019*** (6.1)
LRPH(-1)	-0.0165*** (5.3)	0.025*** (6.1)
LRPDI(-1)	0.026*** (3.2)	
LRR(-1)	-0.0014*** (2.8)	
LKH(-1)	-0.035*** (4.8)	-0.021*** (3.5)
DU	-0.0039*** (3.5)	
U(-1)		-0.0014*** (6.8)
DLRGW	0.059*** (4.2)	0.087*** (6.6)
CRISES	-0.0029*** (2.7)	-0.0042*** (4.7)
R2	0.56	0.53
SE	0.015	0.012
OBS	1081	1081
KAO	-1.4* (0.08)	-4.3*** (0.0)
COUNTRIES	18	18

Note: Notes: lrph is the log real house price, lrr is the long term real rate, lrpdi is the log real personal disposable income, lrliabs is the log real household credit, lrgw is the log gross wealth, lkh is the log of the housing capital stock, u is the unemployment rate, and crises is a dummy for financial crisis taking a value of 1 when a financial crisis has occurred and 0 otherwise. Whenever a "d" appears in front of a variable it denotes the variable is in first differences. *** denotes that the coefficient is significant at the 1 per cent significance threshold, a ** denotes significance at the 5 per cent threshold and a * at the 1 per cent threshold. T-stats are reported in parenthesis below each estimated coefficient.

To address the weak cointegrating relationship in real house price growth we estimate country by country error correction equations in a seemingly unrelated regression (SUR) framework. For the sake of completeness we perform the same robustness check for real household credit growth. The results are reported and discussed in Section 4.5.

It can be seen in Table 4.7 that for house prices the dynamic specification includes real personal disposable income, real long rates, unemployment and real household wealth and also the lagged difference of credit. It also includes a lagged house price variable as an "accelerator". In the long run, the specification includes the levels of RPDI, long real rates and the housing capital stock, all with correct signs. As regards credit growth, the dynamic terms are real personal disposable income and real wealth while the long term effects arise from house prices, the stock of housing, and the level of unemployment. The crisis variable is significant for both house prices and credit. The Kao panel cointegration test is passed at the 99 per cent level for the credit equation but only 90 per cent level for the house price equation.

We tested the macroprudential variables in this framework one by one, (for variable definitions see Tables 4.4 and 4.5). We see in Table 4.8 that house prices are affected significantly by the summary variables MPI (which aggregates all macroprudential variables) and MPIB (aggregating macroprudential variables affecting the borrower), as well as LTV, DTI, TAX (taxes on financial intermediaries) and LTV_CAP (the subset of LTV measures used as a strict cap on new loans). Credit growth is affected by MPI, MPIF (aggregating macroprudential policies which are aimed at financial institutions assets or liabilities), DTI (with the wrong sign), TAX, and INTER (limits on interbank lending).

The summary BIS variable PRU (general prudential measures affecting housing) is significant for house prices over the period since 1990, as is MON (non interest monetary measures affecting housing) for credit over the same period.

For European countries there are similar albeit somewhat weaker results from this specification, see Table 4.9. LTV however is not effective in house prices (although LTV_CAP remains significant), while MON is not significant for lending.

We then went on to assess how results would differ using a more simple specification that is typical of the literature. So for example in Akinci and Olmstead-Rumsey (2015), effectiveness of policies in curbing bank credit and house prices is assessed using a dynamic panel data model where control variables besides a lagged dependent variable include real GDP growth, change in nominal monetary policy rates (R3M) and the VIX volatility measure based on US share prices. This specification has the advantage of enabling developing and emerging market countries that have relatively sparse macroeconomic data to be included in the regression. In contrast our extended specification could not readily cover a wider

Table 4.8: Results with the first IMF and BIS datasets using baseline equations

Variable	Real house price growth (DLRPH)	Real household credit growth (DLRLIABS)
MPI	-0.002** (2.4)	-0.0016** (2.3)
MPIB	-0.0023** (2.3)	0.0018 (1.5)
MPIF	-0.0013 (0.9)	-0.0031*** (3.8)
LTV	-0.0023* (1.7)	-0.0023 (1.3)
DTI	-0.004** (2.0)	0.0043* (1.8)
FC	0.007 (0.7)	-0.0036 (1.0)
TAX	-0.0039* (1.7)	-0.0074*** (4.7)
INTER	0.0006 (0.2)	-0.0045*** (2.7)
CONC	-0.004 (0.6)	0.0026 (0.6)
LTV_CAP	-0.0047** (2.4)	0.0024 (1.1)
MON	0.0015 (0.6)	0.0021 (0.9)
PRU	-0.00010 (0.3)	0.00067 (0.8)
MON (estimated from 1990)	0.0007 (0.4)	-0.0088*** (2.5)
PRU (estimated from 1990)	-0.0012* (1.7)	-0.00073 (0.9)

Notes: for variables definitions see tables 4 and 5. T-stats are reported in parenthesis below each estimated coefficient.

Note: for variables definitions see tables 4.4 and 4.5. T-stats are reported in parenthesis below each estimated coefficient.

Table 4.9: Results with the first IMF and BIS datasets using baseline equations (Europe only)

Variable	Real house price growth (DLRPH)	Real household credit growth (DLRLIABS)
MPI	-0.0025* (1.9)	-0.0028*** (3.6)
MPIB	-0.0052* (1.9)	-0.0016 (0.6)
MPIF	-0.0017 (1.1)	-0.0032*** (3.7)
LTV	-0.0016 (0.9)	-0.0057*** (2.8)
FC	0.0074 (0.8)	-0.0029 (0.9)
TAX	-0.0049** (2.0)	-0.0072*** (4.2)
INTER	0.00008 (0.1)	-0.0046*** (2.6)
LTV_CAP	-0.0074** (2.1)	-0.0026 (0.7)
MON	0.0012 (0.5)	0.0014 (0.6)
PRU	-0.0008 (0.8)	0.00064 (0.6)
MON (estimated from 1990)	0.0098** (2.2)	-0.00066 (1.4)
PRU (estimated from 1990)	-0.0019* (1.9)	0.00052 (0.5)

Notes: for variables definitions see tables 4 and 5. T-stats are reported in parenthesis below each estimated coefficient.

Note: for variables definitions see tables 4.4 and 4.5. T-stats are reported in parenthesis below each estimated coefficient.

range of countries. The simpler specification for the same 18 countries is depicted in Table 4.10 below. Note this is not a direct comparison with Akinci and Olmstead-Rumsey (2015) since we are using EGLS rather than GMM as in their work and also we are using different datasets of macroprudential variables. Rather, it is an exercise in assessing the impact of using a richer range of independent variables in tests of macroprudential policies in OECD countries.

From Table 4.11 it can be seen that with this specification a significant number of macroprudential tools are shown to be effective across these major OECD countries, including MPI and MPIB for house prices and credit growth, and MPIF for credit. Also, LTV, DTI, TAX and LTV_CAP are shown to be effective for both. FC (Limits on Foreign Currency Loans)

Table 4.10: Simpler specification typical in the literature (2000Q1-2015Q4)

Variable	Real house price growth (DLRPH)	Real household credit growth (DLRLIABS)
C	0.008*** (2.7)	0. 006** (2.1)
DLGDP(-1)	0.121*** (2.7)	0.108** (2.2)
DLGDP(-2)	0.045 (1.0)	0.139*** (2.9)
LVIX	-0.0024** (2.5)	-0.0005 (0.5)
DR3M (-1)	-0.0006 (0.6)	-0.0015 (1.5)
DEPENDENT (-1)	0.562*** (22.4)	0.392*** (14.6)
R2	0.454	0.353
SE	0.016	0.015
OBS	1145	1135
COUNTRIES	18	18

Notes: T-stats are reported in parenthesis below each estimated coefficient.

Note: T-stats are reported in parenthesis below each estimated coefficient.

and INTER (interbank lending limits) are effective for credit also. Of the BIS variables, PRU is shown to be effective for both also, as is MON if estimated back to 1990.

For the EU only there are similar positive results in most cases (Table 4.12), albeit not for MPI or MPIB in the case of house prices, MPIB and PRU for credit or for DTI in both cases.

We went on to test the second IMF database on the extended and simple model (Table 4.13). We find as above that there are more significant variables with the simple than the extended model. That said, there are significant results in the extended model for cumulated concentration rules for house prices and for cumulated general prudential controls, capital requirements and interbank exposure limits as well as general prudential limits, non-cumulated capital requirements and interbank exposure limits for credit. There are also significant variables with the wrong sign in the case of reserve requirements bearing on local currencies and LTV limits.[4]

For the simple model we find a great deal more significant variables for house prices such

[4]The difficulty in getting "right signs" for reserve requirements may link to their dual role as an instrument of monetary policy and of macroprudential policy. See for example Izquerido et al. (2013) on related issues in Latin America.

Table 4.11: Results using simpler specification

Variable	Real house price growth (DLRPH)	Real household credit growth (DLRLIABS)
MPI	-0.0019*** (2.9)	-0.0023*** (3.7)
MPIB	-0.002*** (2.9)	-0.002** (2.1)
MPIF	-0.0018 (1.5)	-0.0027*** (3.2)
LTV	-0.0049*** (4.2)	-0.0058*** (3.9)
DTI	-0.0037** (2.3)	-0.0037* (1.9)
FC	0.0022 (0.2)	-0.0063* (1.8)
TAX	-0.0042** (2.2)	-0.0048*** (3.2)
INTER	-0.0004 (0.2)	-0.0035** (2.0)
CONC	-0.0044 (0.7)	-0.0034 (0.7)
LTV_CAP	-0.0039*** (2.7)	-0.004** (2.2)
MON	0.0033 (1.4)	0.0035 (1.3)
PRU	-0.001* (1.9)_	-0.0018*** (2.6)
MON (estimated from 1990)	-0.0006** (2.1)	-0.0002 (0.7)
PRU (estimated from 1990)	-0.0006 (0.9)	-0.0009 (1.4)

Notes: for variables definitions see tables 4 and 5. T-stats are reported in parenthesis below each estimated coefficient.

Note: for variables definitions see tables 4.4 and 4.5. T-stats are reported in parenthesis below each estimated coefficient.

Table 4.12: Results using simpler specification (Europe only)

Variable	Real house price growth (DLRPH)	Real household credit growth (DLRLIABS)
MPI	-0.0017 (1.6)	-0.0027*** (3.4)
MPIB	-0.0032 (1.2)	-0.0047 (1.6)
MPIF	-0.0015 (1.2)	-0.0027*** (3.2)
LTV	-0.0053*** (3.1)	-0.0078*** (3.8)
DTI	-0.036 (0.5)	-0.008 (1.1)
FC	0.0026 (0.2)	-0.0063* (1.8)
TAX	-0.004** (2.0)	-0.0048*** (3.2)
INTER	-0.00027 (0.1)	-0.0036** (2.1)
LTV_CAP	-0.0046 (1.3)	-0.0066* (1.6)
MON	0.003 (1.3)	0.0032 (1.2)
PRU	-0.002* (1.8)	-0.0018 (1.4)
MON (from 1990)	-0.00035 (1.0)	0.00045 (1.2)
PRU (from 1990)	-0.0019 (2.0)	-0.0008 (0.7)

Notes: for variables definitions see tables 4 and 5. T-stats are reported in parenthesis below each estimated coefficient.

Note: for variables definitions see tables 4.4 and 4.5. T-stats are reported in parenthesis below each estimated coefficient.

Table 4.13: Results with second IMF database

Variables	Extended specification		Simpler specification	
	House prices	Real credit	House prices	Real credit
_SSCB_RES	0.0003 (0.1)	-0.0037 (0.8)	-0.0016 (0.3)	-0.0011 (0.2)
_SSCB_OTH	0.004 (0.2)	0.00167 (0.2)	0.0096 (0.5)	0.0062 (0.6)
_SSCB_CONS	0.0043 (0.2)	0.0016 (0.2)	0.0096 (0.5)	0.0062 (0.6)
_SSCB	0.0006 (0.1)	-0.0011 (0.4)	0.0024 (0.1)	0.0065 (0.2)
_RR_LOCAL	-0.001 (0.4)	0.0073*** (3.1)	-0.0029 (1.1)	0.0064** (2.4)
_PRUC2	-0.0006 (0.4)	-0.002* (1.7)	-0.0013 (1.0)	-0.0041*** (3.1)
_PRUC	-0.0006 (0.4)	-0.002* (1.7)	-0.0013 (1.0)	-0.0041*** (3.1)
_LTV_CAP	0.0039* (1.8)	0.0053** (2.4)	0.004* (1.8)	0.0045* (1.9)
_IBEX	-0.00028 (0.1)	-0.0075*** (3.1)	-0.0028 (0.6)	-0.0076*** (3.0)
_CONCRAT	-0.0047 (1.3)	0.0016 (0.4)	-0.026 (0.8)	-0.0042 (0.8)
_CAP_REQ	-0.0004 (0.3)	-0.008*** (4.2)	-0.0012 (0.6)	-0.0097*** (4.8)
_CUM_SSCB_RES	0.0009 (0.4)	0.0001 (0.1)	-0.0058*** (3.2)	-0.011*** (6.4)
_CUM_SSCB_OTH	-0.001 (0.2)	0.0024 (0.9)	0.0037 (0.8)	0.0068*** (2.6)
_CUM_SSCB_CONS	-0.001 (0.2)	0.0024 (0.9)	0.0037 (0.8)	0.0068*** (2.6)
_CUM_SSCB	0.0003 (0.2)	0.0005 (0.6)	-0.0025* (1.8)	-0.0025** (2.3)
_CUM_RR_LOCAL	0.0021 (1.3)	0.0048*** (3.7)	0.0048*** (3.6)	0.0076*** (5.5)
_CUM_PRUC2	-0.0007* (1.7)	-0.0013*** (3.5)	-0.001*** (3.4)	-0.0017*** (5.1)
_CUM_PRUC	-0.0007* (1.7)	-0.0013*** (3.5)	-0.001*** (3.4)	-0.0017*** (5.1)
_CUM_LTV_CAP	0.0011 (1.3)	0.0003 (0.3)	0.0049 (0.7)	0.00035 (0.4)
_CUM_IBEX	-0.0009 (0.7)	-0.0031*** (3.3)	-0.0025** (2.0)	-0.0011 (1.5)
_CUM_CONCRAT	-0.0019 ** (2.1)	-0.0045*** (3.4)	-0.0037*** (4.9)	-0.0072*** (5.4)
_CUM_CAP_REQ	-0.0015* (1.9)	-0.003*** (3.9)	-0.0014** (2.4)	-0.0042*** (6.4)

Notes: For variable definitions see table 6. T-stats are reported in parenthesis below each estimated coefficient.

Note: for variables definitions see tables 4.6. T-stats are reported in parenthesis below each estimated coefficient.

as cumulated interbank exposure limits, concentration limits, capital requirements, general prudential controls and real estate capital buffers as well as local reserve requirements with the wrong sign. For real credit, besides the above, we see an effect of real estate capital buffers as well as consumption and other buffers with the wrong sign.

Tables 4.14 and 4.15 provide a summary of results from the Section. As can be seen, the extended estimates (with a wider range of appropriate variables) show less favorable results for macroprudential policies than the simple estimates more typical of the literature. That said, it is clear that some policies are shown as more effective than others in the 18 countries we study over 2000-2013. These include, in particular, taxes on financial institutions (TAX) and strict loan-to-value ratio limits (LTV_CAP). Limits on foreign currency lending (FC), debt-to-income ratio limits (DTI), limits on interbank exposures (INTER) and concentration limits (CONC) are also shown to be effective in some estimates. We cannot exclude that the use of these policies being quite limited and also affected by the financial crisis, further significant effects could emerge in the future.

The second IMF database highlights cumulated concentration rules (CUM_CONCRAT), general prudential controls (CUM_PRUC and PRUC2), implementation of Basel capital requirements (CUM_CAP_REQ) and interbank exposure limits (CUM_IBEX), whereas local currency reserve requirements on deposits (CUM_RR_LOCAL) appear to be often counterproductive. Capital buffers themselves (SSCB and SSCB_RES) are also supported by these estimates to some extent.

Table 4.14: Summary table for macroprudential tools (first IMF and BIS databases)

Variable	Extended global PH	Extended global CR	Extended Europe PH	Extended Europe CR	Simple global PH	Simple global CR	Simple Europe PH	Simple Europe CR
MPI	-**	-**	-*	-***	-***	-***		-***
MPIB	-**		-*		-***	-**		
MPIF		-***		-***		-***		-***
LTV	-*			-***	-***	-***	-***	-***
DTI	-**	+*			-**	-*		
FC						-*		-*
TAX	-*	-***	-**	-***	-**	-***	-**	-***
INTER		-***				-**		-**
CONC								
LTV_CAP	-**		-**		-***	-**		-*
MON								
PRU					-*	-***	-*	
MON 90		-***	+**		-**			
PRU 90	-*		-*				-**	

Note: + denotes a positive relationship between the variables of interest, - denotes a negative relationship. Significance at the 1, 5 and 10 per cent thresholds are denoted by ***,** and * respectively.

Table 4.15: Summary table for macroprudential variables (second IMF database)

	Extended Global		Simple Global		Extended Europe		Simple Europe	
Variables	PH	CR	PH	CR	PH	CR	PH	CR
_RR_LOCAL		+***		+**		+***		+**
_RR_FOREIGN				-***				
_PRUC2		-*		-***	-*		-***	-***
_PRUC		-*			-*		-***	-***
_LTV_CAP	+*	+**	+*	+*		+*		
_IBEX		-***		-***		-**		-**
_CONCRAT								-*
_CAP_REQ		-***		-***		-***		-***
_CUM_SSCB_RES			-***	-***			-*	-***
_CUM_SSCB_OTH				+***				
_CUM_SSCB_CONS				+***				
_CUM_SSCB			-*	-**			-*	-***
_CUM_RR_LOCAL		+***	+***	+***		+***	+***	+***
_CUM_PRUC2	-*	-***	-***	-***	-*	-***	-***	-***
_CUM_PRUC	-*	-***	-***	-***	-*	-***	-***	-***
_CUM_LTV_CAP							+**	+***
_CUM_IBEX		-***	-**					
_CUM_CONCRAT	-**	-***	-***	-***	-***	-***	-***	-***
_CUM_CAP_REQ	-*	-***	-**	-***		-***	-***	-***

Notes: + denotes a positive relationship between the variables of interest, - denotes a negative relationship. Significance at the 1, 5 and 10 per cent thresholds are denoted by ***,** and * respectively.

4.5 SUR estimates

As shown in Table 4.7, the Kao panel cointegration test of the long-run components of the regression specification (the variables in levels) delivers a strong rejection of the null of no cointegration for real household credit growth and a weak rejection for real house prices. To address the concern that the long- run components fail to cointegrate we adopt a different strategy and estimate the long-run components on a country by country case rather than in a panel framework, thus allowing the coefficients of the long-run regressions to be different across countries.

Once the long-run relationships have been estimated we take the residuals and combine them with other short-term dynamics to produce a set of country by country regressions in error correction form using a seemingly unrelated regression (SUR) estimation procedure. Although the coefficients that result from the SUR estimates do not benefit from the panel dimension of the data, the variance-covariance of the estimates still make use of the panel dimension by allowing the possibility that the error terms of the different countries are correlated.

The main advantage of this approach is that it tackles the concern of lack of cointegration of the long-run components of the error correction equations. The drawback is a loss of data. Our macroprudential dataset is composed of dummy variables and some of the countries in our sample have variables that take the same value for the whole sample. While this variable can be included within the context of a panel regression, it can no longer be used in a SUR procedure as it would produce a singular regressor matrix.

Tables 4.16 and 4.17 report the specification of the first stage equations that we run for real house prices and real credit growth, respectively, and whether the resulting residuals are stationary or not. In all instances the equations represent an inverted demand function that includes a supply side effect. We have tried to use the same variables for all countries although it has not always been possible. As it can be seen, in all instances we obtain that the resulting residuals reject the null hypothesis of non-stationarity according to the augmented Dickey-Fuller test.

To account for possible short term deviations from the long-run relation we take an augmented equation that regresses real house price growth onto the residuals from the long-run relationship and a set of control variables in first differences. Results are presented in Table 4.18 for house price growth and Table 4.19 for real household credit growth. We estimate the system with a SUR procedure. The set of controls that we include in each regression is consistent with the control variables included in the panel regressions of Section 4.4. For some countries, such as for instance Belgium in the house price growth regressions, we have excluded some of the regressors as they turned out to be highly insignificant and reduced the adjusted R^2 statistic for that country. In addition, in some instances, such as Norway, we lacked data for some of the regressors.

From Table 4.18 we can see that the coefficients in front of the error correction term (the long-run relationship) are negative and significant in most instances, as expected. If there are deviations from the long-run relationship this term ensures that the dependent variable returns gradually to the long-run condition. We also obtain that house price growth depends positively on real income growth and, in most instances, negatively in the long term real

Table 4.16: Log real house price, first stage: specification and test for stationarity

Countries	Controls	Sample period	Stationary residuals?
Australia	Log real personal disposable income, long term interest rate and log housing investment	1986 onwards	***
Belgium	Log real personal disposable income, long term interest rate and log housing investment	1991 onwards	**
Canada	Log real personal disposable income, long term interest rate and log housing stock	1970 onwards	***
Denmark	Log real personal disposable income, long term interest rate and log housing investment	1991 onwards	**
Finland	Log real personal disposable income, long term interest rate and log housing investment	1993 onwards	**
France	Log real consumer wage, long term interest rate and log housing investment	1971 onwards	*
Germany	Log real personal disposable income and log housing stock	1985 - 2008	***
Greece	Log real personal disposable income, long term interest rate and log housing investment	2006 onwards	***
Ireland	Log real personal disposable income, long term interest rate and log housing investment	1982 onwards	*
Italy	Log real consumer wage, long term interest rate and log housing investment	1986 onwards	***
Japan	Log real personal disposable income, long term interest rate and log housing investment	1966 onwards	*
Netherlands	Log real personal disposable income, long term interest rate and log housing investment	1986 onwards	**
Norway	Log real personal disposable income, long term interest rate and log housing stock	2010 onwards	*
Austria	Log real personal disposable income, long term interest rate, log housing investment and crises	1971 onwards	**
Portugal	Log real consumer wage, long term interest rate and log housing stock	2005 onwards	***
Sweden	Log real personal disposable income, long term interest rate and log housing investment	1970 onwards	***
Spain	Log real personal disposable income, long term interest rate and log housing investment	1980 onwards	**
UK	Log real consumer wage, long term interest rate and log housing investment	1993 onwards	***
US	Log real consumer wage, log housing investment and crises	1985 onwards	***

Notes: we have used the Augmented Dickey-Fuller test to test for stationary residuals. A *** means that the null hypothesis of non-stationarity is rejected at the 1 per cent significance level, a ** means the null is rejected at the 5 per cent level and a * at the 10 per cent level. A blank means that we cannot reject the null.

Table 4.17: Log real household credit , first stage: specification and test for stationarity

Countries	Controls	Sample period	Stationary residuals?
Australia	log real house price, log housing stock, unemployment and log real disposable income	1990 onwards	**
Belgium	log real house price, log housing stock, unemployment and log real disposable income	1980-2005	**
Canada	log real house price, log housing stock, unemployment and log real disposable income	1990-2008	**
Denmark	log real house price, log housing stock and log real disposable income	1996-2004	***
Finland	log real house price, log housing stock, unemployment and log real disposable income	2000 onwards	**
France	log real house price, log housing stock, unemployment and log real disposable income	1970 onwards	***
Germany	log real house price, log housing stock, unemployment and log real disposable income	2000 onwards	***
Greece	log real house price, log housing stock, unemployment and log real disposable income	2000 onwards	**
Ireland	log real house price, log housing stock, unemployment and log real disposable income	1970-2013	**
Italy	log real house price, log housing stock, unemployment and log real consumer wage	2000 onwards	***
Japan	log real house price, log housing stock, unemployment and log real disposable income	1980 onwards	**
Netherlands	log real house price, log housing stock, unemployment and log real disposable income	1970 onwards	***
Norway	log real house price, log housing stock and log real disposable income	2010 onwards	***
Austria	log real house price, log housing stock, unemployment and log real disposable income	1970 onwards	**
Portugal	log real house price, log housing stock and log real disposable income	1995 onwards	***
Sweden	log real house price, log housing stock, unemployment and log real disposable income	1975 onwards	**
Spain	log real house price, log housing stock, unemployment and log real disposable income	1971 onwards	**
UK	log real house price, log housing stock, unemployment and log real disposable income	2010 onwards	**
US	log real house price, log housing stock, unemployment and log real disposable income	2000 onwards	**

Notes: we have used the Augmented Dickey-Fuller test to test for stationary residuals. A *** means that the null hypothesis of non-stationarity is rejected at the 1 per cent significance level, a ** means the null is rejected at the 5 per cent level and a * at the 10 interest rate.

From Table 4.19 we obtain again that the coefficient for the long-run relationship is negative for most countries and for those for which is not, is not statistically different than zero. Just as with house price inflation we also obtain that credit growth is positively related with income growth and negatively related with the long term real interest rate, although in several cases the latter control does not appear to be statistically different than zero.

The set of regressions presented in Tables 4.18 and 4.19 constitute our baseline specifications upon which we add, one at a time, each of the macroprudential variables from the first IMF and BIS datasets. Given the short time span covered by the datasets, 2000Q1-2013Q4, it is often the case that some of the country macroprudential variables do not display any variation during the whole sample period. In Section 4.4 this was not a problem given the panel framework but in the SUR procedure this gives rise to singular matrices. In such instances we have excluded in each set of regressions all countries for which the macroprudential variable was constant. In addition, we omit the results of the regressions for which the coefficient on the macroprudential variable is not significantly different from zero for all the countries in the sample. Tables 4.20 and 4.21 report the estimates of the effects of each macroprudential variable on real house price growth and household credit growth, respectively.

In both Tables 4.20 and 4.21 we observe that whenever the coefficient is statistically different from zero, the effect goes, in most instances, in the expected direction: macroprudential variables reduce house price and credit growth. However, a large number of estimates are not statistically different from zero; a phenomenon that may be product of the binary nature of the underlying data.

Table 4.18: Real house price growth, second stage: baseline equation

	Australia	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy
Constant	-0.001	0.009 ***	-0.002	0	0.004 *	0.003 **	-0.004 ***	-0.01	0.002	-0.001
	-0.003	-0.002	-0.001	-0.002	-0.002	-0.001	-0.001	-0.011	-0.002	-0.002
Long run	-0.081 ***	-0.023	-0.05 ***	-0.029	-0.241 ***	-0.03 ***	-0.246 ***	-0.092	-0.046 **	-0.077 ***
	-0.03	-0.02	-0.014	-0.027	-0.047	-0.008	-0.072	-0.172	-0.023	-0.022
dlrph(-1)	0.573 ***	-0.062	0.649 ***	0.521 ***	0.398 ***	0.53 ***	-0.136	0.022	0.288 ***	0.569 ***
	-0.079	-0.094	-0.054	-0.067	-0.081	-0.056	-0.098	-0.186	-0.076	-0.063
dlrr(-1)	-0.006 *	-0.003	-0.002	-0.006 *	0.003	-0.001	0.001	0.006	-0.006 **	0.002
	-0.003	-0.004	-0.001	-0.004	-0.004	-0.002	-0.003	-0.009	-0.003	-0.002
dlrpdi±	0.039	0.246 *	0.228 ***	0.155 **	0.189 **	0.087	0.292 ***	0.271 ***	0.114	0.379 ***
	-0.089	-0.133	-0.053	-0.064	-0.092	-0.095	-0.099	-0.097	-0.075	-0.107
drliabs(-1)	0.175		-0.164 ***	0.003	-0.129	0.01	0.069	0.078	0.161 ***	0.154 **
	-0.107		-0.025	-0.059	-0.095	-0.04	-0.102	-0.233	-0.059	-0.067
dlrgw	-0.008	-0.061	0.4 ***	0.254 ***	0.138 **	0	-0.039	-0.036	0.084	0.081 *
	-0.059	-0.059	-0.126	-0.047	-0.053	-0.03	-0.049	-0.029	-0.066	-0.042
Du	-0.004		-0.008 ***	-0.004	-0.003	-0.009 ***	0.001	-0.019 ***	-0.012 ***	0.002
	-0.006		-0.002	-0.005	-0.005	-0.003	-0.004	-0.006	-0.004	-0.004
Crisq	-0.003	-0.009 **	-0.012 ***	-0.006	0.01	-0.001	0.004	0.006	-0.019 ***	-0.002
	-0.005	-0.003	-0.003	-0.004	-0.008	-0.003	-0.007	-0.011	-0.005	-0.002
Adj. R2	0.31	0.01	0.69	0.7	0.38	0.46	0.11	0.39	0.57	0.59
D-W	1.96	1.86	1.97	1.96	2.12	2.08	1.94	2.43	2.2	2.01

Notes: Numbers in parenthesis are standard deviations. Long run are the residuals estimated from the first stage, dlrph is the change in log real house prices, dlrr is the change in the long term real rate, dlrpdi is the change in log real personal disposable income, dlrliabs is the change in log real household credit, dlrgw is the change in gross wealth, du is the change in unemployment rate and crisq is a crisis dummie. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold. Adj. R2 denotes the adjusted R-squared statistic and D-W denotes the Durbin-Watson test for serial correlation of the residuals. ±: for some countries we use dlrcwage instead, as specified in Table 4.16.

Continuation

	Japan	Netherlands	Norway	Austria	Portugal	Sweden	Spain	UK	US
Constant	-0.002 **	0.004 ***	0.004	0.005 **	-0.006 **	0.001	0.004	0.002	0.003 **
	-0.001	-0.002	-0.006	-0.002	-0.003	-0.002	-0.002	-0.002	-0.001
Long run	-0.01 **	-0.043 **	-0.377 **	-0.018	-0.633 ***	-0.034 **	-0.038 ***	-0.173 ***	-0.061 ***
	-0.005	-0.019	-0.187	-0.022	-0.138	-0.015	-0.013	-0.034	-0.018
dlrph(-1)	0.782 ***	0.356 ***	0.656 ***	0.003	0.317 **	0.402 ***	0.606 ***	0.233 **	0.354 ***
	-0.04	-0.104	-0.221	-0.066	-0.146	-0.065	-0.06	-0.091	-0.082
dlrr(-1)	-0.003 **	-0.004	-0.006	0.002	-0.004	-0.006 **	0.003	0.004	-0.003
	-0.001	-0.004	-0.018	-0.005	-0.006	-0.003	-0.002	-0.005	-0.002
dlrpdi±	0.201 ***	0.296 ***	0.807 ***	0.956 ***	0.008	0.428 ***	0.126 ***	0.396 ***	0.186 *
	-0.05	-0.073	-0.255	-0.102	-0.196	-0.076	-0.048	-0.13	-0.101
drliabs(-1)	-0.055 ***	-0.018	-0.663 **	-0.032	0.09	-0.042	-0.015	0.275 *	0.113
	-0.02	-0.101	-0.294	-0.106	-0.1	-0.057	-0.084	-0.152	-0.074
dlrgw	0.14 ***	0.013		-0.013	0.137	0.129 ***	0.081 **	0.11 *	-0.015
	-0.022	-0.01		-0.086	-0.262	-0.032	-0.033	-0.064	-0.03
du	0.004	-0.017 ***		-0.029 ***	0.002	-0.008 *	0	-0.022 ***	0.002
	-0.004	-0.006		-0.009	-0.004	-0.005	-0.003	-0.008	-0.003
crisq	-0.001	-0.006		0	0.005	-0.006	-0.009 **	-0.002	-0.011 ***
	-0.001	-0.004		-0.006	-0.004	-0.004	-0.004	-0.004	-0.002
Adj. R2	0.79	0.43	0.36	0.37	0.52	0.54	0.61	0.56	0.56
D-W	2.27	1.93	1.92	1.9	2.28	2.11	2.05	1.92	1.83

Notes: Numbers in parenthesis are standard deviations. Long run are the residuals estimated from the first stage, dlrph is the change in log real house prices, dlrr is the change in the long term real rate, dlrpdi is the change in log real personal disposable income, dlrliabs is the change in log real household credit, dlrgw is the change in gross wealth, du is the change in unemployment rate and crisq is a crisis dummie. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold. Adj. R2 denotes the adjusted R-squared statistic and D-W denotes the Durbin-Watson test for serial correlation of the residuals. ±: for some countries we use dlrcwage instead, as specified in Table 4.16.

Table 4.19: Real household credit growth, second stage: baseline equation

	Australia	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy
Constant	0.012 ***	0.005 ***	0.003	0.011 ***	0.005 **	0.009 ***	-0.001 **	0.041 ***	-0.003	-0.007 **
	-0.002	-0.002	-0.002	-0.004	-0.002	-0.002	-0.001	-0.007	-0.004	-0.003
Long run	-0.101 ***	-0.156 *	-0.256 ***	-0.4 **	-0.028	-0.024	-0.209 ***	0.045	-0.323 **	-1.08 ***
	-0.038	-0.09	-0.073	-0.204	-0.035	-0.021	-0.065	-0.078	-0.15	-0.221
dlrliabs (-1)	0.223 ***	-0.284 ***	0.302 ***	-0.111	0.513 ***	-0.004	0.368 ***	-0.072	0.791 ***	-0.073
	-0.085	-0.096	-0.089	-0.16	-0.086	-0.003	-0.11	-0.139	-0.108	-0.12
dlrr(-1)	0.002	-0.007 *	-0.004 *	0.005	0	0.208	0.002	-0.01	-0.002	-0.016 **
	-0.002	-0.004	-0.002	-0.008	-0.005	-0.193	-0.003	-0.006	-0.005	-0.008
dlrpdi±	0.018	0.368 **	0.124 *	0.365 **	0.287 ***	0.049	0.034	0.33 ***	0.217 ***	0.391 ***
	-0.065	-0.151	-0.07	-0.157	-0.098	-0.053	-0.072	-0.107	-0.056	-0.141
dlrgw	0.136 ***	0.071 *	0.508 ***	0.32 ***	0.091 **	-0.004	-0.02	-0.043	0.274 ***	0.007
	-0.042	-0.037	-0.159	-0.099	-0.044	-0.005	-0.049	-0.027	-0.093	-0.071
Crisq	-0.007 *	-0.421	11.272 ***	1.763	21.76	0.009	-0.001	-0.027 ***	0.001	0.009 **
	-0.004	-1	-5.11	-1.187	-23.178	-0.002	-0.001	-0.009	-0.005	-0.003
Adj. R2	0.18	0.21	0.22	0.36	0.34	0	0.07	0.5	0.75	0.49
D-W	2.06	1.8	1.78	1.86	2.21	2.04	2.06	1.87	1.71	1.47

Notes: Numbers in parenthesis are standard deviations. Long run are the residuals estimated from the first stage, dlrliabs is the change in log real household credit, dlrr is the change in the long term real rate, dlrpdi is the change in log real personal disposable income, dlrgw is the change in gross wealth and crisq is a crisis dummie. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold. Adj. R2 denotes the adjusted R-squared statistic and D-W denotes the Durbin-Watson test for serial correlation of the residuals. ±: for some countries we use dlrcwage instead, as specified in Table 4.17.

Continuation

	Japan	Netherlands	Norway	Austria	Portugal	Sweden	Spain	UK	US
Constant	0.017 ***	0.007 ***	0.009 ***	0.003 ***	0.001	0.005 ***	0.007 ***	0	0.004 **
	-0.002	-0.002	-0.003	-0.001	-0.002	-0.002	-0.002	-0.001	-0.001
Long run	-0.209 ***	-0.021	-0.892 ***	-0.035	-0.015	-0.073 ***	-0.034 *	0.165	-0.092 *
	-0.058	-0.018	-0.189	-0.023	-0.024	-0.025	-0.018	-0.16	-0.048
dlrliabs (-1)	0.11	0.034	0.084	-0.055	0.643 ***	-0.027	0.224 ***	-0.007	0.627 ***
	-0.078	-0.065	-0.128	-0.052	-0.061	-0.059	-0.069	-0.121	-0.075
dlrr(-1)	0	-0.006 **	0.005	0.004	0.004	-0.002	0	0.013	0.001
	-0.003	-0.003	-0.01	-0.003	-0.003	-0.003	-0.002	-0.009	-0.003
dlrpdi±	0.202 **	0.48 ***	0.514 ***	0.605 ***	0.46 ***	0.364 ***	0.055	0.121 *	0.01
	-0.09	-0.059	-0.127	-0.054	-0.131	-0.088	-0.044	-0.069	-0.085
dlrgw	0.058	-0.006		0.125 ***	0.462 ***	0.261 ***	0.132 ***	0.244 ***	0.046
	-0.05	-0.011		-0.045	-0.129	-0.037	-0.029	-0.04	-0.032
Crisq	-0.017 ***	0.005		0.002	-0.005 *	-0.005	-0.007 **	-0.012 ***	-0.005 **
	-0.003	-0.005		-0.003	-0.003	-0.004	-0.003	-0.003	-0.002
Adj. R2	0.34	0.25	0.56	0.49	0.84	0.32	0.3	0.7	0.62
D-W	2.06	1.62	1.55	2.13	1.78	1.86	2.01	1.76	2.31

Notes: Numbers in parenthesis are standard deviations. Long run are the residuals estimated from the first stage, dlrliabs is the change in log real household credit, dlrr is the change in the long term real rate, dlrpdi is the change in log real personal disposable income, dlrgw is the change in gross wealth and crisq is a crisis dummie. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold. Adj. R2 denotes the adjusted R-squared statistic and D-W denotes the Durbin-Watson test for serial correlation of the residuals. ±: for some countries we use dlrcwage instead, as specified in Table 4.17.

Table 4.20: Real house price growth: impact of macroprudential variables

	Australia	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy
MPI			-0.0026 *		-0.0101	0.0008				
			-0.0014		-0.007	-0.0036				
MPIB			-0.0026 *							
			-0.0013							
MPIF					-0.0099	0.0002				
					-0.0071	-0.0036				
LTV			-0.0054 **		-0.0019					-0.0023
			-0.0027		-0.0047					-0.0025
TAX					-0.0089	0.0001				
					-0.0072	-0.0036				
LTV_CAP			-0.0052 *							
			-0.0027							
MON		-0.0014	0.0002		0.0013	-0.0017	0.0003	0.0324 **	-0.0013	0
		-0.0024	-0.0005		-0.0039	-0.0013	-0.0006	-0.016	-0.001	-0.0004
PRU	0.0034		0.0011	0.0015		-0.0007			0.0025	-0.0002
	-0.0022		-0.0007	-0.005		-0.0039			-0.0032	-0.0044

Notes: For variable definitions see Table 4 and Table 5. Numbers in parenthesis are standard deviations. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold.

Continuation

	Japan	Netherlands	Norway	Austria	Portugal	Sweden	Spain	US
MPI		-0.0054 **	-0.0155 ***	0.007	-0.0026	-0.0097 *		0.0083
		-0.0027	-0.0044	-0.0048	-0.0027	-0.0058		-0.0056
MPIB		-0.0043				-0.0101		
		-0.0038				-0.0061		
MPIF		-0.0189 ***	-0.0156 ***	0.008 *	-0.0028			0.0073
		-0.0067	-0.0044	-0.0049	-0.0027			-0.0056
LTV		-0.0092				-0.0084		
		-0.0077				-0.006		
TAX		-0.0181 ***		0.0139	-0.001			
		-0.0067		-0.01	-0.0042			
LTV_CAP		-0.0086				-0.0101		
		-0.0077				-0.0061		
MON	-0.0014	-0.0004		-0.0011	-0.0069		-0.002	0.0005
	-0.0012	-0.0033		-0.0047	-0.0072		-0.0035	-0.0022
PRU		-0.0048 **	-0.0116			0.0037 *	0.0046	
		-0.002	-0.021			-0.0022	-0.0037	

Notes: For variable definitions see Table 4 and Table 5. Numbers in parenthesis are standard deviations. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold.

Table 4.21: Real household credit growth: impact of macroprudential variables

	Australia	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy
MPI			0.0022		-0.0125 **	-0.0141 **	0.0005			
			-0.0014		-0.0048	-0.0059	-0.0006			
MPIB										
MPIF					-0.0122 **	-0.0138 **	0.0006			
					-0.0049	-0.006	-0.0006			
LTV										
TAX					-0.0135 ***	-0.0148 **	0.0004			
					-0.0052	-0.0065	-0.0014			
LTV_CAP										
MON		0.0021	-0.0016 ***		0.0067	-0.0028	-0.0019	0.0124	0	0.0139 ***
		-0.0043	-0.0006		-0.0072	-0.0019	-0.0034	-0.0146	-0.007	-0.0046
PRU	-0.007 **		0.0019	-0.0189		-0.0053		0.0073	0.0015	
	-0.0014		-0.0054	-0.0136		-0.0046		-0.015	-0.026	

Notes: For variable definitions see Table 4 and Table 5. Numbers in parenthesis are standard deviations. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold.

Continuation

	Japan	Netherlands	Norway	Austria	Portugal	Sweden	Spain	US
MPI		-0.0049	-0.0043 *	-0.0031 *	-0.0056 **	-0.0031		-0.005
		-0.0032	-0.0021	-0.0016	-0.0027	-0.0043		-0.0043
MPIB		-0.0026				-0.0047		
		-0.0058				-0.0045		
MPIF		-0.0096 *	-0.0044 **	-0.0031 *	-0.0053 *			-0.006
		-0.0057	-0.0021	-0.0016	-0.0028			-0.0043
LTV		-0.0051				-0.0047		
		-0.0115				-0.0045		
TAX		-0.0088		-0.0077 **				
		-0.0063		-0.0033				
LTV_CAP		-0.0034				-0.0045		
		-0.0115				-0.0045		
MON	0.0007	0.0041		-0.0014	0.0066 **		-0.0145 ***	
	-0.0031	-0.0028		-0.002	-0.0032		-0.0032	
PRU		-0.005 **	-0.017 ***		-0.006 **	0.0099 ***	0.0066 **	
		-0.0022	-0.0055		-0.0031	-0.0033	-0.003	

Notes: For variable definitions see Table 4 and Table 5. Numbers in parenthesis are standard deviations. *** denotes that the coefficient is significant at the 1 per cent significance threshold a ** denotes significance at the 5 per cent threshold and a * denotes significance at the 10 per cent threshold.

4.6 Conclusions

Macroprudential policy is focused on the financial system as a whole, with a view to limiting macroeconomic costs from financial distress (Crockett (2000)), with risk taken as endogenous to the behaviour of the financial system. However, "analysis is still needed about the appropriate macroprudential tools, their transmission mechanism and their effect" (Galati and Moessner (2014)). Theoretical models are in their infancy and empirical evidence on the effects of macroprudential tools is still scarce. Nor has a primary instrument for macroprudential policy emerged.

Accordingly, in this paper we have provided an overview of the state of the art in macroprudential tools, transmission and modelling before undertaking some testing of tools on a dataset of up to 19 OECD countries during 2000-2014, using available global databases (from the IMF and the BIS). We contend that extant empirical evidence is often unsatisfactory in the sense of omitting important control variables (for understandable reasons since these variables are simply unavailable for all but the most advanced countries), leading to excessively favourable results for the impact of macroprudential policies in OECD countries, and show the impact of this in terms of different specifications.

Nevertheless, overall, it is clear that some policies are shown as more effective than others in the up to 19 countries we study over 2000-2014. These include, in particular, taxes on financial institutions, general capital requirements and strict loan-to-value ratio limits. Limits on foreign currency lending, debt-to- income ratio limits, limits on interbank exposures and concentration limits are also shown to be effective in some estimates.

We contend that the way forward for reduced form modelling is a more sophisticated form of the baseline equations such as we include here. There could also be an assessment of the impact of macroprudential tools on a wider range of variables than credit and house prices. These could include for example spreads on loans. However, a potential issue is that the impact of macroprudential policies on the cost of lending is ambiguous, at least for some policies, since they may on the one hand raise bank costs, tending to widen the spread, but also reduce bank risk, tending to narrow it.

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