The London School of Economics and Political Science

Harbingers of Modernity: Monetary Injections and European Economic Growth, 1492-1790

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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 60,938 words.

Abstract

In this dissertation I assess some of the effects for the early modern European economy which resulted from the large-scale discovery and exploitation of precious metals in the New World. I argue that the monetary injections which were a direct result of the increased precious metals availability were an important cause of stimulus for several early modern European economies. The thesis mainly consists of three papers.

In the first paper I argue variation in production of precious metals in America can be helpful to identifying the causal effects of money in a macroeconomic setting. Using a panel of six European countries for the period 1531-1790, I find strong reduced-form evidence in favor of non-neutrality of money for changes in real economic activity. The magnitudes are substantial and persist for a long time: an exogenous 10% increase in production of precious metals in America leads to a hump-shaped positive response of real GDP, peaking at an average increase of 1.3% four years later. The evidence suggests this is because prices responded to monetary injections only with considerable lags.

The following two chapters are focused on different aspects of the measurement and analysis of the causal effects of the monetary injections for the English economy. In the second paper, I put forward new data on annual coin supply for England over the long run. This is offered not only as a data construction exercise within the specific context of England, but also as a methodological contribution which in principle can be reproduced for some other countries.

Finally, in the third paper, I present a historical discussion of the long-term effects of the early modern monetary injections in the context of the English economy. I show the increased availability of precious metals led to liquidity injections which matter for our understanding of the English industrious, industrial, and financial revolutions during early modern period.

Acknowledgements

I am grateful to more people than I can individually acknowledge here without writing a whole paper on the matter, which would further risk obscuring those I am most grateful to. In the front page of each chapter I provide additional thanks, always limited to an academic nature and depending on the topic in question. Here my acknowledgements are also often of a broader type. Of course, the usual disclaimer applies: all errors are my own.

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Monetary phenomena are like a seismograph that not only registers earth tremors, but sometimes brings them about

Marc Bloch (1933)[1]

[1] "[L]es phénomènes monétaires sont ... quelque chose comme un sismographe qui, non content de signaler les tremblements de terre, parfois les provoquerai" ; Bloch, M. (1933). Le problème de l'or au moyen age. *Annales d'Histore Économique et Sociale 5*

Chapter 1. Introduction

My dissertation mainly consists of three essays which consider some of the consequences for the European economy that resulted from the discovery and subsequent exploitation of large amounts of precious metals in America during the early modern period. It is intended both as a contribution to macroeconomics and to economic history. I argue that the injections of money resulting from the higher availability of precious metals were an important cause of stimulus for the early modern European economies, particularly those of Northwestern Europe.

In this introduction (chapter 1), I summarize the contribution of each chapter, emphasizing how they all come together. I also make reference to other on-going papers which I have that would have naturally been part of this thesis (some in co-authorship), but which I was forced to leave out due to time constraints. Chapter 2 is a literature review, where I provide some historiographical context and I discuss how my thesis relates to, and differs from, earlier ideas from both macroeconomics and economic history. I discuss in detail how my ideas relate to earlier attempts to relate the early modern monetary injections to the evolution of the early modern European economy. Chapters 3 to 5 correspond to the main papers in this thesis. Finally, chapter 6 concludes, pointing out which questions were left open and setting out such a research agenda for the future.

Because the papers in the thesis are technical in nature and aimed at an audience of economic historians and economists, it was not possible to include a non-technical summary or an extended historiographical discussion within each paper. In this introduction as well as the next chapter I do this to some extent, in particular focusing on the broad intellectual debate which frames my research as viewed from a historiographical perspective. Unfortunately, it is not always possible to completely avoid technical language.

1. Thesis chapters

While macroeconomists and monetary economists have for long been interested in the causal effects of variation in the quantity of money in macroeconomic variables such as income, prices, interest rates and unemployment, they are faced with the considerable identification difficulty presented by the fact that money is endogenous: the monetary authority responds to the

state of the economy. This implies that simple regressions of money such variables are not very informative as far as causality is concerned. Yet it is the existence of a causal effect under different conditions that is important to estimate for policy purposes.

In chapter 3, "*The Existence and Persistence of Liquidity Effects: Evidence from a Large-Scale Historical Natural Experiment*", I use discoveries of precious metals in America as a source of exogenous variation for Europe's money supply. I take advantage of a new panel of six European countries for the period 1531-1790, which I build relying on the work of economic historians over the last 10 years. This is the longest macro dataset ever constructed. I am able to identify econometrically the reduced form effects of money on a series of macroeconomic variables of interest, in particular, output and prices (unfortunately, the equivalent data on interest rates is unavailable). I find strong evidence in favor of non-neutrality of money for changes in real economic activity. The magnitudes are substantial and persist for a long time: an exogenous 100% increase in production of precious metals in America leads to a hump-shaped positive response of real GDP, peaking at an average increase of 13% four years later. The evidence suggests this is because prices responded to monetary injections only with considerable lags. Several exogeneity tests – notably using weather shocks as a source of exogenous variation for the state of the European economy – provide credibility to the experiment, and other robustness checks also confirm the results.

The following chapters are focused on different aspects of the measurement and analysis of the causal effects of monetary injections for the English early modern economy. In chapter 4, *Reconstruction of annual coin supply over the long run: the case of England, 1279-1790*, I put forward new data on coin supply for England over the long run. I use this dataset in the following chapter, and in some of my related work which is not part of the thesis. This chapter is offered not only as a data construction exercise within the specific context of England, but also as a methodological contribution which in principle can be reproduced for other countries as well.

While chapter 3 focuses on the "short-term" effects of money, using the data from chapter 4 I am able to turn to long-term effects in chapter 5: "*Money and modernization: liquidity, specialization, and structural change in early modern England*". These are harder to identify using statistical methods than the short-term effects, which by their nature are easier to test for. Consequently this chapter is more narrative, historical, and perhaps more speculative. I argue that the discovery and exploitation of rich mines of precious metals in America allowed for a

substantial increase of the monetization and liquidity levels of the English economy, decreasing transaction costs, increasing market "thickness" and changing the relative incentive for participating in the market. Hence the additional liquidity available led to increased levels of specialization, market participation, and structural change. While a large literature has considered the negative impact of precious metals imports for Spain (Hamilton 1934, Forsyth and Nicholas 1983, Drelichman 2005a, 2005b), my argument here is that, whether that was the case or not, the monetary injection which was transmitted to Northwestern Europe had beneficial effects there.

By making trade with Asia possible – more on this in the next section – the silver also let new and desirable goods enter Europe, and these goods further encouraged market participation at both the intensive and extensive levels. Finally, the increased monetization and market participation made it easier for governments to collect taxes and by consequence provide for public goods, helping build up fiscal capacity. The structural change and market participation which ensued helped pave the way to modernization, hence transforming a level effect on a growth effect. The conclusion is that we need to pay closer attention to monetary developments and the avoidance of deflationary forces as critical precondition for the emergence of modern economic growth. It is important to emphasize, however, that my hypothesis concerns necessary, rather than sufficient, conditions for growth. Certainly, the monetary injections interacted with specific characteristics to the English economy at that time.

2. My other related work

I now briefly discuss my other ongoing work which is part of this research program umbrella but unfortunately has not entered this thesis due to time constraints. Nonetheless, much of this work is now at an advanced state, and it is possible for me to not only summarize it but also explain how it integrates with the work in this PhD dissertation. There are three papers which I will mention, two of which written in co-authorship.

American precious metals, in particular silver, mattered for Europe not only because of the direct effects they had there but also because they made trade with Asia possible. Taste for variety is an important feature of preferences, and over the early modern period imports of products from Asia mattered a great deal for Europe, encouraging both market participation

and industrial development. In *"Spending a Windfall: American Precious Metals and Euro-Asian Trade 1492-1815"* (Palma and Silva 2015), we use a combination of empirical evidence and structural modeling in a contribution towards understanding the role of American precious metals in stimulating Euro-Asian trade during the early modern era. We estimate the size of injections to Europe's stock of precious metals, and use this information in a dynamic general equilibrium model with iceberg-type transportation costs and endogenous money demand to reproduce observed history as well as calculate a no-shock counterfactual. Our conclusion is that the discovery of a windfall of American precious metals by Europeans was a major driving impulse behind early modern Euro-Asian trade.[2] The simulations further suggest most of the observed increase in Euro-Asian trade is explained by the monetary injections, as opposed to lower transaction costs associated with the new discovery of sea routes to Asia.

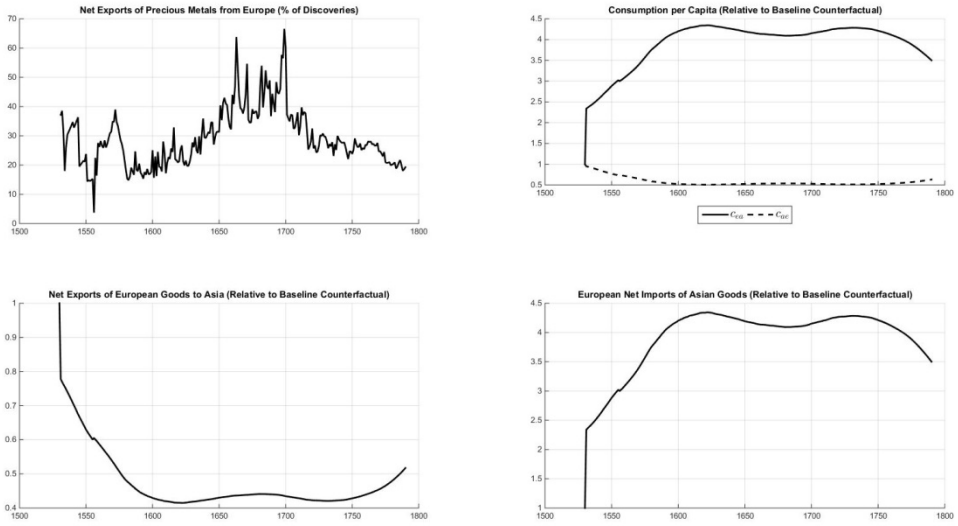

Figure 1. Simulation results for the baseline parameterization of the model in Palma and Silva (2015)

Figure 1 reproduces the baseline simulated quantitative results for the baseline model. It compares a situation where new routes were found to Asia and America and precious metals were found in America, with a counterfactual where no new routes were found Europe received no precious metals endowment. The top-left panel shows the percentage of the European windfall of American precious metals exported to Asia. The model is able to reproduce

[2] The term "discoveries" here stands for plunder from native American civilizations as well as discoveries of new mines and subsequent extraction of precious metals from the ground. Discoveries refer to production in America rather than arrivals to Europe. While not much stayed in the American continent over this period, much of the production went to Asia directly through the Pacific. "Europe" here refers to "Europe plus empire".

the empirical fact that "China was the main and ultimate destination – directly or through intermediaries – of Spanish American silver since the sixteenth century" (Irigoin 2009, p. 207, fnt.1). The top-right panel, in turn, shows that while Europe's consumption of Asian goods (c_{ea}) were up to four and a half times what they would have been in the counterfactual, Asia's consumption of European goods (c_{ae}) down to half what they would have been – in line with the fact that Europe's exports (of goods, precious metals excluded) to Asia fell and its imports of Asian goods rose, as depicted in the bottom panels. As is well known, from 1500 to 1800 silver compromised 90% of China's imports from Europe and European colonies (Pomeranz 2001, p. 273), a situation which was in line with the experience elsewhere in Asia (Steensgaard 1995, Chaudhuri 1968, Prakash 2003, 2004, Pearson 2001, de Vries 2003, p. 94).

While the counterfactual in the results in Figure 1 corresponds to the simulation for the historical situation compared with that for a counterfactual of *both* no precious metals in America *and* no sea-routes to Asia, Figure 2 breaks down the effect into the part of the variation which can be attributed each.[3] The conclusion is that, as shown in the top-right panel, new routes to Asia might have increased Euro-Asian trade by 50% at most over the early modern period, while it is the American precious metals that were the main culprit for the increase of over four times relative to what would have been observed. Furthermore, as suggested by the bottom panels, under no windfall of precious metals given to the European agents, the structure of trade would have been more "balanced" – the Asian agents would have imported a much higher percentage of European goods, rather than almost exclusively precious metals.

We hence confirm an historical hypothesis which proposes that American precious metals were the main cause of the observed nature and volumes of trade with Asia during this period. But while historian's traditional explanations for this have relied on Asian's tendency to hoard precious metals (Hamilton 1929, p. 347, Maddison 2007, p. 312, Kindleberger 1989), we instead offer an explanation based on optimal decision-making in a dynamic general equilibrium context. Given the role that Asian luxuries had for early modern Europe, both in inducing market participation at both the intensive and extensive margins, and in promoting industrialization (Berg 2004, 2007), American precious metals can be hence given a causal role in understanding the origins of those changes.

[3] In the model, there is an iceberg-cost parameter which stands for transportation and agency costs associated with intercontinental trade. We are able to estimate this parameter using historical information for the value of Euro-Asian trade during the late medieval period.

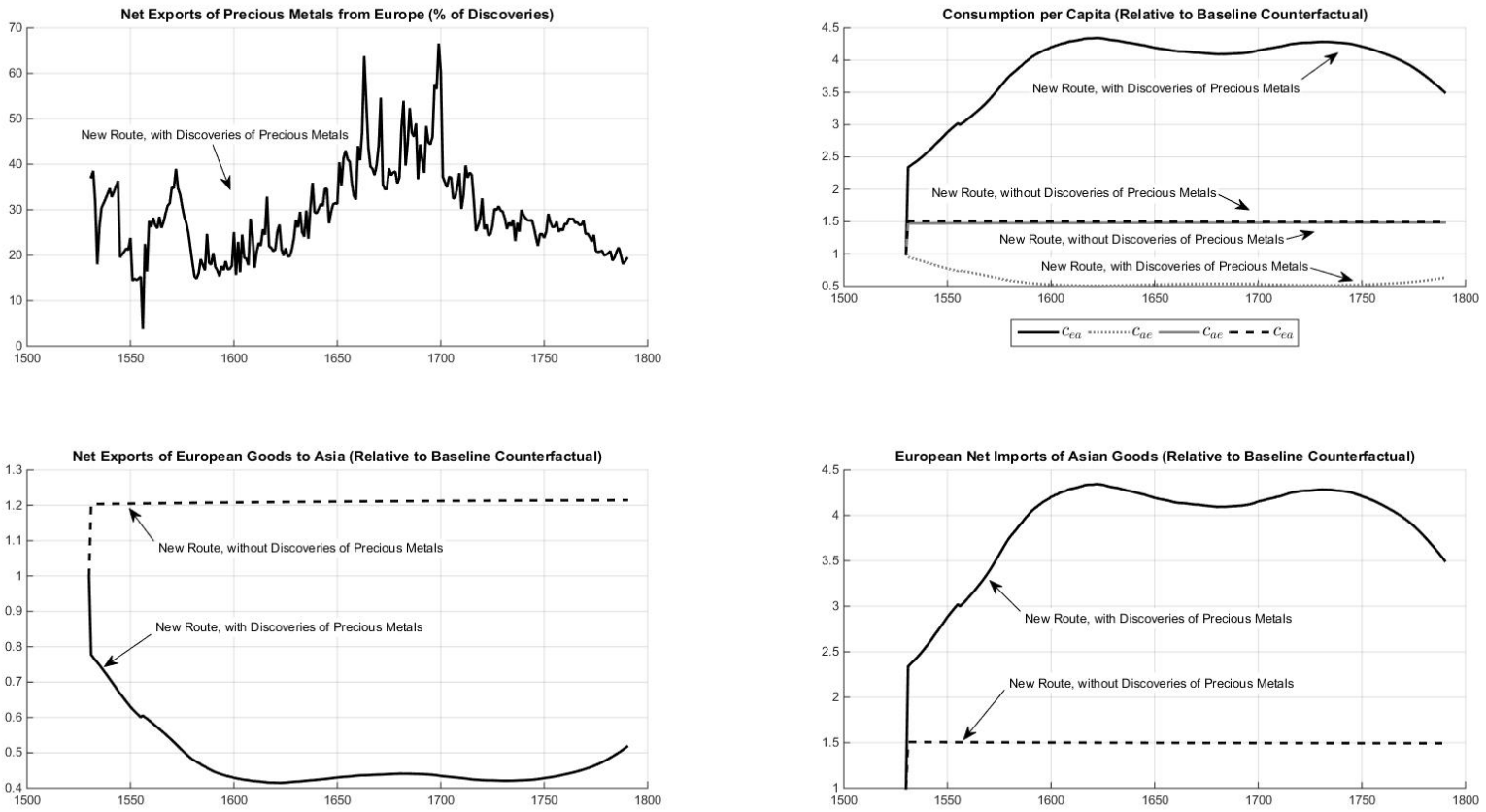

Figure 2. Simulation results for the baseline parameterization of the model in Palma and Silva (2015): breaking down the effects of the new sea route to Asia vs. that of discoveries of precious metals in America

In another paper, "*The Golden Empire and the Industrious Nation: Anglo-Portuguese Trade and Monetary Transmission during the Eighteenth Century*," I provide a case-study of the discovery of large amounts of gold in Brazil in the late seventeenth century, and the effects that had for the two main economies directly involved: the first-order receiver, Portugal, and the main ultimate beneficiary, England (Palma 2015). I show the monetary injection to England which can be directly attributed to Brazilian gold was of considerable magnitude (about £40 million pounds of 1700 in the 1700-1770 period, which compares favorably with an English GDP of 65 million in 1700 and coin supply of £10.76 million in 1700 and £44 million in 1790.) I have done considerable work for this paper, including the collection of micro-level primary source bilateral trade data, and I hope to be able to finish it over the next few years.

The final paper I wish to mention is entitled "*Danger to the Old Lady of Threadneedle Street? The Bank of England, Financial Intermediation, and the Regime Shift to Paper Money, 1797-1821*" (O'Brien and Palma 2015). In this paper we show that the restriction period, 1797-1821, encompassed a regime shift to paper money: as a response to the extraordinary threat of the French revolution and subsequent overseas events, from 1789 to 1821 direct advances from the Bank of England to the state led per capita M2 to increase from £5 to £8 in real terms, while contemporaneous population growth meant per capita coin supply fell from £4 to £3 over the same period, also at constant prices. The events of the last decade lead to a decisive move towards an increased public role of the Bank, and yet once the warfare shocks were over, the increased liquidity stayed in the financial system, despite the full restoration of convertibility in 1821. Several results from this paper are used in this dissertation, and it is also complementary to it as it helps delineate the period of the former – commodity-money dominated money supply until the 1790s. This point is of importance for my thesis as the causal importance of the American precious metals windfall partially rests on the impossibility of otherwise expanding money supply using substitutes. (I explain in detail why it is that it would not have been possible to drop convertibility before the very end of the eighteenth century in chapter 5.)

3. The big picture

The "big picture" message of my thesis is that changes in money supply can have casual, persistent, quantitatively large effects on the performance of the economies affected – including

over the long run. This message speaks to both the historical and the monetary economics literatures.

To the historical literature, I point out that monetary developments deserve a more central explanatory place in understanding the performance of the European early modern economies than has been so forth attributed. My thesis is essentially about one aspect of the "Columbian exchange" (Crosby 2003/1967) which deserves careful attention: the enormous endowment of precious metals which became gradually available in America in the early modern period. While recent papers have considered quantitatively the importance of aspects such as new crops, particularly potatoes (Nunn and Qian 2011), there is simply no modern quantitative research which systematically considers the quantitative impact of an "elephant in the room": the large-scale discoveries of precious metals, which allowed for a large-scale monetary expansion in Europe.

My thesis supports the view that the New World mattered a great deal to understanding why Europe was able to pull ahead of the rest of the world (see also Palma 2016, and the literature reviewed there). In fact, Europe already had comparatively efficient institutions by the late middle-ages (Van Zanden 2009). Those may well help explain why Europe, and not China, expanded to America.[4] Still, the following words have stood well the test of time:

> "Looking back at the Industrial Revolution and its repercussions, we should neither omit nor exaggerate the driving force [of European expansion since 1492]. It did not give Europe her central, predominant place in the world, but it may well have helped her retain it" (Braudel 1995 [1963] p.388).

O'Rourke and Williamson (2002) suggested that in a precise sense, globalization only began in the nineteenth century. Wherever this is true or not largely depends on the exact definition of "globalization", but my thesis instead reinforces the idea that the New World was having a decisive impact for the historical development of Europe well before the nineteenth century.

To the macroeconomics and monetary economics literature, I point out that first, there is very strong evidence that exogenous changes in money supply have real effects in the "short run", because prices were sticky in the early modern period, just as they are today. While from the

[4] Evidently, when referring to Europe as an entity I am incurring in some violence to its regional diversity. This may also be the appropriate place to say that when in this thesis I refer to Spain or Italy as "countries", I am using the familiar "modern borders" convention.

late 1970s and until recently it was still debated among macroeconomists whether money could have short term real effects on the economy, it is now widely accepted that is does, with few exceptions.[5] In this sense, my result complements the results of recent macroeconomic research which uses large microeconomic datasets to argue that even if prices look volatile this is due to temporary sales following sticky plans, and hence the aggregate price level is indeed, sticky (Nakamura and Steinsson 2008, Kehoe and Midrigan 2015).

However, my angle of attack to the problem is very different, at three levels. In the first paper (chapter 3), my focus is on the identification of credibly exogenous changes and their short-term effects. This has little parallel in the macroeconomics literature, although some studies exist at much shorter time horizons (for a review see Nakamura and Steinsson 2013). While the nature and methodology of these studies is quite different from mine, the results are in line with the conclusion that nominal rigidity is an important feature of reality. One striking aspect of my results – to me, at least – is that early modern economies reacted to monetary injections in a way which is quantitatively broadly consistent with the way we expect modern economies to do, despite evidently much less sophisticated banking systems.

Chapter 3 is focuses on identifying "short term" – or what sometimes is called business-cycle frequency – effects. There is no question that monetary injections stimulated these economies, though the extent to which they did is conditional to certain characteristics of the receiving economy. But as a measure of the long-term effects, the statistical method used in chapter 3 is by construction limited.[6] In other words, the estimates are at best a very conservative measure of the long term impact of the monetary injections which resulted from European expansion to America. In order to test for longer-term growth effects, in chapter 4 I construct new, annual money supply data for England. My dataset, covering the period 1279 to 1790, is by far, the largest continuous and non-interpolated time series for money supply ever constructed.

Using this data, I argue in chapter 5 that the historical experience of early modern England suggests that the doctrine of long-run monetary neutrality is false. For this particular econo-

[5] For recent examples of researchers claiming that money is neutral even in the short run, see Kehoe and Prescott 2007, Williamson and Wright (2010), Head et al (2012).
[6] In technical terms, since the model is estimated in first differences, the autocorrelation function must be going to zero. The main dependent variable is the growth rate, so by showing this is (temporarily) affected, I am also showing that income levels were permanently affected, all else constant.

my the classical dichotomy between the real and the nominal economy did not hold over the long run. (My emphasis is on monetary developments as necessary, not sufficient, conditions.) Long-term non-neutrality of money is admittedly harder to prove than the existence of short or medium-term liquidity effects, but it is also potentially far more important insofar as our understanding the origins of modern economic growth is concerned. As I explain in detail in chapter 5, the view that – at least under certain conditions – money neutrality does not hold over the long run goes against much of modern macroeconomics doctrine and practice (for a summary of the standard view of macroeconomists on this issue, see for instance McCallum 2004). For those cases when the result is externally valid, it has important policy implications, which I will not pretend to fully understand at this stage. But even if the results are conditional on the nature of the early modern period economies under study here, I shall be more than happy to have given a small contribution to our understanding of this exciting period.

Finally, it goes without saying that even what I have done here is just the tip of the iceberg. I have been able to study quantitatively the causal effects of the discovery and exploitation of American precious metals for the evolution of the early modern European economy thanks to the efforts of economic historians which over the last ten years have put forward long-term historical statistics of traditional macro aggregates. The potential of the resulting data is only now beginning to be explored. In my own application, using this dataset has permitted overcoming shortcomings of both the macroeconomics and economic history literatures, by allowing for an explicitly quantitative testing of hypotheses over long horizons – more often than not, macroeconomic analyses are too short and do not have exogenous policy variation, hence miss most of the action. But this is just the beginning. In addition to those I am working on already, I can think several additional papers which could be written on different aspects of the effects of the early modern monetary injections. In the conclusion to this thesis (chapter 6), I discuss some directions which I feel would be interesting to explore in the future.

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Chapter 2. Literature review

1. Introduction

In this chapter I review the literature which leads to the hypotheses being tested in the main chapters of the thesis. I first consider the theoretical and empirical debates in macroeconomics regarding short and long-term neutrality of money. I then consider the equivalent debates among economic historians, with special attention to the Hamilton thesis. Despite having so much in common, these two lines of debate have so far remained like ships passing through each other at night.

In section 2, I provide a review of the concept of monetary neutrality, a key idea with a long history which still plays a key role in modern macroeconomics today. I discuss its intellectual origins, and then proceed in more detail to the discussion of its evolution for the thinking of economists since the 1970s. I argue that with regards to neutrality of money at the business cycle level, there has been intellectual convergence to the idea that money can indeed affect real variables, despite the fact that dissent still remains. However, there is no agreement about the timing or impact magnitudes of monetary policy, and we know very little about how these features may be conditional on the nature and state of different economies. I also argue that with respect to long-term monetary neutrality, there has been a post-1970s convergence towards agreement that money has to be neutral on the long run.

In section 3, I review historical episodes which can be interpreted as tests for the neutrality proposition and argue that: first, we can profit a great deal from paying attention to them; and second, the most reasonable interpretation of them is that money is not neutral, thought not many quantative studies which pay attention to identification exist. I also provide some discussion with regards to the historical mechanisms through which increased monetization led to increasing commercialization, specialization, and economic growth.

Finally, in section 4 I discuss the key methodological challenges which exist to identifying the effects of money and monetary policy for macroeconomic aggregates such as nominal and real GDP and the price level at both short (up to half a dozen years) and longer horizons. I argue that the disagreement which exists is a result of the severe identification problems which afflict macroeconomics and economic history. I discuss how recent trends in applied econometrics derived from the fields of development and labor economics, which have been turning

away from theoretical models and even "structural" estimation and in the direction of "clean" identification, can be fruitfully applied to macroeconomic and historical questions. These methods usually have important limitations with respect to the kind of questions that can be answered, as for some of the most important questions that we can ask within a given field there may be simply no credible source of exogenous variation available. However, I argue that simply by looking back into the past there is much for macroeconomists to learn from the application of these methods to historical data. Similarly, economic historians can acquire a much better understanding of the past as well.

2. Monetary neutrality

2.1. The concept of monetary neutrality

> "This tension between two incompatible ideas – that changes in money are neutral unit changes and that they induce movements in employment and production in the same direction – has been at the center of monetary policy at least since Hume wrote" Lucas (1996)

The neutrality of money is one of the oldest economic propositions. In its simpler form, it says that due to its purely nominal nature, the stock of money cannot influence the real side of the economy: variables such as real exchange rates, real wages, unemployment, or real output. This doctrine is squarely focused on money's role as a unit of account: if the stock of money changes, all prices change proportionally, and thus real allocations are invariant to the quantity of money in circulation.[7] (This is sometimes called the "classical dichotomy").

On a theory level, it important to understand that on a standard Arrow-Debreu world of complete markets, there is no need for money. In such an imaginary world, transaction costs are zero and fiat money has no value, while precious metals would only have a usage through their "intrinsic", direct utility value (eg. as jewelry). In the real world, the fact that cash is used must mean there are frictions in the economic environment.

[7] A close (and stronger) variant is the notion of "superneutrality", which posits that changes in the rate of money growth – as opposed to the level of the money stock – can affect inflation but not real allocations. Weaker variants do exist where welfare and labor supply can be affected in the short run.

But there are different reasons why monetary neutrality can fail to hold. Prices and wage contracts may be sticky, taking time to adjust to changes in the money stock, especially if these were not anticipated. It is also possible that it is plans that are sticky – it may be difficult for firms to know when to change them. Yet another possibility is that relative prices change following a monetary injection, or that wealth effects generated by the order of receivers matter.[8] Finally, people may have bounded rationality and confuse unit-of-account changes with real changes (monetary illusion); people have the tendency to think about money in nominal terms even when it is real quantities that should matter for their welfare (the concept was first proposed by Fisher 1928; for empirical evidence on its existence, see Shafir, Diamond, and Tversky 1997). For instance, people seem to strongly dislike negative changes in nominal wages, but react much better to an equivalent drop in their real wage as long as its achieved through inflation. Similarly, past economies seem to react asymmetrically to unit-of-account changes (Velde 2009).

Historically, the concept of monetary neutrality has had different meanings and has been accepted in different versions. I begin with an historical survey regarding the theory of monetary neutrality, drawing attention to a number of cases in which different versions of the theory have and have not been accepted. The early formulation of the neutrality of money is related to the development of the quantity theory of the purchasing power of money – usually short-handed as the quantity theory of money – but they are independent propositions.[9]

There are presently two different meanings in the literature attached to the expression monetary neutrality. One is that money is neutral in the long run, but it affects the economy transitorily, in the short run, due to, for example, staggered contracts or plans. The emphasis can be on the cost of changing prices (under the umbrella term of "menu costs"), or on the informational difficulties in knowing when to do so. This is what I call the weak or short-run version of money neutrality. In practice, different versions of the monetary neutrality doctrine vary as to the time lag to which it applies, but the essence of it is that, at least in the long run, real

[8] This effect is related to money's role as a store of value.

[9] I will not deal in detail with the quantity theory, except where it is of use due to its connection with the doctrine of monetary neutrality; see Laidler 1991a, 1991b for a history of the quantity theory. Their basic link is that under certain conditions (assumptions about V and Y), the quantity theory implies either long-term or short-term neutrality, as briefly outlied below.

output and real wages are invariant to a monetary shock, or to the systematic component of monetary policy.

There is a different version that states that money is always neutral, even in the short run. This story corresponds to the pure classical dichotomy, implying that the monetary and the real sectors of the economy are separated and do not influence each other. This is what I call the strong version of money neutrality.

From an accounting perspective, monetary neutrality follows directly from the exchange equation $MV = PY$ if Y is fixed (eg. at what is usually interpreted as the "long run" or "full employment" level), and the velocity of money V is fixed as well. If so, it must be the case that all changes in money, M, will directly translate to changes in prices, P.

Why would changes in M not influence either Y or V, especially in the short run? The most obvious situation is one of rational expectations together with instant market clearing. If prices can adjust without any costs being incurred, if agents have rational expectations and if a monetary increase is fully expected, it follows that money is simply a unit of account, a *numeràire* which cannot affect real allocations. (As in an Arrow-Debreu world of complete markets where transaction costs are zero and there is no reason why one would hold fiat money.) In reality, however, various informational frictions and menu costs exist which imply that money is not neutral, including departures from rationality such as "monetary illusion".

We shall see that for some authors from the past, even when prices and expectations have fully adjusted to the monetary shock, the result will be a permanent effect on real income. Historically, all versions of monetary neutrality have had their sponsors. I now consider some of the main authors and discuss some cases where from a modern point of view there is some ambiguity over an author's position on this matter.

2.2. A short history of the concept of monetary neutrality up to the 1970s

The quantity theory of money was initially developed by the sixteenth century "Salamanca School" of economic thought in Spain, by Jean Bodin in France, and then most clearly set out

as well as popularized by John Locke and David Hume (Schumpeter 2006/1956). For Locke, money is perceived only as a medium of exchange, and thus as formulated by him, the quantity theory only meant that the level of prices is always in proportion to the quantity of money in circulation. As so, Locke accepted the classical dichotomy between the real and the monetary sector of the economy and the strong version of monetary neutrality holds in this system.

In turn David Hume was the first to state that money could have some real effects, "heating" up the economy, at least in the short run: "We find, that, in every kingdom, into which money begins to flow in greater abundance than formerly, everything takes a new face: labour and industry gain life …some time is required before the money circulates through the whole state…At first, no alteration is perceived; by degrees the price rises, first of one commodity, then of another; till the whole at last reaches a just proportion with the new quantity of specie which is in the kingdom" (Hume 1742).

Hume seems conflicted on whether the effects are only transitory. On the one hand, he clearly states that "[i]n my opinion, it is only in this interval or intermediate situation, between the acquisition of money and rise of prices, that the increasing quantity of gold and silver is favourable to industry" (Hume 1742). Hume's position in the latter quote seems to be in clear conflict with the notion that money only influences "labour and industry" in the short run, however, since he also says that:

> "[S]ince the discovery of the mines in America, industry has increased in all the nations of Europe, except in the possessors of those mines; and this may justly be ascribed, amongst other reasons, to the increase of gold and silver … [T]he prices of all things have only risen three, or at most, four times, since the discovery of the West Indies … But will anyone assert, that there is not much more than four times the coin in Europe, that was in the fifteenth century, and the centuries preceding it? ... And no other satisfactory reason can be given, why all prices have not risen to a much more exorbitant height, except that which is derived from a change of customs and manners. Besides that more commodities are produced by additional industry, the same commodities come more to market, after men depart from their ancient simplicity of manners." (Hume 1987/1742, p. 33)

Richard Cantillon, too, was a non-neutralist, and stressed the need to explore "mechanisms": "Mr. Locke has clearly seen that the abundance of money makes everything dear, but he has not considered how it does so. The great difficulty in this question consists in knowing in what way and in what proportion the increase of money raises prices" [Cantillon 2010/1755)]. The *Cantillon effect*, as it is presently known, concerns the effects of a monetary

shock on the relative price structure. If the relative price structure is altered, then different conditions for the accumulation of capital and growth may develop, creating long run effects from a monetary shock, and thus leading to non-neutrality.

In turn, the large number of writers usually bundled together as "mercantilists", despite expressing a variety of views on different subjects, did tend to have in common a preoccupation with economic growth, and with the role that access to precious metals played in achieving it. This was later criticized by Adam Smith and other "classical" writers as nonsense, though in light of more modern views of state-building and warfare in a non-cooperative world that may well have not been the case (eg. Findlay and O'Rourke 2007)

In the nineteenth century, real effects of money were central to the banking vs currency school debates, and influential economists such as John Stuart Mill argued for monetary neutrality. Just as quantity-theory ideas about the mechanism for long-run neutrality would flow from David Hume to Irving Fisher, to Milton Friedman, and ultimately to Robert Lucas, it was also the case that Cantillon's ideas would be picked up by early twentieth-century economists and would momentarily become influential. Adolf Löwe's 1926 article on the *Weltwirtschaftliches Archiv* (Löwe 1997/1926) was a critique of the then existing separation between theories of the trade cycle, and equilibrium theory. Löwe noted that simple static equilibrium models could not explain simple business cycle facts such as joint co-movement of prices and quantities.

Löwe's paper was thus a methodological plea to the usage of dynamic models: "Those who wish to solve the business cycle problem must sacrifice the static system. Those who adhere to the static system must abandon the business cycle problem… The transformation of our existing static system into a dynamic one thus appears to be required from open problems of economic theory over the entire field" (Löwe 1926). Frederick Hayek knew the article and had it in mind when writing his 1928 article in the same journal (Hayek 1928), as well as his book *Monetary Theory and the Trade Cycle* [Hayek 1933(1929)], and also *Prices and Production* (Hayek 1931). Hayek's early multi-sectoral model was an attempt to incorporate monetary theory with general equilibrium theorizing and an answer to Löwe's challenge.

Hayek followed Mises (1981[1912]) in rejecting the quantity theory, arguing that it ignored the effects of a monetary shock on relative prices. They rejected the notion of macroeconomics for the same reason, as they considered that price aggregates concealed critical changes in relative prices. Hayek (1931) draws on Mises, Wicksell, Böhm-Bawerk, and Löwe to build a multi-sectoral dynamic model of the cycle that contains strong policy consequences (see Hagemann and Trautwein 1998).

Hayek argued that an artificial (i.e. not caused by a change in agents' preferences, but by the central bank's monetary policy) change in the interest rates, pulling the market rate away from the natural rate (in a Wicksellinan sense) has opportunity-cost consequences in the inter-temporal structure of production. Suppose there is a positive monetary shock. According to Hayek, the reduction in interest rates caused by subsequent credit expansion (mis)directs resources toward capital-intensive processes and early stages of production and is the key to the subsequent inevitable slump.

This is the overinvestment theory of the cycle that Keynes promptly dismisses in the *General Theory* (Keynes 1997/1936). The theory from *Prices and Production* implies that a positive monetary shock first affects the relative price structure and consequently the capital structure of the economy. This means that at least in the short-run, money is not neutral as it affects the real side of the economy. In the longer run, the result of the monetary expansion is a slump. This slump is necessary restore the original opportunity-cost structure of the economy. Because of this, Hayek was a non-neutralist, though his views – echoed by modern "Austrian" economists – are quite opposite to those of most non-neutralists, which tend to claim that non-neutralities mean that central banks have the power to smooth the business cycle, and do so. Instead, Hayek's view was that the business-cycle itself was largely a consequence of monetary policy.

With the rise of Keynesian economics and then the rational expectations revolution, Hayek's ideas have lost all influence except among a cohort of self-described "Austrian" economists. (Notice that the "Austrian theory of the business cycle" theory seems incompatible with the notion of rational expectations, unless, perhaps, a particular information structure is assumed).

I mention these debates not because they are very relevant today, but because they emphasize that the tension between static and dynamic models, and between partial and general equilibrium analyses (the notion of uncertainly was less relevant) were often at the center of much early disagreement over the possibility of monetary non-neutralities. Today, there is basically full agreement that macroeconomic models designed to study the short-run need to be dynamic, (sometimes) stochastic, and general equilibrium, but it is easy to write down models with those characteristics that lead to all kinds of results with respect to monetary neutrality, even when starting with assumptions that intuitively "make sense".

The story of how at the University of Chicago in the 1950s, Milton Friedman and his associates revived the "quantity theory of money" which had supposedly survived through "oral tradition" is well-known and does not to be recalled here, but it must be reminded that Friedman argued that liquidity effects existed. Friedman's insistence that monetary policy could not peg interest rates of unemployment for more than "very limited periods" (Friedman 1968) was one part of his insistence that there was a clear distinction between the effects of alternative systematic components of monetary policy, as compared with the effects of shocks has had a lasting effect on the views of modern macroeconomists. Friedman (1968, p.7) wrote:

> "As an empirical matter, low interest rates are a sign that monetary policy has been tight – in the sense that the quantity of money has grown slowly; high interest rates are a sign that monetary policy has been easy-in the sense that the quantity of money has grown rapidly … Paradoxically, the monetary authority could assure low nominal rates of interest-but to do so it would have to start out in what seems like the opposite direction, by engaging in a deflationary monetary policy. Similarly, it could assure high nominal interest rates by engaging in an inflationary policy and accepting a temporary movement in interest rates in the opposite direction … [these considerations] explain why interest rates are such a misleading indicator of whether monetary policy is "tight" or "easy." For that, it is far better to look at the rate of change of the quantity of money."

In the long-run, though, according to Friedman the central bank was only able to affect inflation – a proposition which would be questioned by the rise of Sargent and Wallace's (1981) "unpleasant monetarist arithmetic" and the fiscal theory of the price level.

2.3. Monetary neutrality debates since the 1970s

Friedman's argments regarding the sub-optimality of attempts at pegging the interest rate or or employment were the prelude to Kydland and Prescott (1977), but it should be noted that the existence of liquidity effects did not start to be seriously questioned until the 1980s. In fact, Robert Lucas's early work gave fair amount of attention to money as a source of fluctuations (Lucas 1972), and it was only once the Real Business Cycles (RBC) research program appeared and became increasingly dominant that much of the macroeconomists' profession moved away from considering that monetary policy had the capacity to cause (or help smooth) business cycles, or even economic growth (see Stein 1970 for a review which suggests that into the 1970s many macroeconomists did not think of the long-run as unconditional to monetary factors). By the time of his 1995 Nobel Lecture, Robert Lucas was a defender of the idea that anticipated changes in monetary policy could only have inflation effects (Lucas 1996), a position which then echoed much of the American macroeconomics profession. This risked the rise of a new consensus where money was deemed to be usually neutral, even in the short-run. This program would be taken to its extreme by proponents of the RBC "Minnesota school", which go as far as attempting to explain the Great Depression and related episodes without reference to monetary factors whatsoever (see the collection of essays in Kehoe and Prescott 2007). This school of thought (together with the separate but related "New monetarist" school, nowadays led by Randall Wright, which shares much of its intellectual origins at Minnesota as well) has many followers, and indeed it has effectively made obsolete Schumpeter's view that: "Monetary Analysis … [considers] that essential features of the capitalist process may depend upon the [monetary] 'veil' and the 'face behind it' is incomplete without it … this is almost universally recognized by modern economists" (Schumpeter 2006/1956, p. 278).

And yet, from the 1980s onwards, it has become increasingly evident that regardless of what simple "new classical" models might suggest, following a monetary injection liquidity effects do tend to dominate anticipated inflation, which implies that, at least in the "short-run" money is not neutral (Cochrane 1989; see also Mishkin 1982). As New Keynesian models developed in the form of dynamic general equilibrium models with rational expectations which incorporated demand for money in the form of money in utility, cash-in-advance, or shopping-time constraints, it has become clear that, as long as either sticky prices or some informational fric-

tion were present, money can be non-neutral in the short run (see Edmond and Weill 2008 for a review of models). At the same time, models which attempt to go "deeper" in modelling microfoundations, and emphasize the origins of money as the result of limited commitment also suggest that moments of illiquidity could easily lead to large macroeconomic fluctuations (Kiyotaki and Moore 1997, 2002) hence providing a modern theoretical foundation to the empirical work of economic historians on financial crises.

The return to the old consensus that liquidity effects exist was supported by parallel empirical research (e.g. Bernanke and Mihov 1998). But identification implied using strategies such as the "narrative approach" of Romer and Romer (1989, 2004) or recursive VAR's (Christiano, Eichenbaum and Evans 1999) have never been consensual (Leeper 1994, Chari Kehoe and McGrattan 2008). As far as long-term neutrality is concerned, there was an abundant literature in the 1990s (reviewed in Bullard 1999), which, I argue in retrospect, suffered from severed identification problems, and which despite being inconclusive did not prevent the acceptance of the long-term neutrality proposition by most economists today.

2.4. Money neutrality, macroeconomics, and economic history

Modern economic models take as a given the existence of fiat money and the ability of central banks to inject as much liquidity as they wish – including recently through "unconventional" means such as buying longer maturities of government debt and even low default risk commercial debt, when the short-term nominal interest rate on government bonds is close to zero. Realizing that the ability to do this is a historically recent situation is, I would argue, an important first step towards understanding why such policies work today.[10]

The long run neutrality of money is today almost universally accepted by macroeconomists on both theory and empirical grounds. The theoretical reason is that it is an outcome of many models under particular, but standard, assumptions.[11] As a theoretical proposition it is certainly seductive to argue that in the long-run, all real allocations must be determined by pref-

[10] Furthermore, and while it can be argued that we live in "special times", it is undeniable that central banks in the developed world have been having little difficulty in keeping nominal interest rates close to zero for a number of years now, without this generating significant amounts of inflation or inflationary expectations.
[11] Additionally, developing microeconomic foundations for nominal rigidity or "stickiness" is hard, so more often than not these are introduced in an exogenous and relatively ad-hoc manner, as with the case with "Calvo" prices or wages.

erences, endowments, and technology. (Theorists usually also leave out institutions.) But another reason is empirical: across a broad cross section selection of countries, the time-series correlation between money and growth is essentially zero (see Walsh 2004 for a literature review). Yet there is a sense in which this conflicts with long run historical evidence. In fact, over large horizons, it is almost certainly false that there is a correlation between long run growth and the stock of money – the correlation is certainly positive. Evidently, by itself this says nothing about causation, however. Unlike modern macroeconomists, economic historians do sometimes have more perspective on these matters, and sometimes refer to the ability of money to support economic growth, as the following example illustrates:

> "European demand for silver, if only to provide for the liquidity necessary to accompany its not inconsiderable economic growth during this period, seems to have been important … The discovery of the New World silver had a major impact on the economies of Eurasia, stimulating price rises, and facilitating both monetization and commercialization" (Findley and O'Rourke 2008)

Why do economies need to be monetized? First, the double coincidence of wants problem constrains specialization by limiting the feasibility of barter. Second, governments may find it difficult to tax and administer in societies with low levels of monetization. In particular, it would be difficult to collect revenues and provide public goods over long distances.

Because the long-run neutrality as a doctrine is widely accepted by macroeconomists, it regularly serves as a foundation for much empirical work in monetary economics. In particular, the Blanchard and Quah (1989) identification conditions for vector auto-regressions impose it as a maintained assumption. These conditions are widely used in central banks all over the world to estimate the impact of monetary injections on macroeconomic conditions. My work questions the validity of this exercise, by pointing out that if we are to estimate this impact accurately, we must be careful not to assume a priori that there is a persistent no-growth effect, especially following major liquidity injections or a prolonged period of deflation. Since such episodes are historically unusual, and tend to happen in "special periods", it is also necessary to interpret history with care, as the type of data which monetary authorities have at hand may simply be inappropriate and insufficient to draw meaningful conclusions. Indeed, the Blanchard and Quah (1989) results are based on quarterly data from 1950 to 1987, hence a total 148 of only observations – a sample size in fact not unusual in macroeconomics. By con-

trast, my results in chapter 3 are based on about 1,500 observations for six countries, across three centuries.

2.5. Potential channels of non-neutrality

Under which conditions can monetary neutrality fail? Briefly, the channels more usually considered by macroeconomists are nominal rigidities – prices and especially wages can be "sticky" – or there can be informational "stickiness". One channel that is not as often mentioned is that if some prices are more "sticky" than others, a change in money supply can lead to changes in relative prices that can have real consequences.

Short-term non-neutralities such as these, I argue, can transform themselves into long-term non-neutralities through a process of path-dependence and hysteresis by interacting with other features of an economic environment. In fact, though the connection with money is not always made explicit, as the following examples illustrate, this sort of effect has been explored by several economic historians.

3. Some economic history debates concerning monetary non-neutralities

3.1. Long-term consequences of the "price revolution"

The purchasing power of silver in Europe declined to approximately a third of the pre-discovery level in the sixteenth and the seventeenth centuries (Harley 2004); this is sometimes called the "price revolution". Landes (2003 [1969], p.18) suggests that the long inflation of the sixteenth century, "which "found many peasants holding long-term leases whose burden diminished" was strongly associated with reducing seigneurial authority and enhancing the personal and economic status of the peasantry.[12] In this he seems to be agreeing with Cantillon,

> [I]f the increase of money in the state comes from a balance of foreign trade … this annual increase of money will enrich a great number of merchants and entrepreneurs in the state, and will give employment to numerous artisans and workmen who provide the goods sent to the foreigner from whom money is drawn. This will gradually increase the consumption of these industrious inhabitants and will raise the price of land and labor … Those who will suffer from

[12] For a more modern discussion, centered in the case of England, see Whittle (2013, p. 12), and some of the other essays in that volume.

> these higher prices and increased consumption will be, first of all, the property owners, during the term of their leases (Cantillon 2010 [1755], p.148-150)

This is only one example of a political economy non-neutrality channel. We know that at least for modern economies, even a moderately sized zero-sum redistribution shock can have quantitatively important persistent effects (e.g. Doepke and Schneider 2006), and it seems plausible that this would have been the case in early modern economies as well. If Landes is right, then, this could have mattered, in light of the fact that:

> For the industrial revolution to be successful, it had to overcome the problem of incumbent landed powers who drew their political, social, and economic strength from the existing blend of feudal customs and traditional arrangements ... Above all, there had to be a way to make room for a rising merchant and industrialist class (Mokyr and Nye 2007, p.4- 5).

The case of Dutch disease and institutional resource curse in early modern Spain provides another example of long-term non-neutralities, though this is not always put in this way. By generating inflation, the imports of precious metals would have led to an appreciation of the real exchange rate, making exports dearer, and imports cheapter, and hence ruining national industry (Hamilton 1934; Drelichman 2005a). The additional resources could also have changed the political institutions in a way which negatively affected growth (Drelichman 2005b).

Standard monetary theory and empirics do not include institutional elements in the models, but for some questions this is essential.[13] In this thesis I mostly focus on positive effects, while if the Hamilton-Drelichman thesis is correct, the effect (for Spain) was negative, but this is of no consequence to the fact that it implicitly implies long-term non-neutrality. Perhaps there was a positive effect for Spain too, but it was dominated by these negative effects. Regardless,

[13] The ambition I have for macroeconomic models is that they take into account that the business cycle and economic growth are the result of one and the same set of forces, and affect each other – including through institutional channels. While the real business cycles literature has made an important contribution by insisting in the use of "micro-founded" models and suggesting that productivity change can affect the business cycle, its most basic contention that TFP shocks could explain most variation in the business cycle without reference to nominal rigidities has not stood well the test of time. The need to introduce these types of frictions opens doors to the real effects of money but at the same time the difficulty of modelling the micro-foundations for sticky prices and money demand leads those who insist on adhering closely to a close interpretation of the "Lucas critique" to reject monetary models altogether. At the same time, RBC and indeed all modern DSGE models reject any direction of causality from monetary forces to the long-run development or growth process. By contrast, I argue here (particularly in chapter 5) that monetary forces usually associated with the business cycle are in fact also important for our understanding of long-run economic development and growth.

for reasons that will become clear in chapter 3, I shall remain agnostic about whether Spain was negatively affected in the long-run or not. My emphasis in this thesis is on positive effects, particularly for Northwestern Europe.

3.2. Trade, the New World and the industrial revolution

3.2.1. Moving beyond the methods and conclusions of the *Annales* school

> "'Looking back at the Industrial Revolution and its repercussions, we should neither omit nor exaggerate the driving force [of European expansion since 1492]. It did not give Europe her central, predominant place in the world, but it may well have helped her retain it" (Braudel 1995/1963, p.388)

The *Annales* school deserve credit for working on global comparative economic history at a time when economic historians in England and the United States were squarely focused on their own histories – and would largely continue to be so for the next forty or so years. As Eric Jones – himself an early proponent of this approach in the Anglo-Saxon world – argues, comparative history may not be a perfect way of arriving at the important answers, but it is the best chance we have (Jones 1988).

The worldly approach of the *Annales* school was ahead of its time, both in the above sense and in directing effort to the understanding of the lives of ordinary people (as opposed to the "Great Men" view of history). Still, these advances were acquired at an eventual cost. While the *Annales* school initially adopted quantitative methods which were advanced for the standards of the time, the "cliometric revolution" never made a dent and the "cultural turn" was in turn embraced, with evident consequences for development of much of the subsequent continental historiography. This inhibited progress, because there is only so far one can go without a sharp and explicitly quantitative approach. But "[s]ocial historians' insistence on the cultural specificity of social institutions and practices was ill at ease with the comparative methods that had underpinned social and economic history since at least the early twentieth century" (Grafe 2015).

In the quote above, Braudel is making two related, but separable, statements. First, Europe already had a "predominant" place in the world by 1492. It must be say upfront that, if one identifies "predominant" with wealthy, commercialized, literate, heavily populated, or techno-

logically advanced – and then again what other meaning could "predominant" possibly have? – then today's scholarship does not fully support this interpretation (Allen et al 2005, Allen et al 2011). Pomeranz (2001), and other members of the so-called "California school" have argued that if the right regional comparisons are made, China was not much behind Europe as late as 1800; However, the claims of the "California school" have been successively pushed back in time, and now even Pomeranz admits that by 1800, it is almost certain, Europe was richer (Pomeranz 2011; see the discussion in Broadberry 2013).

By 1492, however, the question is far from resolved, despite the Europe's clear superiority in military technology. But in subtle institutional ways which reflected themselves in credit and labor markets, it is also clear that Europe was ahead even at the dawn of the middle ages (Van Zanden 2009). It does seem to be the case that by the eighteenth century, the most advanced parts of Europe were ahead in terms of real wages and well-being, as well as productivity in industry and services that even the most advanced parts of Asia (Broadberry and Gupta 2006, Li and Van Zanden 2012)

Second, Braudel claims that European expansion was a "driving force" behind the industrial revolution. There is no hope to answer this without a specific model which can help assess the counterfactual. Recent research on this has focused, for example, on the role of New World raw inputs (e.g. Clark et al 2008). Instead, I focus on precious metals and their consequences for money supply and equilibrium prices. In the debate about the price revolution (Fisher 1989, Schwartz 1987, Goldstone 1984) one issue is generally missing: that Europe was an open economy. Because most of the silver left for Asia, the size of the injection is underestimated if it is simply proxied by the price revolution. In a closed economy prices would have increased much more.

Braudel can be easily criticized for not framing his research in a way that can be tested. How to evaluate counterfactuals? This is related to the point that sometimes there is no point, that is, no specific question is being asked, let alone answered. Yet, as with much of the work of the *Annales* school, Braudel's work is in my view complementary to much which has been done by cliometricians, because the more traditional methods allow often sharp responses only at the cost of narrowing the research question to the kind of answers which can be easily answered, either because the right data or the right identification strategy was at hand, missing historically important "blind spots".

Still, Braudel's (and the *Annales* school more generally) emphasis on the *longue durée* and the historical experience of the common people, as opposed to the political and diplomatic history of the elites, is in line with much modern economic history. Despite evident limitations with regards to representativeness and despite the usual lack of comparative elements, the emphasis of many third-generation *Annales* scholars (eg. Ladurie 1976) on mentalities and social history also sounds remarkably modern in light of the recent shift of attention from economists and economic historians towards cultural explanations (see for instance, Becker and Woessmann 2009). While this sort of work is certainly complementary to cliometrics, we now also have a great deal of new data and empirical methods which can be put to use with great profit to test specific hypotheses systematically and in a rigorous manner.

3.2.2. Trade, fluctuations, and growth: case of New World precious metals

Braudel's view of the importance of America is reminiscent of the well-known opinion of Adam Smith that "The discovery of America, and that of a passage to the East Indies by the Cape of Good Hope are the greatest and most important events recorded in the history of mankind" (Smith 2003/1776). This sharply contrasts with the view of O'Brien (1988) that "for the economic growth of the core, the periphery was peripheral" (see also, for instance, Mokyr 1985, or Harley and McCloskey 1994). Patrick O'Brien no longer holds that view, however (see for instance, O'Brien 2006), which is again a barometer of the times: Findlay and O'Rourke (2007, p. 339) write that international trade is critical to understand why the British Industrial Revolution was sustained, and also claim that the "success of the European Industrial Revolution is intimately connected with trade and overseas expansion" (p.364); see also Palma (2016).

Indeed, criticizing trade's importance by measuring the static size of external trade compared with GDP is inadequate. What mattered is the dynamic effects – the effect of trade on structural change, in turn generating growth from agglomeration economies (this sort of growth was not well understood until the 1990s). Additionally, I emphasize that monetization mattered because it allowed levels of specialization and market participation that otherwise would have been impossible. In later examples of export-led growth, including Germany or Japan, the ability of the state to issue fiat which supports the transformation of society can be taken as granted, but in early modern England it could not.

As O'Brien and Palma (2015) show, it was only with the extraordinary threat of the French revolution that the Bank of England was able to issue fiat beyond a level that had been so far stable as a percentage of coin since it's creation. It also only then that it began issuing denominations such as £1 and £2, which common people could actually use, at that time. It is difficult to believe it could have done so earlier – even the American revolutionary war had not been enough to press forward faster fiat-monetary developments. Consequently, if money supply was to expand, gold was necessary, both to be minted into coinage and by serving as collateral and allowing for increases in bank of England fiat money. This provided for the needs for liquidity of a growing and increasingly urbanized society, with high levels of specialization or division of labor.

Despite the empirical challenges to doing so, we need a way to formally test and quantity the effects of the New World on the Old World, and whether that relationship had anything to do with the rise of modern economic growth. Elsewhere, I have followed a reduced-form but "global" approach to this problem, focusing on the role of intercontinental trade (Palma 2016); Instead, in this thesis I propose one way to go deeper is to take up the challenge in a piecemeal way. I focus on the impact of one of the main imports from American to the Old world, one which generated global-level general equilibrium effects – American precious metals.

Classic accounts of the English industrial revolution present a long period of stagnation followed by a fast take-off. This picture has been adopted by models of the unified growth theory school (Galor 2005) and seems to be confirmed by the real wage data of economic historians (Phelps-Brown 1956, Robert Allen 2001 and Gregory Clark 2005, 2007). However, recent GDP data (as well as earlier evidence by historians of material culture) suggest this is a historically inaccurate portrait of early modern England. Slow but steady per capita economic growth preceded the transition. The changes were in part driven by specialization and structural change accompanied by an increase in market participation at both the intensive and extensive levels. These, I suggest, were supported by the gradual increase in money supply made possible by the discovery and exploitation of rich mines of precious metals in America.

They allowed for a substantial increase in the monetization and liquidity levels of the economy, hence decreasing transaction costs, increasing market "thickness", changing the relative incentive for participating in the market, and allowing for agglomeration econo-

mies. By making trade with Asia possible, they also induced demand for new desirable goods, which in turn encouraged market participation at both the intensive and extensive levels.

Finally, the increased monetization and market participation made it easier for governments to collect taxes, helping build up fiscal capacity and as a consequence provide for public goods. The structural change and market participation that ensued helped pave the way to modernization, hence transforming a level effect on a growth effect. The conclusion is that we need to pay closer attention to monetary developments and the avoidance of deflationary forces as critical preconditions for the emergence of modern economic growth.

3.2.3. Hamilton's weak and strong hypotheses

> "The conclusion is inescapable that the discoveries of America and of the Cape route to the East Indies were highly important factors in the rise of modern capitalism. Changes in trade routes, the widening of markets, contacts with distant lands and strange peoples, and a more perfect knowledge of geography conspired to perturb the minds of men much as does our increasing power over nature to-day. The price revolution set in motion by American gold and silver contributed directly to the progress of capitalism" (Hamilton 1929, p. 355)

Because of the special emphasis on American precious metals in my work, it is worthwhile to discuss its relationship and comparison with that of Earl J. Hamilton in some detail. Hamilton believed that the price revolution led real wages to become depressed as prices rose with the price revolution but nominal wages did not do so as much. He noted this view ran against the subsistence theory of wages which "almost all writers on wages between 1500 and 1700" held as true (Hamilton 1929, p. 355, fnt. 1).[14]

[14] As it turned out, Hamilton used wheat as a proxy for the price level, but the Brown-Hopkins CPI would should a much less steep rise in prices (see Munro 2010, pp. 119-121 for a modern discussion.) It is also worth of notice that the "profit-inflation" mechanism emphasized by Hamilton, by which high profits caused by wage growth lagining behing inflation induced entrepreneurs to invest in capital-intensive technologies, goes again modern interpretations of labor-saving motives for technical change (Allen 2009).

Many economic historians agree that much of the expansion of European trade during the early modern period was made possible by the discovery of large quantities of precious metals in the New World (Findlay and O'Rourke 2007, deVries 2003, Flynn and Giráldez 1995, Harley 2004). The discovery of precious metals was of course not a sufficient condition, as other factors such as advancement of maritime technology were also necessary. But the view is that precious metals were a critical ingredient – a necessary condition – for Europe's expansion can be called the *weak Hamilton hypothesis*.

A stronger version of Hamilton's hypothesis holds that the monetary injections had a direct causal effect on the "rise of capitalism" during the sixteenth and seventeenth centuries, which in turn prepared the way for the industrial revolution and modern economic growth (Hamilton 1929, p. 338). Besides Hamilton, other prominent economists and economic historians from earlier generations believed this episode had important consequences for Europe and beyond, though the precise channels identified were different (Cipolla 1993, Keynes 2010/1936, Landes 2003/1969, p18).

The economic historian John Nef, a colleague of Hamilton at the University of Chicago, writing from 1937 onwards questioned what he saw as the mainstream thinking of the time: "For some time historians and economists have been disposed to regard the price revolution as an important cause for the rise of modern capitalism (Nef 1937; for Hamilton's reply, see Hamilton 1952). Perhaps due to the acceptance of Nef's arguments, despite the support of important economic historians and economists from previous generations the (strong) Hamilton thesis has failed to receive recent attention. This is in line with today's orthodox macroeconomics which states that in the long run monetary injections must be neutral.

It is important to realize that the two hypothesis overlap, and in particular the strong version can have been made operational in association with the weak version. Although in my essays themselves reference to intellectual history is kept to a minimum, and hence references to Hamilton are usually suppressed in the individual chapters, this is the place to acknowledge his influence and point out exactly how my work innovates relative to his.

Hamilton anticipated that he might be criticized on the grounds that the close connection between the East India trade, American treasure and the rise of modern capitalism might be rejected because Portugal and Spain did not do well during the early modern period. Indeed,

the view that these countries declined during this period finds support for Spain in Álvarez-Nogal and Prados de la Escosura (2013) and partial support in the case of Portugal in Palma and Reis (2014). The role of the empire in generating this outcome is unclear due to identification problems, that is, due to confounding problems it is not straightforward to know what would be the evolution of these economies in the absence of links with the empire; see, however, Costa, Palma and Reis 2015).

Hamilton (1929) insisted that "[i]t is true that well-rounded capitalism did not emerge in Portugal or Spain, but this fact is not incompatible with the thesis … that profits from the East India trade and the influx of Mexican and Peruvian silver were the most important, but not the only, factors in the rise of modern capitalism … Factors essential to the progress of capitalism were lacking in Portugal … the mechanism through which American treasure operated did not function in Andalusia, nor presumably in the rest of Spain, as it did in England and France. … Wages lagged behind prices, but not enough to afford extraordinary profits and thus to give a great impetus to capitalism. Through possession of *EI Dorados* in New Spain and Peru, Spaniards expected to wax prosperous without work."

Hamilton's story was later endorsed by Keynes, but the specific mechanism that Hamilton pointed out to be responsible in the case of England – the rise in the profits of capitalists through the suppression of real wage growth – is empirically questionable. But while Hamilton's mechanism in explaining the case of England rested on a change in relative prices and the idea that both rents and wages lag behind prices and returns to capital, in turn his political economy story in explaining the fall of Spain has held up better (Drelichman 2005a, 2005b). My focus and proposed mechanisms are different, but I support the view that American precious metals had a large causal impact in the evolution of Europe's early modern economy. However, my focus is on the impact of Northwestern Europe, particularly England.

Let me consider each of these issues in turn. First, my thesis does not consider political economy mechanisms. Perhaps they were important, and indeed it may well be that political factors were what precious metals interacted with such that in Northwestern Europe they had a very different impact from that in the South, as I document in chapter 3 of this thesis. But I do not consider a "class effects interpretation" of the injections, as does Hamilton, when arguing that in Northwestern Europe the profits of "capitalists" rose through a decrease of real wages

caused by inflation. Instead, in chapter 5 I put the emphasis on the decrease of transaction costs caused by the additional availability of liquidity.

3.3. The Great Depression and "Great Recession" debates

Though I do not wish to develop this topic too much, it must be said that in addition to the well-known position of Friedman and Schwartz (2008/1963) many other prominent views on the explanatory reasons for the Great Depression – such as the notion of debt-deflation or the role of the gold standard (Eichengreen 1992) – imply that, at least in the short-run, money is not neutral. Equally so, the considerable amount of work done in macroeconomics since the mid-1990s on "monetary policy under the zero lower bound" – inspired first by the experience of Japan since the early 1990s and more recently by the "Great Recession" – implicitly assumes that money is not neutral, at least in the short run (Eggertsson and Woodford 2003).

4. How do we identify the effects of money on real variables?

Macroeconomics suffers from severe identification problems. It is very difficult to know the effect of policies because usually no identifying variation exists, which is essentially the same as saying that no valid control groups are available, or that we cannot keep "all else constant" when evaluating the effects of a specific policy. Unfortunately, economic history often shares the same kind of problems.

There are other fields in which these problems are less severe, however, and where because of this, there has been much recent emphasis on "clean identification" – namely, labor and development economics. In these fields, research in the last twenty years has moved away from the use of structural models and towards the usage of randomized controlled trials or, when this is not possible, (quasi-)natural experiments.

Natural experiments have indeed at times been used in economic history applications (eg. Nunn and Qian 2011, Diamond and Robinson 2010), though their usage is still rare. It is well know that there are limitations to these techniques, however. First, they often limit the kind of questions that they let us ask. There are many questions which can be of policy or historical interest but for which no natural experiment is available. Limiting ourselves to studying situations for which plausible natural experiments are available would mean to exclude much of the past (and would encourage conceptual overstretching on the part of researchers). Second,

these are reduced-form methods that do not tell us *why* an effect exists. For that we need a story – a narrative, or a model, which describes a mechanism. Nonetheless, sometimes useful episodes can indeed be found, and in this thesis I propose one.

5. Concluding thoughts

Economic history often faces a trade-off between importance and rigor of subject matter. It is often the case that we know some phenomena is likely to have been important but it is hard to make research progress due to identification problems such as lack of sufficient data on appropriate control groups. The importance of institutions for economic growth is the most obvious example of the difficulties generated by measurement problems and it is this difficulty which may have pushed it – and with it the entire field of economic history, one may venture – down the ranking of economists' research priorities until progress along data and econometric lines has finally made headway in the last decade or so.

The emergence of the "Great Divergence" debate to its now central place in economic history may well be one such story. While twenty years ago economic historians were asking why did the industrial revolution had happened in England and not France (Crafts 1977, O'Brien and Keyder 2011/1978), they are now much more likely to ask the much more important question of why did it happened in Europe and not China (Allen 2012). The key player in bringing about this change has been Kenneth Pomeranz, but other members of the "California School" such as Bin Wong, Jack Goldstone, and Andre Gunder Frank have also been important.

In the case of Europe, the broad views of the "California school" have been mirrored by those who argue, based on real wage evidence, that Europe's economy was essentially stagnated at a long term Malthusian equilibrium until relatively late (Allen 2001, 2003, Clark 2005). There are at least three major problems with this sort of evidence. The first is the obvious one that it ignores land and capital returns, changes in income distribution, and structural change. The second is more subtle, and it is that the measured nominal wage underlying the calculation of the real wage is the *daily* nominal wage. If people were working more hours – an industrial revolution which would have occurred in response to the increased economic opportunities and incentives generated by the empire effects – then this effect would be completely absent from the real wage evidence, which would give a misleading view of stagnation.

In fact, despite the image of stagnation propagated by Allen and Clark, English incomes doubled between the fourteenth century and 1700 and doubled again until 1850 (Broadberry et al 2015). The third reason why evidence based on real wages can be misleading is also relatively non-obvious, and has to do with the effects of changes in relative prices. Basic microeconomics suggests that people should be minimizing the cost of achieving any given utility level, and this would imply that they should be adjusting consumption baskets according to, for example, the relative cost of maize versus wheat-based foods. We know that due to the Columbian exchange and other factors the relative cost of goods changed during the early modern period, and yet most real wage evidence is based on a fixed Strasbourg basket, for 1745-54.

All these reasons suggest that evidence based on real wages greatly underestimates the magnitude of European early modern growth before 1800. These were not static, Malthusian economies. Most of that growth was of a Smithian rather than Schumpeterian kind, granted, but it was intensive growth nonetheless. Much additional growth happened in an extensive form (i.e. through population increases), which, through density and scale effects such as those emphasized by some versions of unified growth theory and the agglomeration economies literature, interacted with European institutions to contribute to the emergence of modern economic growth.

In the last few decades, the macroeconomics profession has tended to "take agency away from money", by instead emphasizing fiscal causes for monetary expansions (Sargent and Wallace 1981, Sims 1994). These have been important. But by contrast, in this thesis, I argue that monetary developments which were independent of government demands for fiscal revenue do matter a great deal for our understanding of the development of the European economy over the early modern period.

In the following chapters, I measure some aspects of the consequences for Europe which resulted from the increase in money supply which followed from its access to the mines of precious metals in America. Specifically, in chapter 3 I identify the "short-run" effect of the resulting monetary injections on European prices, nominal GDP, and real GDP. Then in chapters 4 and 5, which focus on England, I measure the increase in money supply over time, and argue that it allowed for economic growth over the long term, which would have otherwise been largely arrested by deflationary forces, illiquidity, and high transaction costs.

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Chapter 3. The existence and persistence of liquidity effects: evidence from a large-scale historical natural experiment[15]

1. Introduction

Is monetary policy capable of stimulating economies, and if so, by what degree and duration? In this paper I argue that early modern discoveries and production of precious metals in America can be explored for identification of monetary shocks. The key idea is that under the commodity money system which prevailed during the early modern period, variation in availability of precious metals caused by discovery and varying levels of production in American mines lead to exogenous variation in the realized availability of money in Europe. This identification strategy hence allows the recovery of reduced-form point estimates of the effects of exogenous changes in money supply on the economy. I find that after production of precious metals in America increased 10% in any given year, real GDP in Europe subsequently rose, to a peak of 1.3% four years later. The evidence suggests this is because prices responded to monetary injections only with considerable lags.

Modern empirical monetary economics suffers from a difficult identification problem in that variation in the money supply is not exogenous to the state of the economy. Central banks respond to the state of the economy and try to influence, as well as respond, to agents' expectations.[16] This joint causality leads to a fundamental identification problem that prevents straightforward inference. Since central banks tend to pump up the monetary base[17] during, or when they anticipate, a recession, simple correlations could suggest that money has

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[16] Additionally, in modern economies most of the money supply is inside liquidity: created endogenously by the banking system, broadly defined. Furtermore, third-party causality may be a problem, as other (unobserved) factors may affect both the state of the economy and monetary policy, leading to "ommited variable bias".

[17] Nowadays this is done indirectly, using an interest rate rule, hence central banks cannot be said to control the quantity of outside money. Additionally, in modern economies most of the money supply is inside liquidity: created endogenously by the banking system, broadly defined.

no effect, or even a negative effect on output, even if the exact opposite is true in a causal sense.

The modern literature on the identification problem caused by money endogeneity goes back at least to James Tobin's critiques of Friedman and Schwartz (2008/1963), but the debate has not converged to a consensus. Lately, the empirical macroeconomics literature has attempted two main strategies to deal with this problem: some studies attempt to recover structural shocks through a "narrative approach" (Romer and Romer 1989, 2004); others follow a more technical approach, using recursive VAR's (Christiano, Eichenbaum and Evans 1999) or interest rate futures surprises on FOMC dates as instruments (Gertler and Karadi 2015). While many of these studies tend to conclude that money matters, even that basic result is by no means universal. Indeed, much disagreement remains with respect to the timing, transmission mechanism, and importantly, impact magnitude: the estimated effects ranging from essentially zero[18], to moderate[19] to large.[20] Additionally, both the narrative and the recursive VAR identification strategies have been criticized on identification grounds (Leeper 1994, Chari Kehoe and McGrattan 2008).[21]

In principle, every macroeconomist should agree that an empirical approach would preferable to identification based on recursive order, sign restrictions or stand-alone theoretical models, as long as a source of exogenous variation was available.[22] Here, I propose how to construct this, and my empirical study additionally brings the advantage of covering a much longer period that is usually the case in empirical macroeconomics – 231 years. This is probably the longest macro panel ever assembled. Of course, my results apply in the context of the period

[18] Uhlig (2005) uses sign restrictions to argue that full neutrality of monetary policy shocks is not inconsistent with the data. Williamson and Wright (2011) altogether insist that "money is neutral". See also Sims and Zha (2006).
[19] Christiano, Eichenbaum and Evans (1999, 2005) and Coibion (2012).
[20] Romer and Romer (1989, 2004), Angrist and Kuersteiner (2011), Cloyne and Huertgen (2014), Barakchian and Crowe (2014).
[21] I have here cited some of the "modern classics" of this literature, but this is today an active area of research, as new methods are always appearing. To the best of my knowledge all this new research is focused on new methods. Instead, I propose a new approach which relies on new data, spanning over a very long horizon, combined with an historical natural experiment identification strategy.
[22] Of course, as always with IV's and natural experiments, identifying an effect does not tell us why it exists or if it is externally valid, and in this respect structural models which can shed light on mechanisms remain useful and complementary to reduced-form identification methods. Here, by "liquidity effects" I simply mean the reduced form real effects of changes in the quantity of money, without entering into detail about the specific transmission mechanism.

under consideration; I make no claims about the size or persistence of liquidity effects for modern economies.

Nevertheless, my line of attack complements recent developments in macroeconomics. While previous research argued that prices were too volatile to be consistent with the notion of sticky prices (Blis and Klenow 2004), recent research has used large microeconomic datasets to argue that even if prices look volatile this is due to temporary sales following sticky plans, and hence the aggregate price level is, indeed, sticky – and by implication, reactive to monetary policy (Anderson et al 2013, Nakamura and Steinsson 2008, Guimarães and Sheedy 2011, Kehoe and Midrigan 2010, Gorodnichenko and Weber 2016).

In addition to a section on the historical background, this paper has essentially two parts. The first of these takes as a given that the production of precious metals in America was exogenous to the state of the European economy, and identifies the effects of additional availability of outside liquidity on GDP and prices. In the following section I defend the validity of the natural experiment on several grounds. First, I show that the (considerable) variation of nominal GDP and prices explained by regional-level weather shocks (variation in air temperature and rainfall) cannot explain the future variation of production of precious metals in America. Second, I also show that the timing of the discovery of new mines or the intensity of production in America was not responding to the market price of silver and gold in Europe. Third, in order to account for the possible endogenous formation of expectations, I show that variation in the value of production of precious metals in America was close to white noise, so it could not have been predicted in advance. Finally, shifting the discussion from production in America to shipments to Europe, I show that the unanticipated component of the injections can be measured as the difference between the quantities that a comprehensive source which was private information to the receiving agents said was arriving compared with what the commercial newspapers announced. I show that this measure, too, was approximately white noise. Hence, even if agents had rational expectations and were using the best publicly available information, they could not have optimized according to the quantities arriving, as they would not have been able to predict these in advance.

2. Historical background

2.1. The early modern commodity money system

The early modern monetary system was a commodity money system. Precious metals, chiefly silver and gold, were a required input for the production of coinage.[23] In general circulation was by tale (within national boundaries), though in the case of gold and silver coins (but not copper) there was a large component of intrinsic value. There were no central banks in the modern sense, but there was monetary policy – mint policy – and the monetary authority decided the rate at which private agents could transform precious metals into currency. The avaliability of precious metals mattered for the determination of how much new coin supply was minted. Challis (1992, p. 431), for instance, argues that the output of gold, "though a regular feature of production, was subject to wide fluctuation, and it was not unknown for the Mint to have to strike more in a single year than it had in the previous five … but these variations were outside of the Mint's control, since it depended entirely on what importers chose to deliver to it for coining, on windfalls of captured treasure, and on decisions by the government". These decisions themselves evidently depended on the government's perception of the availability of precious metals.

Other liquid means of exchange, which were less liquid than coin but functionally money as well, also existed. These included forms of "inside money" such as bills of exchange and banknotes, but it is important not to exaggerate their importance in this period (Table 1).[24] These were complements to, not substitutes for, the more liquid and widely accepted bullion-based currency (Nightingale 1990), and could not substitute for them over the long term because of credibility restrictions (Palma 2015b). Although the supply of precious metals was inelastic (at least over the medium to long run), and precious metals were a critical input in the production of money, it was nonetheless true that, as today, the total quantity of money

[23] I emphasize that I am here referring to legal tender coinage alone, rather than money more broadly. In some periods there was also some private coinage of mostly small change based on copper, which circulated well above "intrinsic worth" (Seglin 2008). Coins based on copper, whether provided by governments or private parties, were always akin to fiat money, but could only be used for quite small transactions (Sargent and Velde 2002).

[24] Table 1 illustrates the case of England, but in continental Europe coin generally played an even more important role; indeed as late as the 1860s, "On the Continent … specie accounted for somewhere between one-half and three-quarters of the money supply" (Flandreau 2004, p. 3)

was potentially endogenous to the state of the economy (at least in the short run). This was because the decision of the monetary authority to engage in forms of monetary manipulation such as debasements (whether "defensive" or "aggressive") or changes in the mint price were always responses to macroeconomic and political conditions.

	1600 (Mayhew)	1688 (Cameron)	1700 (Capie)	1750 (Cameron)	1750 (Capie)	1790 (Capie)	1870 (Capie)
Coin	3.5	10	7	15	18	44	95
Bank of England notes	-	-	1.5	4.3	4	8	35
Other notes (country banknotes)	-	-	0	0.7	1	4	4.9
Bank balances at the bank of England	-	-	-	1.9	-	-	6.5
Other means of payment	1	10	n/a	18.1	n/a	n/a	n/a
Total (M2)	4.5	20	>8.5	40	>23	>56	>141.4

Table 1. Estimates for the components of English nominal money supply. Unit: millions of £. Sources: Mayhew (2013), Capie (2004) and Cameron (1967). The category "other means of payment" includes Cameron's £ 6m in government tallies and £2 m in inland bills in 1688 and £ 3.1m in deposits in private banks in 1750.

2.2. A New World of precious metals

In a well-documented episode, the Inca emperor Atahulpa, having been captured by the Spanish in November 1532, agreed to exchange his release for a twenty-two-foot by seventeen-foot room filled with gold, and twice that amount in silver. His subjects duly delivered the sum, presenting 13,200 pounds (6,000 kilograms) of gold and 26,000 pounds (11,800 kilograms) of silver to the Spanish, who nonetheless still executed him following a mock trial.[25] The ransom of Atahualpa constituted much of the gold production in Peru during that decade. However, as far as the production of precious metals in the Americas was concerned, this sort of episode was the exception, not the rule – the vast majority of precious

[25] These quantities are an approximation given by TePaske (2010), which cites other figures as well, but there is broad agreement on the approximate numbers. For a lively account of this episode, see Diamond (1998).

metals were extracted, not plundered from American civilizations. Furthermore, and also be-betraying the mythical search for the American *El Dorado*, most of the value came from silver, not gold.

The enormous quantities of precious metals which were duly imported to Europe during the early modern period dwarf the initially available stocks (Table 2).[26] Indeed, the New World was the main source of production for precious metals at the world level during the early modern period (Figure 1; see also Barret 1990). As TePaske emphasizes, much of the overall early modern production occurred in Mexico, especially in Zacatecas and after the mid-seventeenth century.[27] The same is still true, though to a slightly lesser degree, if precious metals are measured in real value terms. In any case, together, Mexico and Peru were responsible for over 99% of the production of silver in the whole of the American continent during the early modern period. In turn Brazil was responsible for most of the production of gold. Despite Christopher Columbus's early obsession with searching for gold – and the early success of finding moderate quantities in the Caribbean (Vilar 1974) – the history of mining up to the eighteenth century was overwhelmingly one of silver (Figures 2 and 3, Table 2).[28]

	Fine silver, tonnes	Gold, silver equivalent tonnes
Initial stock, Europe (1492)	3,600	297
Imports to Europe		
1500-1600	7,500	150
160-1700	26,168	158
1700-1800	39,157	1,400
Total Imports	72,825	1,708

Table 2. Specie stocks and flows. Sources: Initial stock from Braudel and Spooner (1967), as endorsed by Velde and Weber (2000, p. 1230); flows from Morineau (2009).

[26] In fact, Table 2 shows the quantities imported directly to Europe alone, ignoring the importance of the quantities of silver exported directly from America to Asia through the Pacific, which also had important stimulative consequences for the European economies by making the trade with Asia possible (Palma and Silva 2015).

[27] Earlier on, Potosí and other areas of the Spanish vice-Royalty of Peru (much of which including Potosí, located in modern Bolívia) had been dominant from the mid-sixteenth to the mid-seventeenth century.

[28] Figure A1 of the appendix shows the distribution of precious metal production across New World regions.

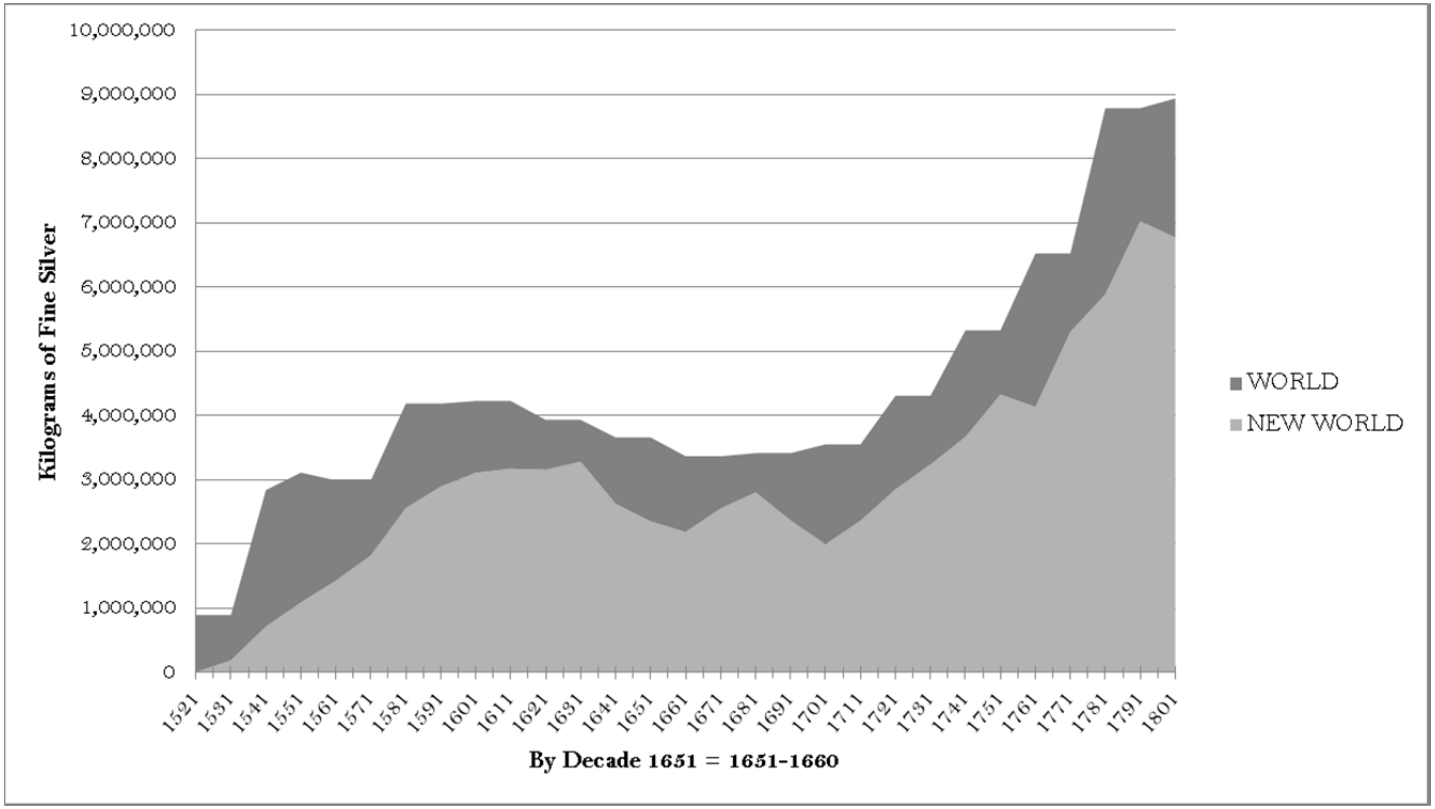

Figure 1. World vs. New World silver output, 1521-1810, in kg. Source: TePaske (2010, p.111)

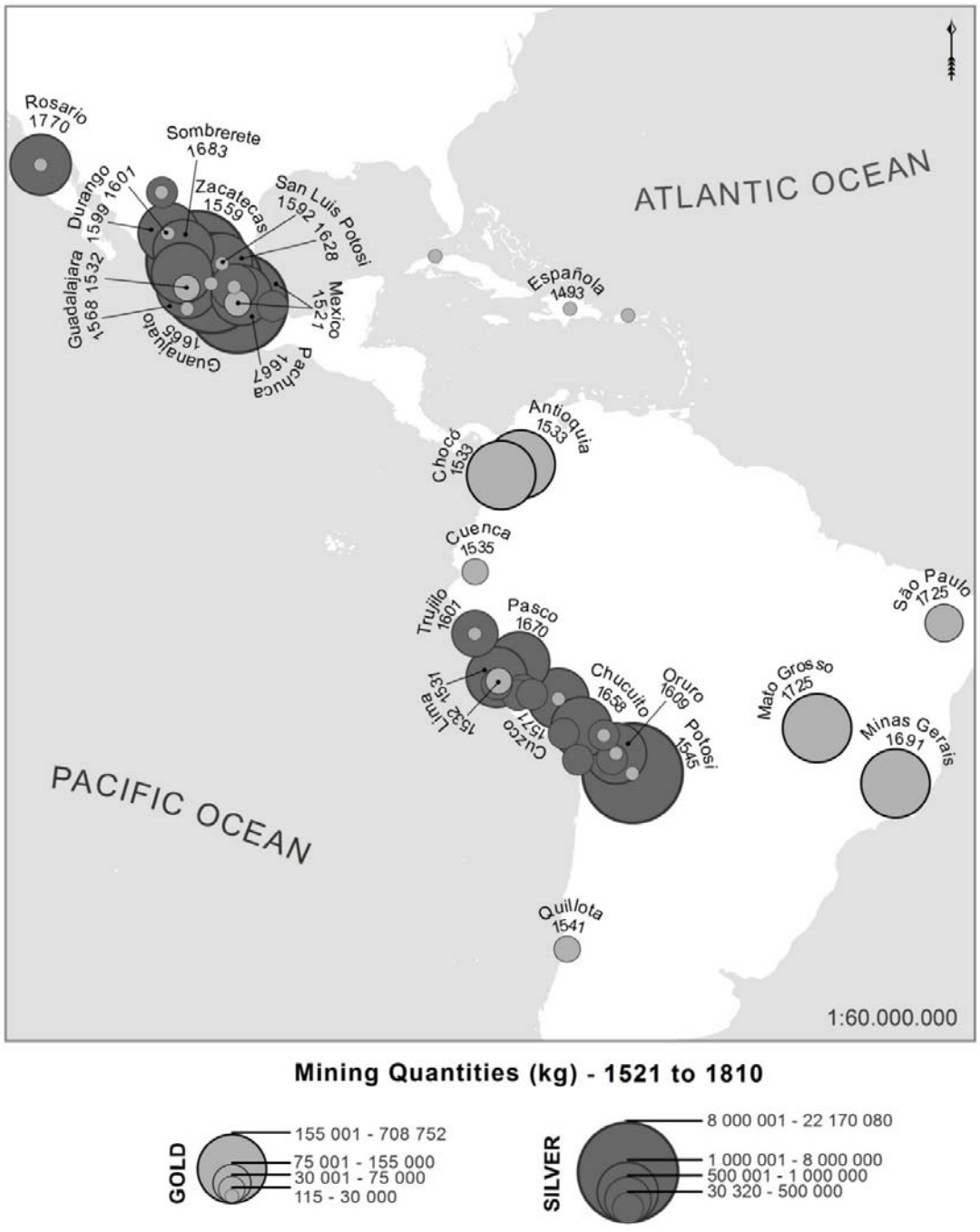

Figure 2. Location of the mines, initial date of records and mining quantities. Source for the underlying data: TePaske (2010)

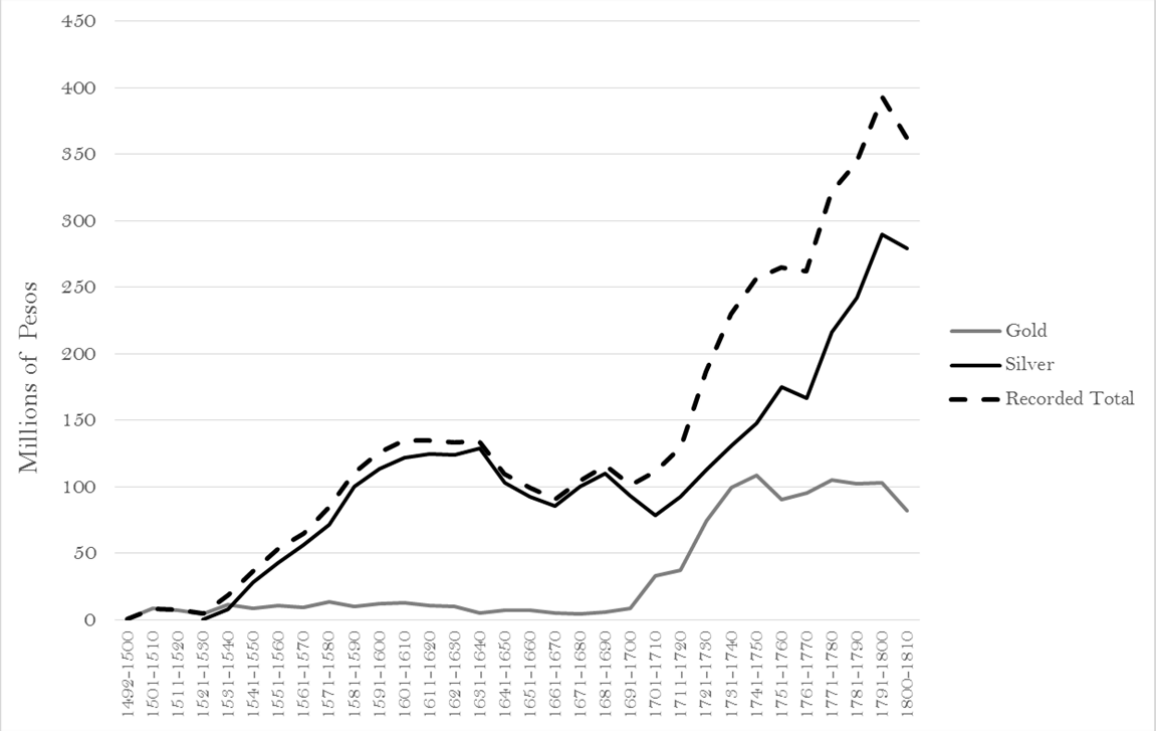

Figure 3. The distribution of New World gold and silver registered production, 1492-1810 (10-year averages). In pesos of 272 Maravedís. Source: TePaske (2010).

2.3. The determinants of the production of American precious metals

Was the discovery and production of precious metals in America exogenous to short-term variation of the state of the European economy? The key identification assumption in this paper is that it was. I now discuss whether it is reasonable to assume this from an historical point of view. In Section 4 below, I additionally defend this assumption using statistical analysis, such as using weather shocks as an IV for the state of the European economy.

The historical evidence suggests that prior to the discovery of the American continent, mining in Europe was indeed largely endogenous to the European economy. The silver mines of central Europe (mainly Saxony, Bohemia and Hungary), which had reopened in the fourteenth century, were explored at the margin, and in fact became uncompetitive and closed towards the mid-sixteenth century once Potosí and the rest of America increasingly became available. But in America matters were different. Faced with the possibility of finding a new mountain of silver or gold, spot prices for precious metals matter little in inducing additional search effort. The search intensity decision was based

on constraints such access to capital and the feasibility of entering unknown territories under reasonable conditions of security and health.

The history of the European colonization of America is, well into the sixteenth century, largely a history of search for sources of precious metals. Over and over again explorers searched – usually in vain – for multiple *El Dorados*. While their motivation and struggles are well documented, there are no documented cases for which either investors or explorers decided to go ahead or cancel an expedition based on a short-term variation in the general economic condition of the home economy or the price for precious metals. This was never a decision on the margin, because it was simply not possible to form expectations, since the relevant probabilities were unknown, and unknowable. It was impossible to know in advance, where, or if, precious metals might exist, even though some characteristics associated with the presence of precious metals were known, such as high altitudes or mountains. Explorers could and did ask the natives, but more often than not the result would be a red herring. Speculation about the possibility of gold or silver mines existing in the Brazilian interior had been going on for about two centuries when significant gold mines were finally found.[29] All available evidence suggests that the timing of gold discoveries was not anticipated.

But even if the timing of discoveries were exogenous to the state of the European economy, were the mining intensity decisions exogenous to the current state of the European economy? This was indeed the case as the intensity of mining was driven by availability of technology and local cost conditions, not demand. Once a rich mine was found, and fixed costs were invested as needed, then for a long time the price was necessarily well above the cost of operation, and price variations would have been insufficient to induce changes in the intensity of mining. Due to capital, entrepreneurial, and physical constraints, in the short term marginal cost was increasing with output. The costs dictated mining intensity, since compared with them, the price which dictates revenue was of second order. This is analogous to modern mining operations in developing countries, for which "operations are expensive to set up and it only makes sense to stop digging if prices fall below variable costs" (The Economist 2013). Furthermore, while today most mining operations are run by large corporate companies

[29] About two decades before, in 1677, the former governor of Rio de Janeiro (the main city at the time) had testified to the national authorities (*Conselho Ultramarino*) that no gold existed in Brazil (Figueiredo 2012, p. 64 and p. 234).

such as Rio Tinto, in colonial America mines were managed by individuals who faced a short life expectancy and much more uncertain property rights, and hence were likely to operate with a much shorter-term planning horizon. This is confirmed by the narrative evidence (eg. TePaske 2010, p. 32-33, 36) and also illustrated by the fact that, as Figure 4 illustrates, following the discovery of a new mine, usually most of the quantities extracted happened in the first few decades immediately after the discovery.

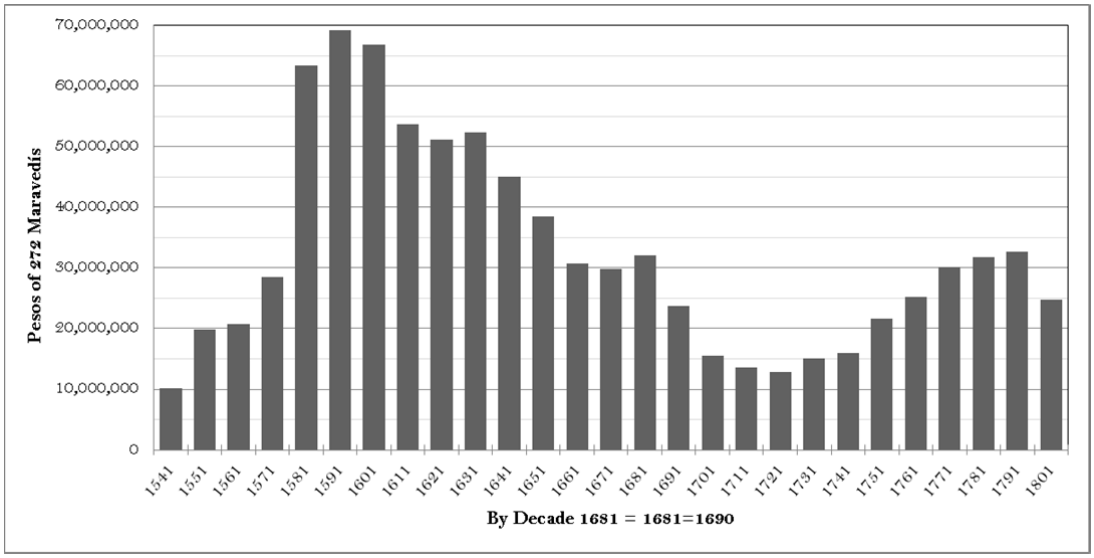

Figure 4. The long-term trends of Potosí silver output. Source: TePaske (2010).

Furthermore, Figure 4 shows unconditional results, but controlling for technical change would make this result even stronger. This is because an exception to the general rule that most of the quantities extracted happened in the decades following the discovery of each mine was sometimes caused by the introduction of new mining techniques, which would raise the TFP of the mining production function. Here I now discuss the most well-known example, which is given by the application of the mercury amalgamation (also known as *patio*) process to the Potosí mines. It supports the general rule that the timing of the decision was not based on the state of the European economy, but instead on local conditions in America.

After the approximately simultaneous discovery of the Mexican and Peruvian silver mines in 1545-6, the first to be explored were the richest veins, following the ancient Native American technology known as the *guaira* technique. Technical progress was present but slow; and by the mid-1560s production was in clear decline following the depletion of the richest surface ores. Yet the exploration of underground ores required

more advanced technology combined with a substantial fixed investment (Gardner 1988, p. 909). Following the visit of the Viceroy Francisco de Toledo in 1570-72, the mercury amalgam process, which had been invented a few years before, was introduced, together with the *mita* system of forced labor, under which a certain percentage of Native Americans had to provide forced labor. Amalgamation was introduced to Potosí between 1571and 1576, and as a result production boomed (Figure 5; see also Bakewell 1977, p. 75).

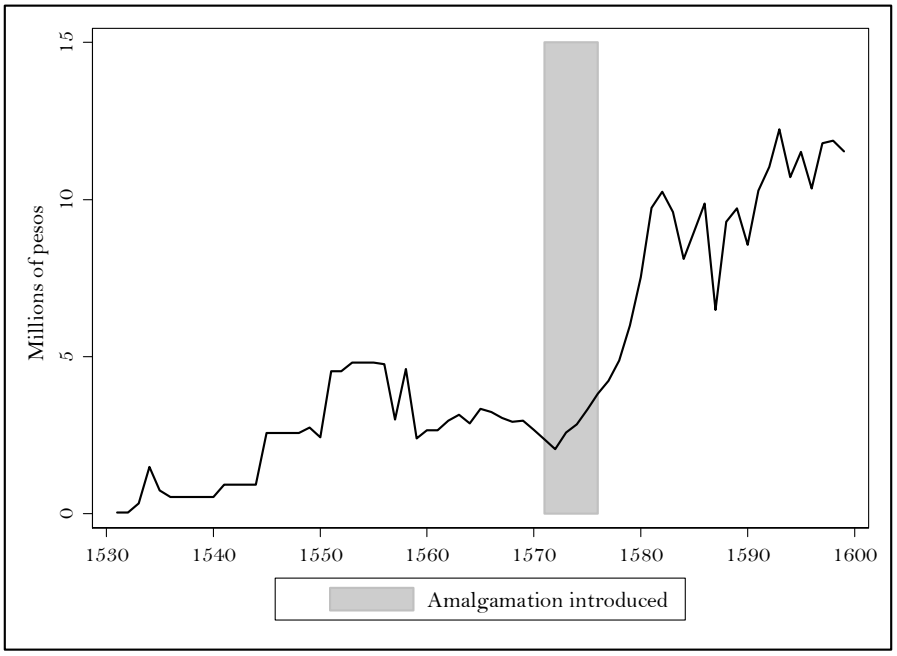

Figure 5. Potosí silver output around the time of the introduction of the amalgamation process. Source: TePaske (2010).

Both of these factors led to an upsurge in the mines' productivity (Vilar 1969, p. 121-2). But it is important to realize that "[w]ithout the capacity to refine poor ores that amalgamation gave to Potosí, enlarging the labour force would have been of little use" (Bakewell 1977, p. 58). This case study suggests that the timing of different quantities of production was hence dictated by local production costs, themselves conditional on the available technology at a given moment, which itself depended, among other things, on local administrative conditions – but not on short-term variation in the state of the European economy. Over a much longer period of time, of course, new technologies developed partly in response to the ambition to produce more precious metals in America. But this surely took longer than a few years, and if so it does not affect the identification strategy which I adopt here.

In sum, while it would be pointless to describe the production cycle of each mine, for each case the timing of discoveries led to the usual hum-shaped production pattern as initially the richest veins were explored, followed by diminishing returns only occasionally interrupted by technical change, access to slaves, or the additional integration of the different elements of the colonial economies, in particular, the farming, grazing, and mining sectors.[30] Several regions simply went through an unconditional hump-shaped response, as suggested by Figure 4 and as also happened in the important case of eighteenth-century Brazil (TePaske 2010, p. 47). In no case has the state of the European economy been given by historians as a reason to explain variation in the timing of short-term production of precious metals in America. Some historians do claim that the timing of the voyages of discoveries themselves had the late-medieval gold bullion famine as a cause (eg. Vilar 1969, Godinho 2008/1944). This does not refer to discoveries of production within America once the continent was found, however, and in any case historians have a much longer term in mind, , i.e. they are only refering to "secular " endogeneity.

3. Empirical implementation and identification strategy

The main idea of this paper is that the discovery and production of precious metals in America during the early modern period can be used as a source of exogenous variation for the money supplies of Europe. The dependent variables of interest are output and a measure of the price level (here the GDP deflator). Since the shock – the production of precious metals in America each year – is common to every country, the identification is not coming from different cross-sectional exposure, but from time-variation in the shock. Given that these were integrated economies[31] , the shocks will have affected them all, even if possibly with different timing.

I independently estimate single equations for nominal GDP, the price level, and real GDP: as long as variation in the dependent variable was indeed exogenous, the estimated parameters identify reduced form point effects, hence an explicit system of equations is not

[30] For a review of the literature for the important case of New Granada see the references cited in TePaske 2010, pp. 38-9, who also endorses this view.

[31] Exactly by how much depends on the exact definition and metric used to measure integration (Federico 2011), but there is no question that all of these economies traded with each other, and it is likely that there was some co-movement in international business cycles.

required. I interpret the mechanism as a "liquidity effect" because I assume it operated through the money supply, though data for this is not observable.[32] As in Romer and Romer (2004, p. 1068), the baseline specification simply includes as dependent variables a constant and lagged values of itself and of the shocks.[33] I additionally show that including measures for supply shocks (weather shocks) has little impact on the results.

3.1. Data

The period covered by this study is 1531 to 1790. Six countries are included: England/GB, Holland, Italy, Spain, Portugal, and Sweden. All the sources and data transformation procedures are described in the appendix. The starting date is determined by data availability for annual mining quantities.[34] As for the second date, it is determined by two reasons. First, it is around that time that coin supply loses its comparative importance as a percentage of money supply, because of the rise of paper money, initially in Britain (O'Brien and Palma 2015), but also progressively elsewhere (Roberts and Velde 2014). And second, the outset of modern economic growth in some of the countries in the sample would lead to nonstationarity in the GDP series (even when using first differences) and hence some confounding problems.[35] The panel is "almost" balanced: Sweden's data starts almost three decades later than the others (1560), but other than this every variable is available for every country annually. This means that this dataset is several order of magnitudes larger than the typical dataset used in the empirical macroeconomics literature that aims to identify the effect of monetary shocks, even when quarterly data is used in those studies.

[32] The only exception is England, for which money supply is available from Palma (2015a). This case confirms a steep increase in money supply during the early modern period. However, as explained in that paper, the reconstruction method, while leading to data which is representative of long-time trends, is likely to miss much high-frequency variation. Hence, it is not liable to be used to identify short-term liquidity effects.

[33] As long as the shocks are indeed structural they will not, up to a random error (asymptotically), be correlated with other variables that influence output so no additional controls need to be included.

[34] The precious metals output data is quite complete after this date (TePaske 2010). In any case I was guided by the principle that I am here estimating a lower bound to the true quantities mined (because of incomplete records or the possibility of smuggling). It would not be possible to go much further back anyway, as evidently earlier there would be no variation in the production levels, which would be flat at zero.

[35] Furthermore, the French revolutionary and Napoleonic wars combined with the rise of paper money also led to inflationary experiences with fiscal origins in several countries during the 1790s (see for instance Sargent and Velde 1995 for the experience of France), events which were unrelated to the production of precious metals in American mines.

The key variables which I use are as follows. (See the appendix for an extensive account of the data sources and characteristics.) The dependent variables of interest are nominal GDP, the GDP deflator, and real GDP. In turn the main independent variable is the value of precious metals production in America. In the case of silver, all data corresponds to annual variation in (the value of) production, with the exception of the short periods of 1536-59 for Lima and 1531-1559 for Mexico, for which I am forced to use the annualized values of ten-year averages as no annual data is available.[36] As far as gold is concerned, unlike in the case of silver to the best of my knowledge no systematic annual production information exists.[37] I hence use ten-year averages, taken from TePaske's (2010) compilation of sources. Translating gold ounces to silver pesos has implied a conversion through both value and the relative price of gold and silver (available through Neal 1990 and McCusker 1978). This leads to some loss of high-frequency variation but the basic results hold whether or not gold is included.

3.2. Basic results for a panel of European countries

I now discuss the reduced-form results for my panel of European countries. For most countries all of the dependent variables are nonstationary across the entire sample. To deal with this there are, in principle, several options, the simplest and most transparent of which is to use first differences.[38] The first equation estimated is as follows:

$$\Delta y_{i,t}^{nom} = const + \sum_{j=1}^{6} a_j \Delta s_{t-j} + \sum_{j=1}^{4} \beta_j \Delta y_{i,t}^{nom} + x_{i,t}' \gamma + e_i + u_{it}$$

Here, i denotes countries and t time periods, at an annual frequency. $\Delta y_{i,t}^{nom}$ is the first difference of the natural log (i.e. approximately the growth rate) of nominal GDP, Δs_{t-j} is the first difference of the natural logarithm of production of precious metals in America at time $t-j$ and $x_{i,t}$ is a vector of optional country-specific controls.[39] Finally, e_i is a time-invariant, country-specific fixed effect, and $u_{i,t}$ is the error term.[40] For all specifications,

[36] Since this corresponds to some loss of high-frequency variation in the dependent variable, it should if anything reduce the statistical significance of my results.
[37] Instead, what does exist at the annual level is both minting and shipping information in the case of Brazilian and Mexican gold in the eighteenth century, and less systematically so in the case of some of the earlier Caribbean and Columbian episodes. See Vilar (1969), Costa, Rocha and Sousa (2013).
[38] Figure A2 of the appendix shows each variable, for each country, in first differences. Panel ADF tests cannot reject at standard levels of significance that the data is stationary in first differences. (They also do not reject a levels equation with a deterministic trend.)
[39] The fact that lags of the dependent variable are included as controls also helps account for serial correlation in the error term.
[40] Notice that the criticism of Nickell (1981) only applies to "short"panels. When T is large, as is the case here, the fixed-effect (within) estimator is consistent, and there is no need to use a dynamic panel model.

the number of lags has been selected according to the BIC criteria. (Unlike the AIC, the BIC is consistent.) For some close specifications the BIC varies little, but it clearly indi- indicates that a large number of dependent variable lags corresponds to overfitting, and that a higher number of lags for the shocks are advised. I have settled for the BIC's optimal choice of 4 lags for $\Delta y_{i,t}^{nom}$ and 6 for the shocks, but the exact choice of lags is not determinant for the results.

In this regression, the a_j's are the main parameters of interest. They identify an unweighted average effect of additional availability of precious metals on nominal GDP, controlling for output dynamics (plus possibly additional controls). Column (1) is a basic specification, while column (2) is the baseline specification which additionally controls for supply-side shocks (here given by weather variation). Column (3) is a placebo robustness test, discussed below. Notice that as long as production levels in America were exogenous to past, present and future realizations of income in Europe, the a_j coefficient identifies the reduced-form effect of precious metal production – an effect which presumably, operated through national money supplies – and no additional controls are required.[41] The controls $x_{i,t}$ include polynomials of a deterministic time trend, to account for any possible remaining dynamics, and supply shocks proxied by weather variables.[42] The latter are alternatively the absolute level or the rate of change of temperature, rainfall, and interactions between these variables.

Table 3 shows the results. These suggest that nominal GDP responds strongly to the increased availability of precious metals, and that the positive effects persist up to at least five years later. These results show that a 10% increase in production of precious metals in the American continent leads to a hum-shaped response of nominal GDP, with a peak effect of about 7% around years 2-3, all else constant.[43] Strikingly, the type of response found here is – not only for nominal output but also prices and real output, as discussed next – is qualitatively consistent with the response to monetary shocks found for the modern US economy in much of the macroeconomics literature (Christiano, Eichenbaum and Evans 1999, Romer and Romer 2004).

[41] Also, notice that for all t, s_t does not vary across i. That is, the shock is common to all countries: $\Delta s_{i,t-j} = \Delta s_{t-j}$ for all i.
[42] The final specification includes only weather variables which control for supply shocks. This is because polynomials of a time trend (e.g.$a_1 t + a_2 t^2$), which I have included to account for any remaining dynamics, turn out not to be individually or jointly significant, and the BIC increases relative to the baseline specification, which suggests overfitting. Hence I have not included them.
[43] Years 2 to 4 are individually significant at conventional levels.

Dependent variable: First difference of the ln of nominal GDP	**(1)**	**(2)**	**(3) (placebo)**
Estimator	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)
Constant	.009** (.004)	.009** (.004)	.009** (.004)
First difference of the ln of nominal GDP(-1)	-.228*** (.026)	-.228*** (.026)	-.230*** (.026)
First difference of the ln of nominal GDP(-2)	-.187*** (.026)	-.188*** (.026)	-.188*** (.027)
First difference of the ln of nominal GDP(-3)	-.056** (.026)	-.053** (.026)	-.054** (.027)
First difference of the ln of nominal GDP(-4)	-.031 (.026)	-.032 (.026)	-.034 (.026)
First difference of the ln of precious metals production (-1)	.034 (.024)	.035 (.024)	.033 (.025)
First difference of the ln of precious metals production (-2)	.069*** (.025)	.069*** (.025)	.068*** (.026)
First difference of the ln of precious metals production (-3)	.067*** (.026)	.066** (.026)	.067** (.026)
First difference of the ln of precious metals production (-4)	.043** (.025)	.043* (.025)	.044* (.026)
First difference of the ln of precious metals production (-5)	.016 (.025)	.020 (.024)	.019 (.025)
First difference of the ln of precious metals production (-6)	-.017 (.023)	-.018 (.024)	-.0194 (.024)
First difference of the ln of precious metals production (+1)	-	-	.016 (.025)
First difference of the ln of precious metals production (+2)	-	-	.003 (.026)
First difference of the ln of precious metals production (+3)	-	-	-.015 (.026)
First difference of the ln of precious metals production (+4)	-	-	-.023 (.026)
First difference of the ln of precious metals production (+5)	-	-	.002 (.026)
First difference of the ln of precious metals production (+6)	-	-	-.012 (.025)
WEATHER CONTROLS	NO	YES	YES
COUNTRY FIXED EFFECTS	YES	YES	YES
BIC criteria	-1718.43	-1699.47	-1585.196
R^2	Within: 0.0747 Between: 0.9868 Overall: 0.0707	Within: 0.0747 Between: 0.9868 Overall: 0.0707	Within: 0.0759 Between: 0.9863 Overall: 0.0720
observations	1491	1491	1455

Table 3. The nominal GDP equation, 1531-1790. The lags of the dependent variable included as controls account for potential serial correlation in the error term. The "weather controls" include the current level and 2 lags of the country-specific air temperature. Standard errors (in parentheses) are bootstrapped with 1000 replications. *, ** and *** denote individual statistical significance at the 10, 5, and 1% levels.

A second equation concerns the price level (Table 4),

$$\Delta p_{i,t} = const + \sum_{j=1}^{6} \delta_j \Delta s_{t-j} + \sum_{j=1}^{4} \phi_j \Delta p_{i,t-j} + x'_{i,t}\,\eta + e_i + u_{it}$$

Where $p_{i,t}$ is the price level, and the remaining notation is as before. The evidence suggests that the response of the price level takes longer, and is much milder, than that of nominal GDP. Lags 5-6 are individually significant at standard levels, but have smaller coefficients than was the case with nominal GDP over a 2-3 year lag. A 10% increase in the production of precious metals in the American continent leads to an increase in prices of about 4%, all else constant, in years 5 and 6 years after the shock.[44]

The fact that the GDP deflator reacts later and less strongly than nominal GDP suggests the existence of liquidity effects. This can be tested directly using real GDP as the dependent variable (Table 5),

$$\Delta y_{i,t}^{real} = const + \sum_{j=1}^{6} \varphi_j \Delta s_{t-j} + \sum_{j=1}^{4} \rho_j \Delta y_{i,t}^{real} + x'_{i,t}\,\vartheta + e_i + u_{it}$$

Here, $y_{i,t}^{real}$ is real GDP per capita and the remaining notation is as before. The results are in Table 5. The baseline estimates are in column (3), while column (1) shows the results without weather controls, and column (2) without controlling for lagged real GDP. In turn, columns (4) and (5) concern specifications which will be discussed in sections 3.4.2. and 3.4.3., respectively. The baseline (column 3) results for real GDP show that only two years after a 10% increase in the production of precious metals in America, average real GDP in the sample European countries was about 0.6% higher, all else constant.[45] Hence we cannot reject the existence of a strongly positive liquidity effect.[46] Notice that the three equations were estimated separately. As noticed before, as long as the shocks are structural the reduced-form effects will be identified, and there is no need to explicitly consider the price level and nominal GDP as part of a system. Furthermore, for all the cases (nominal and real GDP, as well as the price level), all the signs are as expected, even though not all are individually significant.[47]

[44] The baseline results so far are sumarized in Figure A4 of the appendix.
[45] This effect is statistically significant at the 10% level (with p-value: 0.067). Notice this is an "all else constant" effect for the second year only; I discuss the more important cumulative effects below.
[46] If the sample is restricted to the two countries for which better quality data is available, not only is the magnitude of the effect even stronger but the second lag becomes statistically significant at the 1% level; see column (3) of the appendix table A2, and the discussion in section 3.4.4.
[47] Notice that for some of these coefficients, not rejecting zero is indeed the "desired" result, as happens for the effect on the price level for the first few years or nominal GDP for the last one or two years.

Dependent variable: First difference of the ln of the price level	**(1)**	**(2)**	**(3) (placebo)**
Estimator	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)
Constant	.008*** (.002)	.008*** (.002)	.009 (.003)
First difference of the ln of the price level (-1)	-.125 (.122)	-.124 (.123)	-.125 (.122)
First difference of the ln of the price level (-2)	-.184*** (.065)	-.182*** (.066)	-.184*** (.065)
First difference of the ln of the price level (-3)	-.147*** (.048)	-.147*** (.047)	-.149*** (.046)
First difference of the ln of the price level (-4)	-.116*** (.029)	-.115*** (.029)	-.115*** (.030)
First difference of the ln of precious metals production (-1)	-.009 (.021)	-.006 (-.006)	-.010 (.023)
First difference of the ln of precious metals production (-2)	.004 (.026)	.003 (.026)	.000 (.027)
First difference of the ln of precious metals production (-3)	.018 (.035)	.016 (.035)	.015 (.036)
First difference of the ln of precious metals production (-4)	.015 (.014)	.015 (.015)	.017 (.016)
First difference of the ln of precious metals production (-5)	.039*** (.012)	.042*** (.012)	.044*** (.012)
First difference of the ln of precious metals production (-6)	.034** (.014)	.035** (.014)	.032** (.015)
First difference of the ln of precious metals production (+1)	-	-	-.007 (.021)
First difference of the ln of precious metals production (+2)	-	-	-.047** (.026)
First difference of the ln of precious metals production (+3)	-	-	-.043* (.022)
First difference of the ln of precious metals production (+4)	-	-	-.023 (.022)
First difference of the ln of precious metals production (+5)	-	-	.001 (.022)
First difference of the ln of precious metals production (+6)	-	-	.009 (.021)
WEATHER CONTROLS	NO	YES	YES
COUNTRY FIXED EFFECTS	YES	YES	YES
BIC criteria	-2253.174	-2234.322	-2115.97
R^2	Within: 0.0657 Between: 0.8758 Overall: 0.0638	Within: 0.0677 Between: 0.8712 Overall: 0.0657	Within: 0.0568 Between: 0.9905 Overall: 0.0452
observations	1491	1491	1455

Table 4. The price level (GDP deflator) equation, 1531-1790. The lags of the dependent variable included as controls account for potential serial correlation in the error term. The "weather controls" include the current level and 2 lags of the country-specific air temperature. Standard errors (in parentheses) are bootstrapped with 1000 replications. *, ** and *** denote individual statistical significance at the 10, 5, and 1% levels.

Dependent variable: First diff. of the ln of real GDP	**(1)**	**(2)**	**(3)**	**(4) (placebo)**	**(5) (second-order receivers)**
Estimator	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)
Constant	.002 (.002)	.002 (.002)	.002 (.003)	.000 (.003)	
First diff. of the ln of real GDP(-1)	-.078 (.072)	-	-.078 (.072)	-.079 (.071)	-.070 (.076)
First diff. of the ln of real GDP(-2)	-.129* (.077)	-	-.128* (.077)	-.128 (.080)	-.128 (.091)
First diff. of the ln of real GDP(-3)	-.029 (.020)	-	-.029 (.021)	-.029 (.020)	-.023 (.017)
First diff. of the ln of real GDP(-4)	-.080*** (.024)	-	-.082*** (.026)	-.081*** (.025)	-.089*** (.019)
First diff. of the ln of precious metals production (-1)	.038 (.028)	.033 (.022)	.037 (.027)	.036 (.029)	.038 (.042)
First diff. of the ln of precious metals production (-2)	.059* (.032)	.054** (.026)	.059* (.032)	.060* (.034)	.081* (.047)
First diff. of the ln of precious metals production (-3)	.038 (.032)	.027 (.027)	.039 (.033)	.043 (.036)	.041 (.052)
First diff. of the ln of precious metals production (-4)	.014 (.025)	.0085 (.019)	.014 (.025)	.014 (.025)	.016 (.041)
First diff. of the ln of precious metals production (-5)	-.030* (.0164462)	-.042* (.023)	-.029* (.017)	-.031 (.017)	-.044 (.020)
First diff. of the ln of precious metals production (-6)	-.051** (.023)	-.055* (.029)	-.052** (.024)	-.051 (.023)	-.074 (.027)
First diff. of the ln of precious metals production (+1)	-	-	-	.020 (.012)	-
First diff. of the ln of precious metals production (+2)	-	-	-	.047 (.048)	-
First diff. of the ln of precious metals production (+3)	-	-	-	.027 (.045)	-
First diff. of the ln of precious metals production (+4)	-	-	-	.004 (.047)	-

First diff. of the ln of precious metals production (+5)	-	-	-	.021 (.051)	-
First diff. of the ln of precious metals production (+6)	-	-	-	-.006 (.032)	-
WEATHER CONTROLS	NO	YES	YES	YES	YES
COUNTRY FIXED EFFECTS	YES	YES	YES	YES	YES
BIC criteria	-1366.503	-1359.081	-1366.503	-1258.046	-524.1151
R^2	Within: 0.0316 Between: 0.9899 Overall: 0.0310	Within: 0.0074 Between: 0.3256 Overall: 0.0074	Within: 0.0321 Between: 0.9571 Overall: 0.0315	Within: 0.0345 Between: 0.9779 Overall: 0.0339	Within: 0.0339 Between: 0.9925 Overall: 0.0333
observations	1491	1495	1491	1455	985

Table 5. The real GDP equation, 1531-1790. The lags of the dependent variable included as controls account for potential serial correlation in the error term. The "weather controls" include the current level and 2 lags of the country-specific air temperature. Standard errors (in parentheses) are bootstrapped with 1000 replications. *, ** and *** denote individual statistical significance at the 10, 5, and 1% levels.

3.3. Cumulative impulse response functions

Cumulative impulse response functions are computed as follows. Using $y_{i,t}^{real}$ as an example, a shock of size ε at time $t = 0$ to Δs_{t-j}, i.e.$\Delta^2 s_0 = \varepsilon$, has the following effect one year later,

$$\Delta^2 y_{i,1}^{real} = \varphi_1 \varepsilon$$

while two years later,

$$\Delta^2 y_{i,2}^{real} = \varphi_2 \varepsilon + \rho_1 \left(\Delta^2 y_{i,1}^{real}\right)$$
$$= \varepsilon(\rho_1 \varphi_1 + \varphi_2)$$

three years later,

$$\Delta^2 y_{i,3}^{real} = \varphi_3 \varepsilon + \rho_2 \left(\Delta^2 y_{i,2}^{real}\right)$$
$$= \varepsilon[\varphi_3 + \rho_2(\rho_1 \varphi_1 + \varphi_2)]$$

and so on, up to 6 lags for precious metals production and 4 lags for the lagged dependent variable (in this example, real output). Hence in each case, there is a direct impact effect, plus an indirect effect accruing from the dependent variable dynamics.

The baseline results of the previous subsection can be visualized by considering the cumulative impulse response to a positive 10% shock relative to the sample average (Figure 6, where I also show the cumulative impulse response function to a 1 standard deviation shock relative to the sample average). As the figure suggests, these effects are of a substantial magnitude, and persist for a long time. After production of precious metals in America increased 10% in a given year, real GDP in Europe was 1.3% higher four years later, all else (except for endogenous output dynamics) constant. The evidence summarized in these graphs clearly suggests this is because prices responded to monetary injections only with considerable lags.

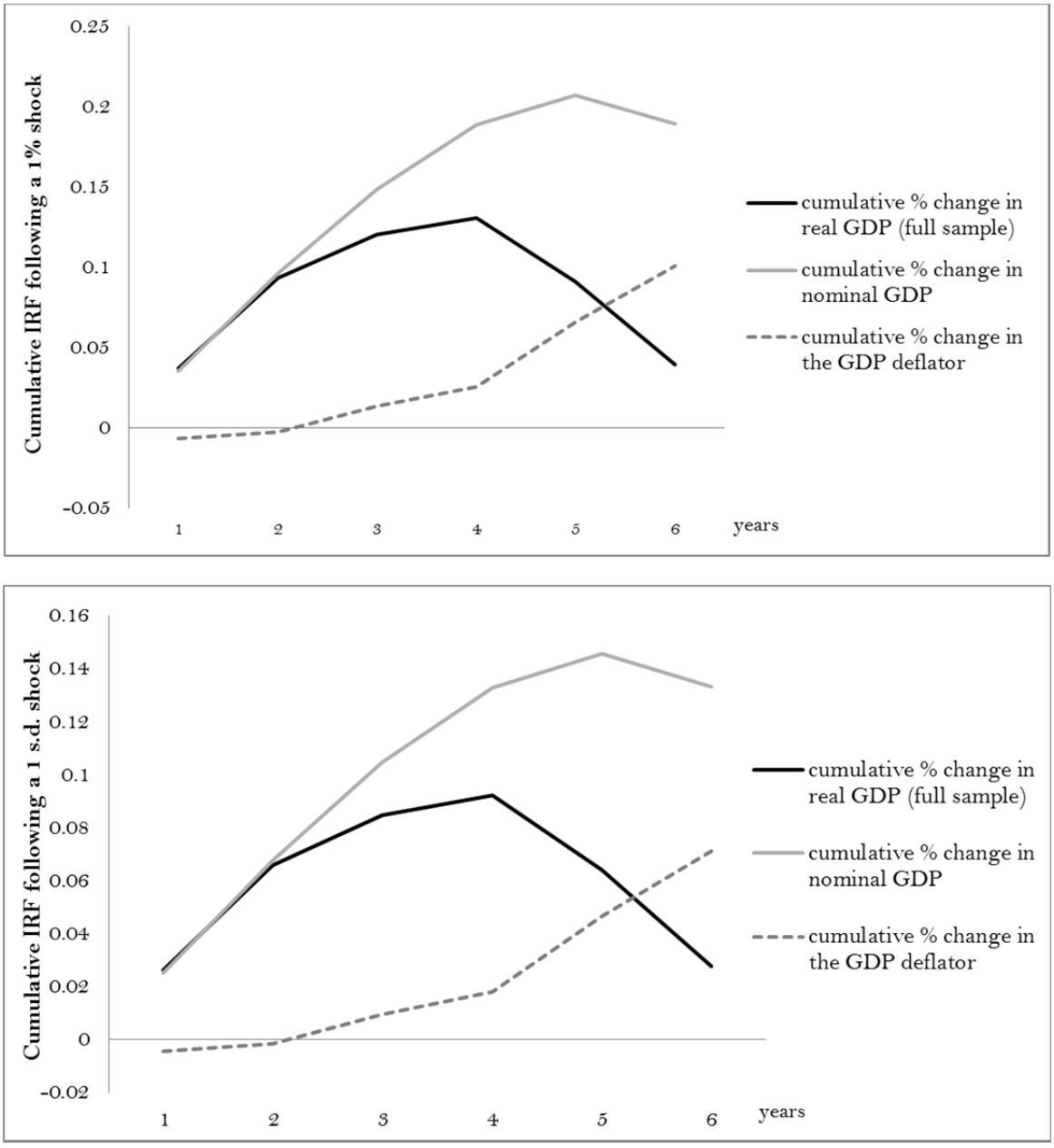

Figure 6. Accumulated impulse response functions of nominal GDP, the GDP deflator, and real GDP to a positive 1% shock and a positive one-standard deviation shock to production of precious metals in America. The horizontal axis denotes the number of years after the shock.

Indeed the effects in the figure correspond to a conservative bound as they correspond to the full specification from the equations in the last subsection – i.e the results in columns (2) in Tables 3 and 4, and (1) in Table 5. If past dependent variable dynamics and other covariates were not being controlled for, the unconditional effect would be even stronger. Additionally, data construction considerations suggest the effect found is an underestimate. Indeed, for all

but two of the countries in the sample, GDP has been reconstructed using a demand-based approach.[48]

Because demand-side reconstruction uses prices to arrive at real GDP, if prices were indeed sticky then the short-run response of those economies will actually be underestimated. This biases the results against finding an effect, since the measured response will then be smaller than the true one, which would have been more vigorous, but unobserved to us. The same is true for the likely fragility of annual data reconstruction for early modern economies: as there is no reason to believe the induced noise is in any way correlated with the growth of precious metals production in America, the fact that I find an effect nonetheless suggests that either there is little annual-frequency noise in the historical GDP reconstruction exercise (which is implausible), or that the true liquidity effect was even stronger than that which I find.

3.4. Robustness considerations

3.4.1. Dealing with potential covariate mismeasurement

As discussed, if precious metals production was seriously mismeasured, this should bias my coefficients downwards in absolute terms.[49] The fact that I find strong and significant results suggests that this is not a relevant problem: lags of the independent variable are indeed systematically correlated with the dependent variables of interest. Still, in order to account for the possibility of smuggling, I now consider data on the use of mercury. Technical change and variable mining productivities meant that the relation between mercury usage and production was far from linear. Still, the correlation was usually tight (Figure 7), which suggests production estimates from fiscal sources are not out of line with reality.

[48] This is the case for Italy, Spain, Portugal, and Sweden, following an application of Deaton and Muellbauer (1980). In the case of England and the Netherlands, GDP was constructed using output data.
[49] As with classical measurment error, there should be attenuation bias.

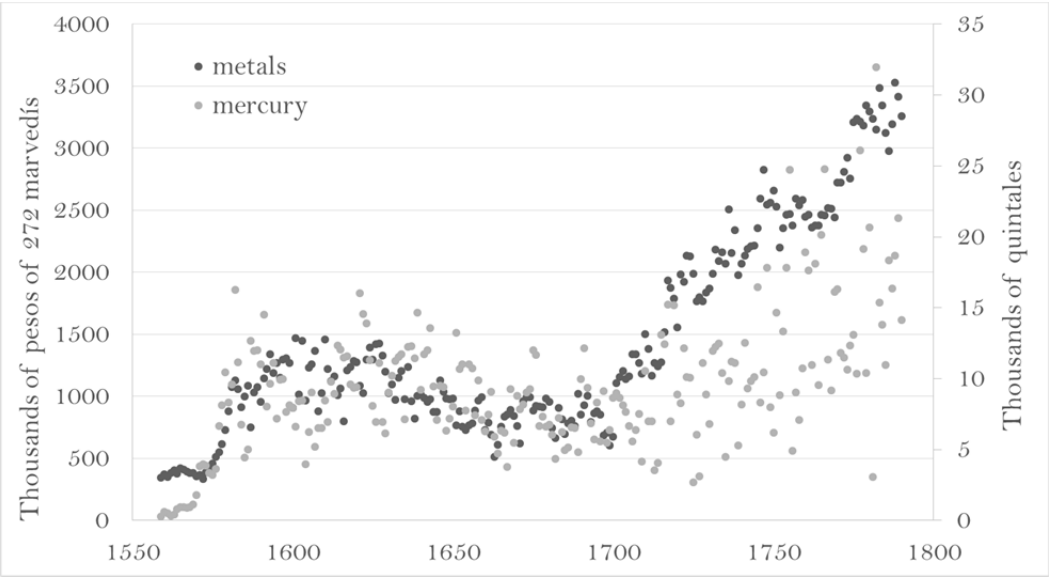

Figure 7. Production of precious metals and mercury usage. Sources: TePaske (2010), Gardner (1988)

As the figure suggests, after about 1700 the correlation breaks down to some extent; while the trends continue to be similar, there is a level effect downwards for mercury usage. There are two reasons for this. First, the eighteenth century was the age of gold, and there is evidence that mercury was particularly useful for silver, not gold. (Figure A3 of the appendix shows that some of the divergence can be accounted for if gold is excluded). But second, the direction of the breakdown matters. If, after 1700, mercury supply had been well above silver production levels, then this might be a sign of increased smuggling after that time. The fact that it was below instead suggests that it corresponds to higher TFP in the mining production function. Indeed, as the figure also suggests, the change corresponds to a level effect only, as the trends continue to be similar. In sum, data on mercury utilization suggest that smuggling was not an important issue and annual volumes of precious metals production are approximately right.

Additionally, scale economies, coordination problems, and strategic security considerations often meant that it made sense to transport precious metals in bulk and in protected convoys or galleons. Even in the case of gold, which compared with silver is potentially easier to smuggle because of its higher value-to-weight ratio, it often made sense not to. In the case of Brazilian gold after 1720, for instance, the state charged a rate of 1% for the transportation of gold across the Atlantic (Costa et al 2013).

3.4.2. Placebo tests

If forward values of production of precious metals are added to the main regression in a symmetrical fashion to the lags, the point-estimates for those forward variables are small in absolute terms, and either with erratic (nominal GDP) or hard to interpret (GDP deflator) signs. Furthermore, they are not individually significant at conventional levels, and an F-test rejects joint significance as well. The results are shown in column (3) of Tables 3 and 4 and column (4) of Table 5. The failure of future precious metals production to affect the results also suggests that agents did not or could not have anticipated in advance the coming of precious metals and optimized accordingly, a topic which I will pick up in more detail in section 4.3.

3.4.3. Was there an heterogeneous response for the first-order receiving countries?

I have so far maintained that the annual production of precious metals in America was exogenous to the state of the European economy taken as a whole, an assumption which I defend in detail in section 4. This assumption is fully compatible with the possibility that once extracted, the distribution among different European countries of the part shipped to Europe was endogenous to the characteristics of those different European countries[50], and that it may have had heterogeneous effects for different economies.

As the main receiving country was Spain, it is interesting to report the results for Spain alone. In fact, the results for Spain diverge from most of the others. A liquidity effect seems to be absent. Surprisingly, this does not seem to be because the price level is responding particularly strongly or fast; instead, even nominal GDP is not responding much either (Table 6, columns 1-3). These results seem strange given that, as is well know, at least parts of Spain suffered from considerable inflation in the sixteenth century. At the same time, other parts of Europe did too, and Spain was an open economy which exported most of the precious metals: in this context no one-to-one effect on the aggregate price level is necessary.[51]

[50] Endogenous to income levels and consequent demand for liquidity; see McCloskey and Zecher (1974).
[51] We do know that in sixteenth century Seville, the arrival of the fleets led to price increases, and if a Dutch disease mechanism existed, it should have operated through an increase in the price level (and an appreciation of the real exchange rate). However, it is not clear how widespread these price changes were in the

Secondly, inflation in sixteenth-century Spain may have had more to do with the introduction of tokens (*vellón*) than American precious metals.

The fact that a liquidity effect is absent for Spain suggests that for the full sample, the timing of real and nominal effects may have depended on factors other than where did the precious metals physically arrived in the first place.[52] It needs to be recognized at this point, however, that the underlying GDP estimates are diverse and not of the same quality. The series for England and the Netherlands were derived from the production side, but the others are based at least in part on a demand side approach, relying on proxies and relatively strong assumptions for the estimation of the size of the industrial and service sectors. I have run separate panel regressions for England and the Netherlands on the one hand and the other four countries on the other hand (the results are shown in the appendix, tables A1 and A2). These results seem to suggest that indeed, the effects are weaker (and less statistically significant) for the countries for which the data has been estimated using more imprecise methods.

But at the same time, the case of the other first-order receiving country, Portugal, provides and interesting comparative dimension to Spain. For Portugal, an effect still exists for the full sample, but if the sample is split so that the regressions are run for the period that Portugal was a receiving country only (after about 1690), the results vanish (Table 6, columns 4-9). The magnitudes become smaller and the standard errors larger. The point of doing this is to interpret Portugal 1531-1689 as a "control group". From this I conclude that perhaps the existence of a liquidity effect is conditional on not being a first-order receiving country, or on other unobserved characteristics of the receiving countries. Indeed, if Spain and Portugal after 1700 are excluded from the sample, the liquidity effect found for the others is even stronger. I compare the liquidity effects on real GDP for the full sample with that for England and the Netherlands, and for the second-order receivers (alternatively defining Portugal before 1690 as one or not) in Figure 8. The results are as expected: England and the Netherlands have the strongest liquidity effects, followed by the other second-order receivers.

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country as a whole. Further, if changes in relative prices occurred (perhaps the price of tradables fell) this need not affect the GDP deflator.

[52] Indeed for the remaining 5 countries there seems to be no systematic correlation between the distance of the capital of each country from Seville (or Cádiz) to the strength of the country-specific liquidity effect.

Sample	Spain, full sample (1531-1790)			Portugal, 1531-1689			Portugal, 1690-1790		
Dependent variable	(1) Ln of Nominal GDP	(2) Ln of Price level	(3) Ln of Real GDP	(4) Ln of Nominal GDP	(5) Ln of Price level	(6) Ln of Real GDP	(7) Ln of Nominal GDP	(8) Ln of Price level	(9) Ln of Real GDP
Estimator	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)
Constant	.010 (.006)	.010 (.010)	.002 (.004)	-.028 (.018)	-.015 (.012)	-.008 (.011)	.006 (.007)	.003 (.007)	.003 (.005)
First diff. of the ln of prec. metals prod. (-1)	-.046 (.041)	-.087 (.062)	.039 (.027)	.074 (.059)	.0418 (.040)	.043 (.034)	-.029 (.066)	-.001 (.063)	-.019 (.049)
First diff. of the ln of prec. metals prod. (-2)	-.003 (.043)	-.034 (.064)	.030 (.028)	.069 (.062)	.055 (.041)	.012 (.036)	.061 (.067)	.083 (.064)	-.012 (.050)
First diff. of the ln of prec. metals prod. (-3)	.015 (.043)	.006 (.064)	.010 (.030)	.147** (.062)	.087** (.041)	.060* (.036)	.033 (.067)	.025 (.064)	.031 (.049)
First diff. of the ln of prec. metals prod. (-4)	.028 (.042)	.013 (.062)	.013 (.027)	.031 (.063)	.061 (.042)	.022 (.035)	.142** (.067)	.096 (.065)	.059 (.049)
First diff. of the ln of prec. metals prod. (-5)	.050 (.041)	.040 (.061)	.008 (.027)	-.049 (.062)	-.000 (.042)	-.002 (.034)	.053 (.065)	.063 (.063)	-.000 (.048)
First diff. of the ln of prec. metals prod. (-6)	.058 (.039)	.082 (.058)	-.022 (.026)	-.048 (.059)	-.028 (.040)	.006 (.032)	-.059 (.063)	-.055 (.060)	.003 (.047)
DEP. VAR. DYNAMICS CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES
WEATHER CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.0737	0.1040	0.0747	0.3289	0.6023	0.1128	0.3872	0.5300	0.2965
observations	253	253	253	152	152	152	100	100	100

Table 6. Nominal GDP, the price level, or real GDP for the receiving countries (Spain, full sample and Portugal, 1690-1790), and for Portugal 1531-1689. The "dependent variable dynamics control" include four lags of the dependent corresponding dependent variable. *, ** and *** denote individual statistical significance at the 10, 5, and 1% levels.

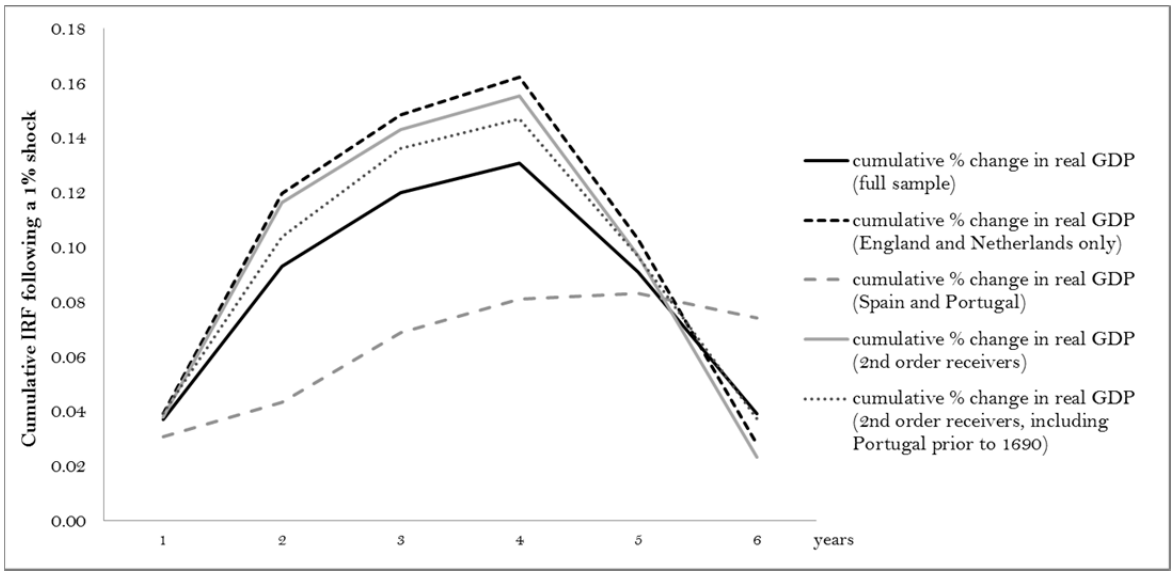

Figure 8. Accumulated impulse response functions of real GDP to a positive 1% shock to production of precious metals in America: comparison of several subsamples.

4. Threats to identification

Threats to the validity of this natural experiment can be classified as follows. First, the timing of the discovery of the mines could have been endogenous to European prices or GDP. Second, mining intensity could have been endogenous to the state of the European economy as well.[53] From the point of view of statistical testing, what matters is whether the total production of precious metals was reacting to the state of the European economy, so these two distinct possibilities can be safely confounded.

In this section, I respond to the endogeneity challenge in several ways. First, I follow an IV strategy: using weather shocks as a source of exogenous variation to the state of the European economy (GDP and prices), I show that these do not cause future changes in the production of precious metals in America. Second, I show that both the production of American precious metals and shipments to Europe were approximately white noise. Third, I show that changes

[53] One might additionally argue that the distribution of the windfall across the different European countries could have been endogenous. This was certainly the case, but it will be internalized by the reduced-form estimates and hence does not represent a threat to identification of either the "average" effect across the European economies in the sample or that for any specific subsample chosen when those regressions are run.

in production in America were not positively correlated with previous changes in the price of precious metals in Europe. Fourth, I show that Granger "causality" tests suggest that changes in the production of precious metals in America predict future changes of GDP and prices in Europe, but not the other way around. They also suggest that changes in the production of precious metals in America predict future changes in the price of precious metals in Europe, but not the other way around. Finally, I show that a credible measure of the lower bound to the unanticipated component of shipments to Europe have the same effect as those which may have been anticipated, hence increasing the credibility of the Granger "causality" tests, by ruling out anticipation effects which would have operated through the endogenous formation of expectations.

4.1. The weather as an instrument for European GDP

The literature on the nineteenth-century gold standard generally assumes that gold production was endogenous to prices. Robert Barro's (1979) model describes the adjustment of money and prices under the gold standard, and it assumes that the supply of gold in the long run is determined by the opportunity cost of producing gold. Hence, if there is a rise in productivity in the non-gold producing sector of the economy, there is a subsequent increase in the demand for money. In turn, this leads to a fall in prices – ie. to a rise in the purchasing power of gold – which stimulates gold production.[54]

The reverse-causality hypothesis can be ruled out using country-specific weather information as an instrument for variation in GDP. Suppose that in a given year, output increased driven by consensually exogenous weather shocks. If a reverse-causation link existed, American production of precious metals should, as a consequence, increase in the next few years. I will now test (and ultimately reject) this hypothesis using a 2SLS model. The second-stage equation is

$$\Delta s_{t+k} = c_0 + c_1 \Delta \hat{y}_{i,t} + e_i + u_{i,t}$$

[54] It would be interesting to test these theoretical predictions for period Barro was writing about using the timing of the discovery and mining intensity of nineteenth century gold rushes in Alaska, Russia, Australia, South Africa, and California. I leave this for future work.

Where $k = 1$ corresponds to the usual first-difference case, but I also consider the possibility of longer response times, i.e. $k > 0$.[55] Here, $\hat{y}_{i,t}$ is the part of nominal GDP which is explained by a first-stage regression of regional-specific air temperature, and interactions of this with lagged output.[56] While the weather would be expected to directly affect mainly agricultural output, it would be expected that this effect would in turn spill-over to the rest of the economy as well. First-stage F-statistics confirm the instruments are relevant (i.e. not weak), which is natural as these were largely agricultural economies for which the weather was critical in determining the success of the harvest. As instruments, I use the absolute level of country-specific and season-specific air temperature. (I have also used country-specific rainfall levels but the results do not change much.) It seems reasonable that the weather in Europe did not affect the production of precious metals in America in other channels in addition to, potentially, differential levels of demand caused by changes in GDP. The results are shown in Table 7.

The important result is that $c_1 = 0$ cannot be rejected at standard significance levels, which supports the hypothesis that it was not the state of the European economy determining the production of precious metals in America. Instead, as argued in section 2 this was driven by local conditions of cost, rather than demand.[57] A similar result holds for the corresponding coefficient for the GDP deflator. Hence, these results suggest that the state of the European economy did not cause future discoveries or mining intensity of precious metals in America.[58]

[55] I report the results for $k = 4$, but the result holds for similar choices of k. I also tried as a dependent variable $s_{t+k} - s_t$, and once again the results hold. I do not consider negative k's because it is not credible that forward-looking agents could anticipate changes in GDP caused by the weather years in advance.

[56] The results are similar if, instead of the level of air temperature, the absolute level of air temperature, the difference relative to the absolute level, or, following the analogous case of rainfall by Miguel et al (2004, p. 733), proportional change is used.

[57] With regards to instrument relevance, in Table 7 I show the IV F-statistic of the first stage regressions, and they are above the usual rule of thumb of 10. I do not perform tests of over-identifying restrictions, since the current consensus is that even when more instruments than endogenous variables are available, these tests cannot be used to test for instrument validity (Parente and Silva 2012).

[58] Previous readers have suggested using weather data for the Americas as a source of exogenous variation in precious metals production in the main regressions. I find this unpersuasive because the exclusion restriction becomes hard to defend: surely, other elements of the colonial economies in addition to precious metals production were affected by the weather in the colonies, hence rendering the exclusion restriction invalid as the weather would have affected the state of the European economy in ways (e.g. the strength of sugar or cotton production) other than through variation in the availability of precious metals.

Independent variable	**Nominal GDP**			**Price level**		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable specification	First difference of ln of the value of precious metals production (+1)	First difference of ln of the value of precious metals production (+4)	First difference of ln of the value of precious metals production (+6)	First difference of ln of the value of precious metals production (+1)	First difference of ln of the value of precious metals production (+4)	First difference of ln of the value of precious metals production (+6)
Estimator	IV: 2SLS	IV: 2SLS	IV: 2SLS	IV: 2SLS	IV: 2SLS	IV: 2SLS
Constant	.011*** (.004)	.012*** (.004)	.012*** (.004)	.0092** (.004)	.011** (.004)	.013*** (.004)
First difference of the ln of the dependent variable (-1)	.032 (.111)	-.104 (.106)	-.063 (.113)	.095 (.147)	.140 (.148)	-.114 (.180)
COUNTRY FIXED EFFECTS	YES	YES	YES	YES	YES	YES
ADDITIONAL CONTROLS	NO	NO	NO	NO	NO	NO
First-stage F-statistic	14.50	16.12	14.10	11.71	11.49	11.07
R^2	0.0003	0.0003	0.0002	0.0002	0.0000	0.0012
observations	1501	1483	1459	1501	1483	1459

Table 7. Nominal GDP, the price level, or real GDP instrumented by weather shocks show that the state of the European economy does not cause future variation in the production of precious metals in America. *, ** and *** denote individual statistical significance at the 10, 5, and 1% levels.

4.2. Granger-causality tests: did production react to the price of precious metals in Europe?

There is also the possibility that mining in America was responding to the price of metals in Europe (as opposed to the "state" of the European macroeconomy more generally, as tested in the previous subsection). Here, I respond to this possibility using the market price for silver in London, taken from Neal (1990).[59] Initially looking at simple correlations, regressions of silver production on prices in London show that a relationship can be safely rejected, whether the relationship is estimated in levels or first differences (with low F-joint significance statistics). Nevertheless, these are just correlations, and do not imply that the production of precious metals in America do not have a causal effect on prices of precious metals in Europe, all else constant.[60]

Indeed, Granger-"causality" tests following reduced form VARs[61] for the first-difference vector show that while it is not possible to reject at standard levels of significance that the production of precious metals is a predictor of future silver prices in London, the opposite is not true (Table 8). Following the estimation of the reduced-form VAR (with a number of lags chosen according to the BIC criteria), Granger-"causality" tests for each variable are simply Wald tests that the coefficients on the lags of the candidate explanatory "cause" are jointly zero. The nulls simply test whether, by not including them, the model loses significant explanatory power (hence it is about prediction, not true causality.)[62]

These results (plus those of the previous subsection) are strong evidence in favor of the idea that local cost conditions in Central and South America, not annual-level variations in the state of the European economy (including the price of precious metals), were the main

[59] While I am not aware of a similar price series for the remaining countries in the sample, the European economy should have been sufficiently integrated at the time that these should be highly correlated to the price in London. Also, these tests can only be done for silver, as in the case of gold, variation in production is not observed annually.
[60] In fact, if the test is reversed and instead forward prices are used as the dependent variable, the F-statistic increases and there is now an individually significant in the first few years, which is consistent with the results from the previous section (and indeed a lower bound to the true causal effect due to downward bias caused by the contemporaneous response of real GDP, which would tend to raise prices).
[61] Notice that in a reduced-form VAR no ordering restrictions are imposed (see for instance, Stock and Watson 2001). They are simply meant to capture dynamic correlations in the data.
[62] As always with Granger-"causality" tests, the null is the hypothesis that the explanatory variable predicts changes in the dependent variable.

determinants of how much precious metals were produced in the New World.[63] Hence, the natural experiment which provides the causal identification for the results in this paper seems to be validated. However, since Granger-"causality" tests are about prediction, not causality, they may be not valid in the presence of anticipation effects. While their presence over long periods of time seems in this case rather far-fetched, I consider the endogenous formation of expectations in the next subsection.

Equation	Excluded	Prob>χ^2
First difference of the Ln of the value of Spanish American silver production	First difference of the Ln of the London price of silver	0.692
First difference of the Ln of the value of Spanish American silver production	All	0.692
First difference of the value of the Ln of the London market price of silver	First difference of the Ln of the value of Spanish American silver production	0.000
First difference of the value of the Ln of the London market price of silver	All	0.000

Table 8. Granger "causality" Wald tests following a reduced-form VAR of the first difference and the value of silver output reject that it does not Granger-cause the price of silver in London, but not conversely. Data sources: see text.

4.3. Accounting for the endogenous formation of expectations

4.3.1. Was future production of precious metals growth predictable?

Even after ruling out the possibility that the production of precious metals in America would have been reacting to the state of the European economy or the price of precious metals in Europe, it could still be the case that variation in these production levels, while exogenous to the European economy, would have been going through regular production cycles which could have been easily anticipated by the European agents.

[63] In figure A5 of the appendix, I additionally show that,outliers excepted, there also does not seem to have existed a correlation between time and number or richness of mines found.

In the previous subsection I have shown that the production of precious metals in America is a good predictor of future developments in GDP, but not the other way around. However, as is well-known, Granger-"causality" tests may not be valid in the presence of anticipation effects. If people could correctly predict the quantities of silver and gold coming every year, then identification could be at stake. One prominent possibility is that as news about the discovery of mines and the shipping of precious metals to Europe spread, agents endogenously adapted expectations, such that, for instance, the real effects on money supply would be neutralized through an increase in prices. It would then be more difficult to justify the effects that I find here.

My interpretation of discoveries and production of precious metals in America as a natural experiment can be made more credible if it can be shown that variation in the growth (first difference of the natural log) of production of precious metals in America – the main independent variable of interest used in the regressions of Section 3 – cannot be easily distinguishable from white noise. In fact, this can be again tested using a Portmanteau or Bartlett's periodogram-based test for white noise, which does indeed suggest agents at the time would have had much difficulty predicting future variation of this variable (Table 10, column 1).

Dependent variable: First difference of the natural log of precious metals production	(1) Main shock	(2) Manifestos shock
Portmanteau (Q) statistic	52.19	84.5721
Prob > $\chi^2(40)$	0.093	0.0000
Bartlett's (B) statistic	2.2056	2.3447
Prob > B	0.0001	0.0000

Table 10. Portmanteau and Bartlett tests for white noise of the first difference of the ln of precious metals production.

4.3.2. Was future monetary growth predictable?

Even if variation in the production levels in America could not have been predicted, it is still arguable that agents would have been trying to form expectations as best as possible from publicly available sources about the arrivals of shipments to Europe. If people could predict in advance how much was arriving, they could – under the additional assumption of rational

expectations – predict how much money would increase over the next few years, and should have reoptimized accordingly. Notice, however, that short-run neutrality implies not only that we assume rational expectations but also instant market clearing. Even today markets do not clear instantly, because of various frictions such as sticky plans, prices, wages, and rational inattention, but it is worthwhile seeing whether this can be tested for.

It is possible to construct a good measure of the unanticipated component of (some of) the shocks. Commercial "newspapers" in Europe regularly announced the quantities arriving. One source which has been studied exhaustively is that of the Dutch gazettes (Morineau 2009). These "newspapers" of the time announced how much was arriving to Spain and Portugal every year. They hence describe the amounts which were "public information". They were hence an informational higher bound, i.e. the quantities that an hypothetical agent which was as well informed as it was possible using public information, and who formed expectations rationally, could best predict.

At the same time, in the case of gold arrivals in Portugal, there is a fiscal source which gives, on an annual basis, the true arrivals. Gold from Brazil to Portugal during the eighteenth century was an important fraction of the total value of arrivals (see Figures A6 to A9 of the appendix), and there is plenty of evidence that these then spread out all over Europe. Tim Blanning, for instance, writes that "the rapidly expanding output of Brazilian mines helped alleviate the chronic shortage of coin and, among other things, allowed the stabilization of European currencies" (Blanning 2008, p. 95).

The data on the "true" gold arrivals was private information to the receiving agents and their intermediaries and to the king of Portugal, and has been obtained from a fiscal source, the *livros de manifestos de 1%*, available at the Lisbon mint. Costa, Rocha and Sousa (2013) describe this source in detail, and it is available for the period 1720-1808. It contains information not only about the amounts arriving but also its receivers, both public and private.[64] The *livros de manifestos de 1%*, was compulsory for all the fleets that transported gold arriving from 1720 onward. Costa, Rocha and Sousa (2013) argue persuasively that any quantities of gold

[64] Since the quantities were often picked up by intermediaries, it is arguable that communication between these could lead to an estimate of the totals. However, the very fact that commercial gazettes were providing these estimates suggests that the total quantities were not otherwise known to the public.

smuggled must have been minor compared with these, since the 1% paid was a relatively small cost once agency, risk and transportation costs are taken into account.

A shock can hence be defined as the quantity that actually arrived minus that which a hypothetical best-informed agent might expect from relying on public information alone (Figure 9 shows the annual innovations; figure A9 in the appendix shows the absolute comparison between the two amounts). In the initial decades, the newspapers exaggerated the quantities arriving, and there was some persistence in these mistakes, as visual inspection of Figure 9 suggests.[65] However, as the century advanced, the variance in these errors diminished, and the direction of the errors also became less systematic.

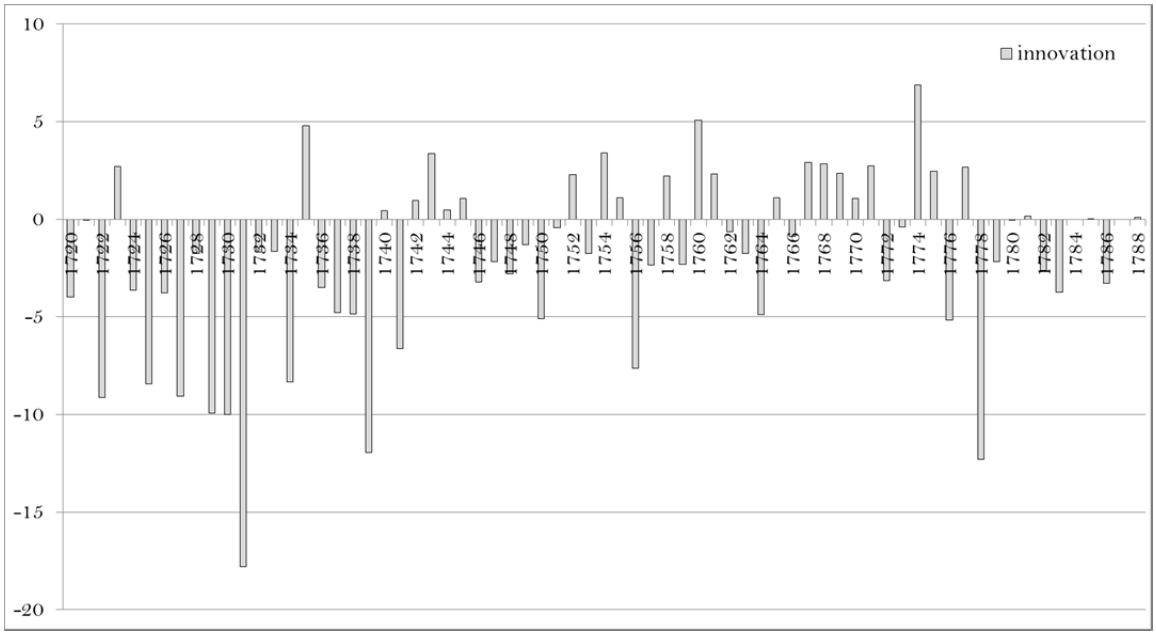

Figure 9. A lower bound to the innovation component of gold arrivals (defined as true arrivals, given by a source which was private information, minus the best-information higher-bound expectation, given by a source which was public information). Unit: Tonnes. Sources: see text.

Notice the revelation of the uncertainty was not observable for the agents, since the true quantities arriving remained, for them, unobservable. Hence the innovation does not correspond to the usual and perhaps more intuitive expression $innovation_t = m_t - E_{t-1}(m_t)$

[65] It is likely that earlier on, following the discovery of the Brazillian mines, the opposite would have been true, though we cannot observe this.

since the agents did not observe the realization of m_t even at time t. (And it is not clear when, or if, the uncertainty was ever revealed to them). In other words, using standard notation, $E_t(m_t) = E_t(m_t|I_t)$ which does not necessarily equal m_t.[66] This innovation was close to white noise (Table 10, column (2), and the appendix figures A10, A11.)[67] This innovation was close to white noise (Table 9, column (2), and the appendix Figures A10, A11), and it was also large relative to the overall size of arrivals – the median annual value for arrivals during the 1720–1788 period was 7.26 tonnes.

The almost absence of serial correlation increases the credibility of arrivals as an exogenous and largely unpredictable shock. Unfortunately, in the case of arrivals to Spain, I know of no good estimates of the true arrivals, so an equivalent measure cannot be constructed. While the Dutch gazettes also reported quantities of Spanish American gold arriving to Europe, no source analogous to *the livros de manifestos de 1%* is available in the Spanish American case (Costa, Rocha and Sousa 2013), hence rendering an analogous calculation of the innovations impossible for that case. But there seems to be no good reason to suppose that the Dutch gazettes would have been able to predict quantities coming from Spanish America any better than they were in the Brazilian case.

4.4. External validity

Most of the considerations in this section have so far been concerned with the internal validity of the results. The safest interpretation is that these liquidity effects correspond apply only to the context of the early modern European economy; the fact that early modern economies were very different from those of today certainly precludes direct extrapolation of the results. It is difficult to know at this stage, for instance, whether prices were more or less sticky than in modern economies, since qualitatively an argument could be made both ways. To my knowledge no study has undertaken a systematic comparison of wage and price rigidities in

[66] This in itself poses interesting questions and identification strategy possibilities to be explored in future work: for instance, in this age before any official publication of macroeconomic statistics by the government, did people respond to the overall quantity of money in circulation or to what they perceived as such? The very fact that no official statistics existed can help us understand better not just this economy but potentially the role that such government-provided information plays today as well.

[67] This is only strictly true in a formal sense if we exclude the 1720-30 period, which exhibited some persistence as well as higher variance than later periods, as is visible from the graphs. But this is of course much clearer to us now that it could have been for the agents at the time.

the past vis-à-vis modern economies. On the one hand, in early modern economies social norms could lead to price and wage rigidities as well as market illiquidity. Land contracts, for instance, were often set for several generations. And unlike today in the early modern period nominal wages (though not prices) only varied very intermittently, often staying constant over an interval of many years. But at the same time, in modern, rich economies prices (but not wages) seem to vary considerably less than they did in the past, perhaps due to the stabilizing influence of modern central banks.

And yet it is striking that the response of past economies to monetary shocks was as similar as that which we expect from those today. The fact that in the European early modern period monetary shocks had effects that match much of what we know about their effects today suggests one of two conclusions. Either the mechanism that generates modern liquidity effects is not, in fact, "modern" -- that is, not as related to the role of financial intermediation as some of the textbook channels of monetary policy transmission suggest -- or instead, they were of a different nature than those of today, but happen to roughly coincide in timing and magnitude of effect. More research is needed, particularly at the micro level, to distinguish between these possibilities.

5. Conclusion

Identification in both economic history and macroeconomics is illusive: convincing natural experiments or instrumental variables which allow us to answer important questions are rarely available. In the case of the identification of the effects of money on the real economy, an extensive literature has developed, but the fact that liquidity effects are so difficult to identify has led to all sorts of conclusions, ranging from monetary shocks having no effects (Sims and Zha 2006, Williamson and Wright 2011) to them having small-to-moderate and persistent effects (Christiano, Eichenbaum, and Evans 1999), to strong and very persistent effects (Romer and Romer 2004).

The early modern monetary injections from America provide a clean source of identification for this problem.[68] While restricted to a period of the past – and because of the different nature of past economies I am certainly not in favor of quick extrapolations of external validity – the evidence is in support of the notion of non-neutrality, and in favor of large, and persistent, effects of money on real output.

Many extensions of this work are possible for the future. For some countries it is possible to split the output data into agricultural versus non-agricultural (industry and service) sectors. It seems likely that the effects are stronger for the latter, which would then suggest that the full results are being driven by an elastic response of industry and services (while in agriculture supply was much more inelastic). Another promising avenue is to consider whether the effects are stronger at times of recession. The exercise is not straightforward since the definition of "recession" is far from clear-cut, and the annual frequency of the data only allows us to consider episodes where the recessions lasted at least two years. Still, one simple possibility would be to define recession as two years below trend growth where in turn this is given by a polynomial approximation, or where the cyclical component is defined by a filter such as Hodrick-Prescott or Baxter-King. This would allow us to consider whether the effects change conditional on the receiving economy being in recession (Ramey and Zubairy 2014, Thwaites and Tenreyro 2016). Finally, my emphasis in this paper has been on reduced-form results but one important future step is to understand the structural mechanism behind them.

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[68] I do not take an active position in this paper on what was the mechanism through which money affected real economic activity. Unfortunately annual data on interest rates is not systematically available for these economies, and more than one type of monetary transmission mechanism is consistent with these results.

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Appendix to chapter *3*

Historical material (Sources)

GDP and GDP deflator data. England/UK from Broadberry et al. (2015). North and Central Italy from Malanima (2011). Holland from Van Zanden and van Leeuwen (2012). Spain from Álvarez-Nogal and Prados de la Escosura 2013), Portugal from Palma and Reis (2014), and Sweden from Schön and Krantz (2012, 2015).

Conversion to grams of silver. Pounds sterling from Munro (undated). Florentine lire to grams of silver from Malanima (2011). Dutch guilders from Van Zanden and van Leeuwen (2012). Spanish reales from Waltis (1994). In the case of Sweden, I used the following conversion rates for the conversion to nominal GDP in 1800: 1 riksdaler specie = 25.2816 gram silver; 1 riksdaler banco = 1 riksdaler specie; 1 riksdaler banco = 1.445 riksdaler riksgälds; 1 SEK = 1 riksdaler riksgälds. These rates correspond to the 1800 average, as the value of riksgälds in riksdaler banco was floating and changed each month. SEK defined as riksdaler specie in 1776-1788, riksdaler riksgälds 1789-1855, riksdaler riksmynt 1855-1873. Hence, 1 SEK = 36.5319 grams of silver, and nominal GDP in 1800 = 133.64 million SEK = 4882.18 tons of silver. For earlier periods, 1 SEK defined as riksdaler specie in 1776-1788, and riksdaler riksgälds 1789-1855. The fine silver content of mark (mark kopparmynt from 1624) was then used, making the 1 SEK = 72 mark kopparmynt conversions in 1777. (Thanks to R. Edvinsson for this info.).

Production of precious metals. In all cases the original units are pesos of 272 Maravedís, here converted to grams of silver at the rate of 1 silver pesos of eight reales (or equivalently, 272 Marvedís) = 25.931 grams of silver; for the conversion rate, which is valid for the entire early modern period, see Munro (2003). Silver production in Peru, 1531-35 from Vilar (1969, p. 110); Silver production in Peru (Lima), 1536-59 (original data by decade, here annualized) from TePaske (2010, p. 187). Silver production, Peru (Potosí), 1545-1559, from TePaske (2010, p. 188). Silver production in Mexico, 1531-1559 (original data by decade, here annualized), from TePaske (2010, pp. 114). Silver production Peru, 1559-1790, from TePaske, Herbert Klein et al. (1982); silver production in Mexico, 1559-1790, from TePaske and Klein

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Mercury supply. In Quintales (1 quintal = 100lbs), 1558-1790. As complied from a wide variety of primary and secondary sources and made available by Richard Gardner, R. at http://www.insidemydesk.com/ (last accessed January 22nd, 2015)

London price of gold and silver. Prices are in pounds sterling per ounce for gold and pence per ounce for silver. This data was taken from Neal (1990) and McCusker (1978), as made avaliable by Officer and Williamson (2015).

Weather shocks data. Seasonal air temperature data from Guiot and Corona (2010), Luterbacher et al. (2004), and Xoplaki et al. (2005). Seasonal precipitation data from Pauling et al (2007).[69] The original data are given in a grid, which varies between 70.75-30.25N and 29.75W-39.75E. I have chosen, for each country, the grid closest to the capital city (the only exception has been Italy, in which I have chosen Florence, as Malanima's data refers to Central and North Italy only.) In a few cases the data was not available for a specific location, and when this was the case I chose the nearest available grid for the same year, fixing the latitude, and searching along the longitude, as described in detail below. Since for each country there is season-specific data for both temperatures and rainfall for each year, the total amount of data collected has been 6*4*2*231=1488 observations. The exact coordinates chosen were as follows. England: 51.25N, 0.25W; Italy (Central and North): 43.25N, 11.25W; Holland: 52.25N, 4.75W, Sweden: 52.25N, 18.25W; Spain: 40.25N, 3.25W, Portugal, 38.75N, 9.25W. When data was missing an approximation was made using the nearest available longitude as follows. Autumn precipitation: Italian longitude proxied by 8.25W, Swedish longitude proxied by 19.75W; Spring precipitation: same as for Autumn; Summer precipitation: Italian longitude proxied by 8.25W, Swedish longitude proxied by 9.75; Winter precipitation: same as for winter.

[69] Taken from http://www.cru.uea.ac.uk/cru/projects/soap/data/recon/, accessed January 2015.

Appendix figures and tables

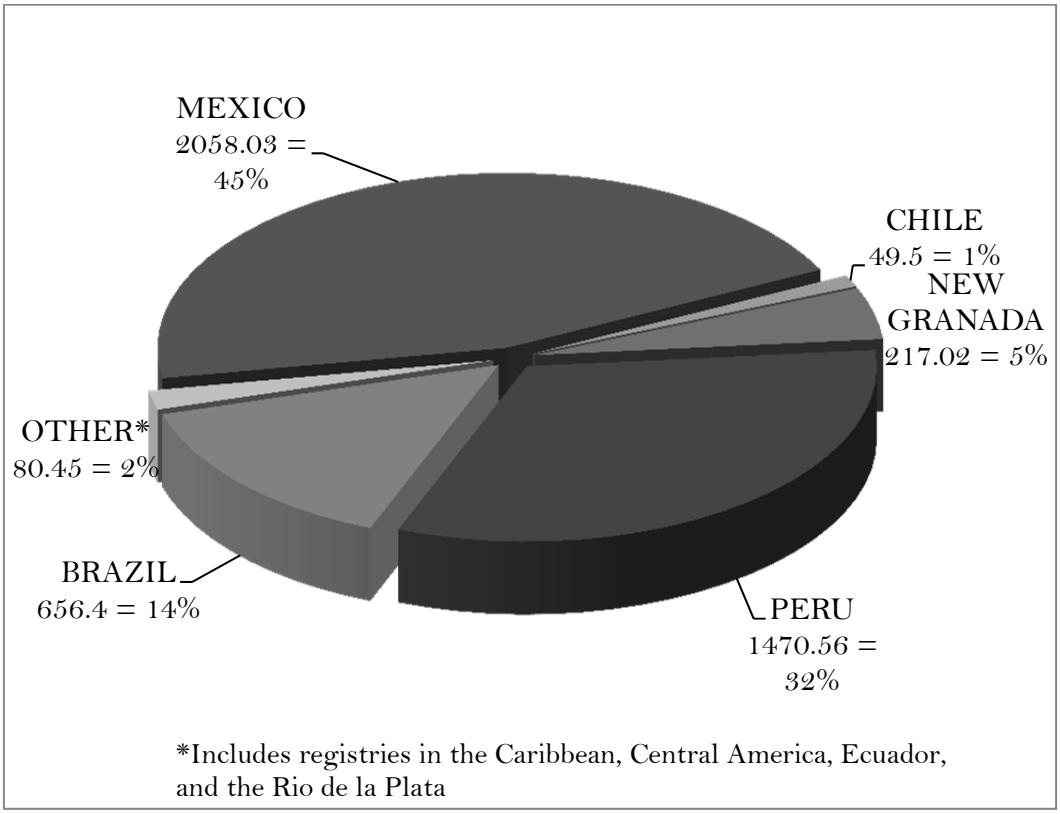
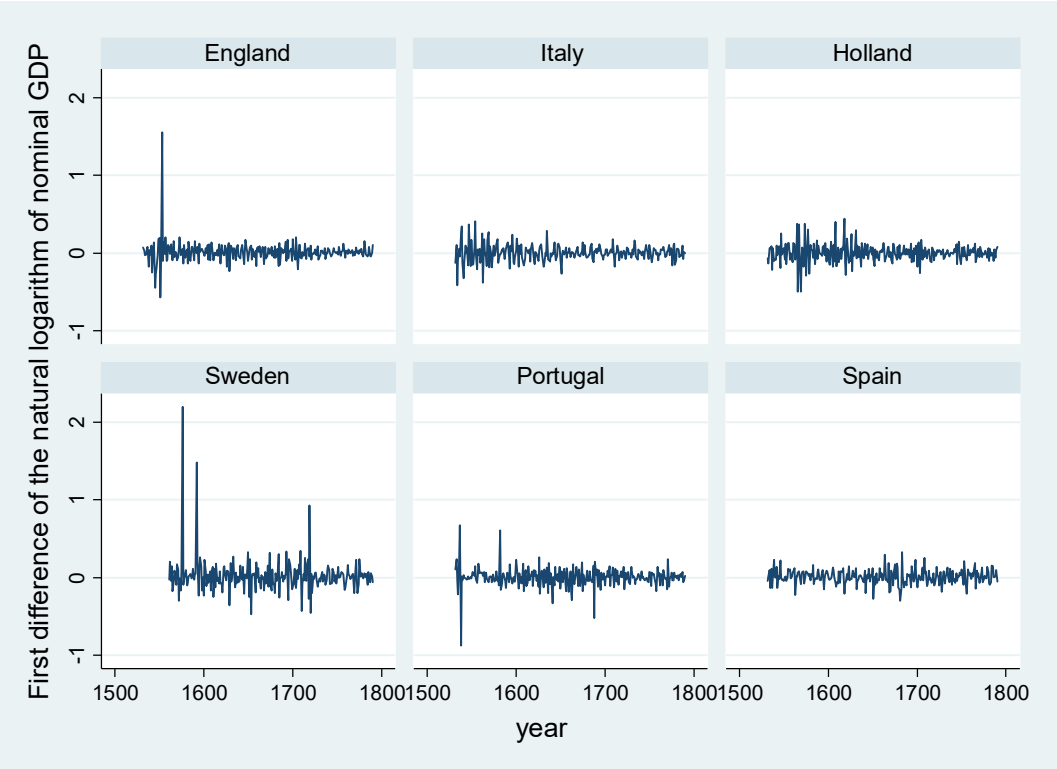


Figure A1. New World gold and silver output distribution, 1492-1803, in billions of silver pesos of 272 maravedís. Source: TePaske (2010)



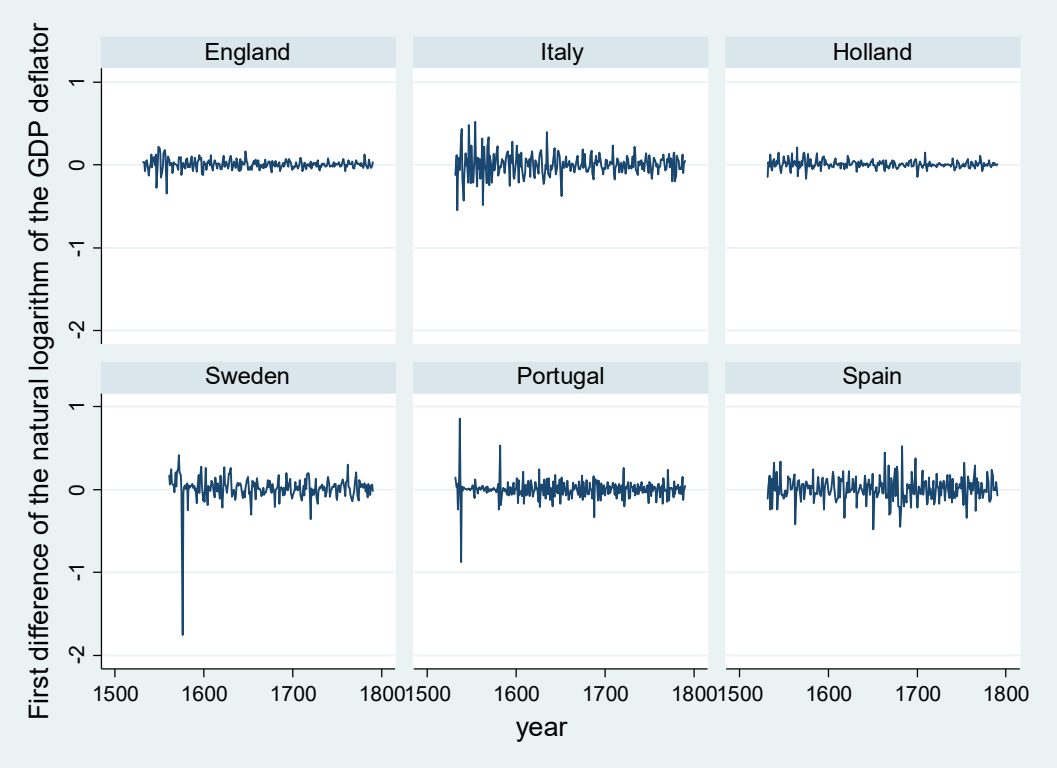


Figure A2. First difference of the natural logarithm of nominal GDP and the GDP deflator. Sources: see the appendix.

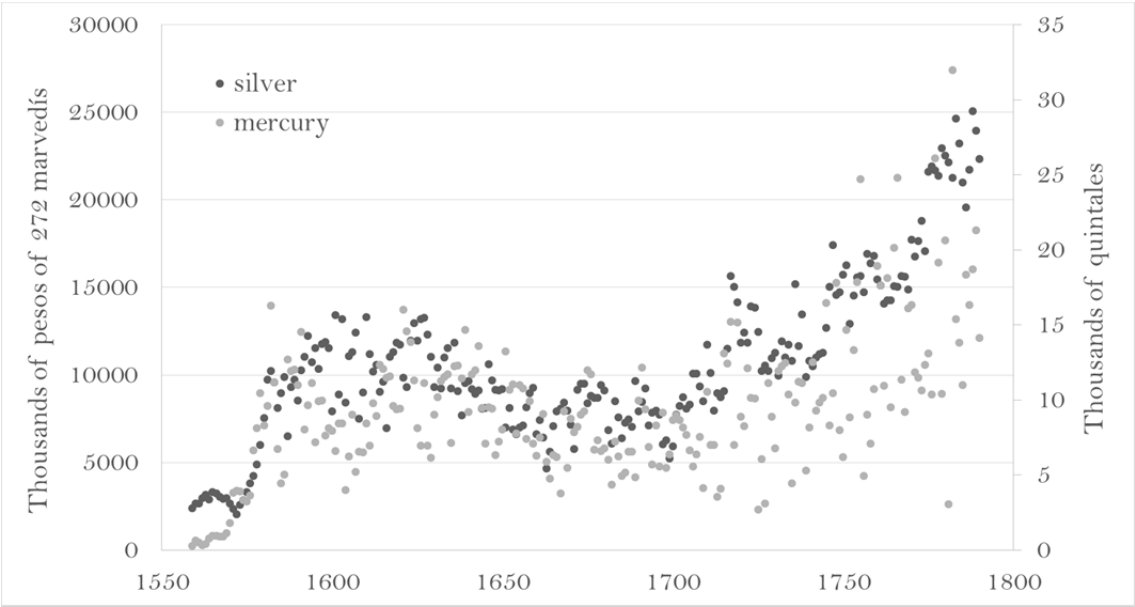


Figure A3. Production of precious metals and mercury usage. Source: Gardner (1988)

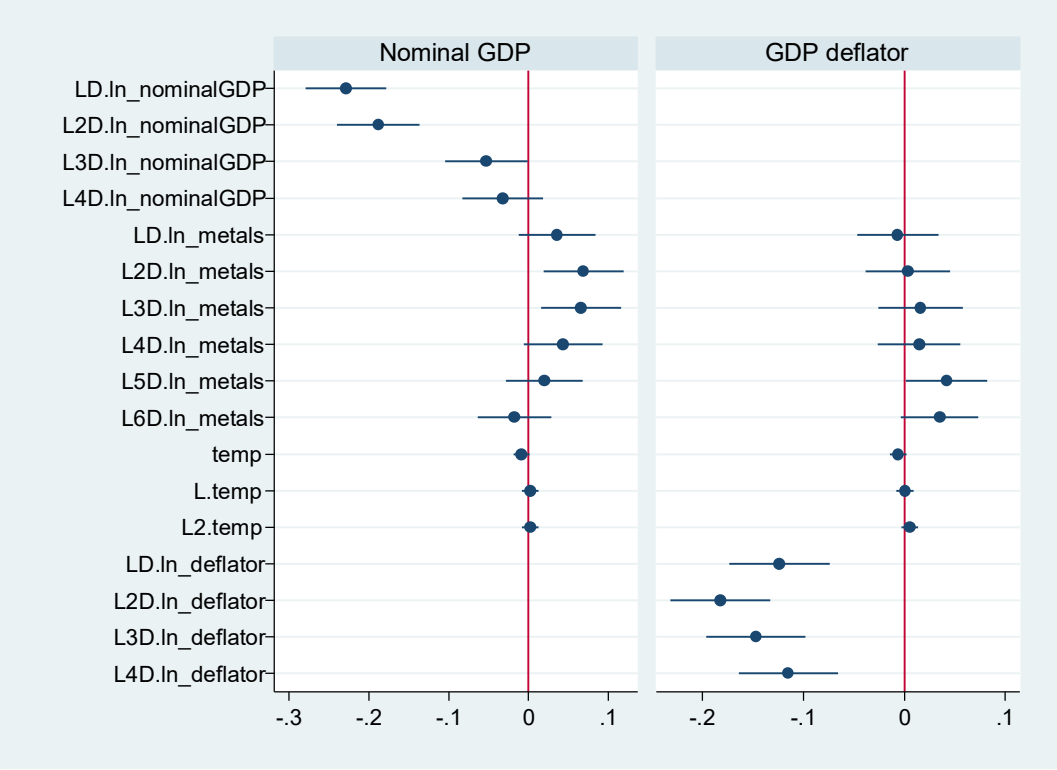


Figure A4. Estimated parameters and coefficient intervals relative to columns (2) of Tables 3 and 4 in the main text.

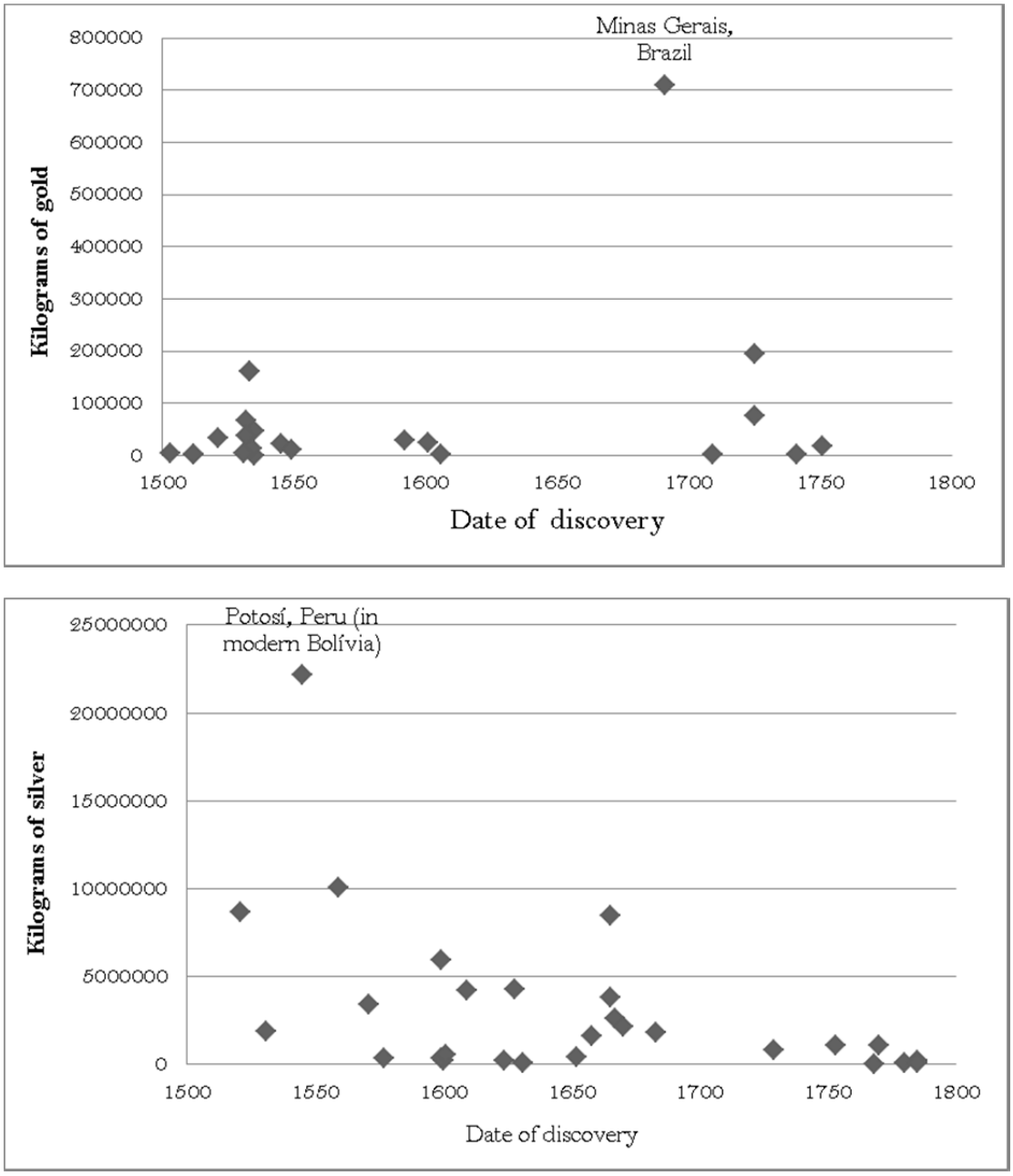


Figure A5. Kilograms mined vs. date of discovery. Sources: TePaske (2010)

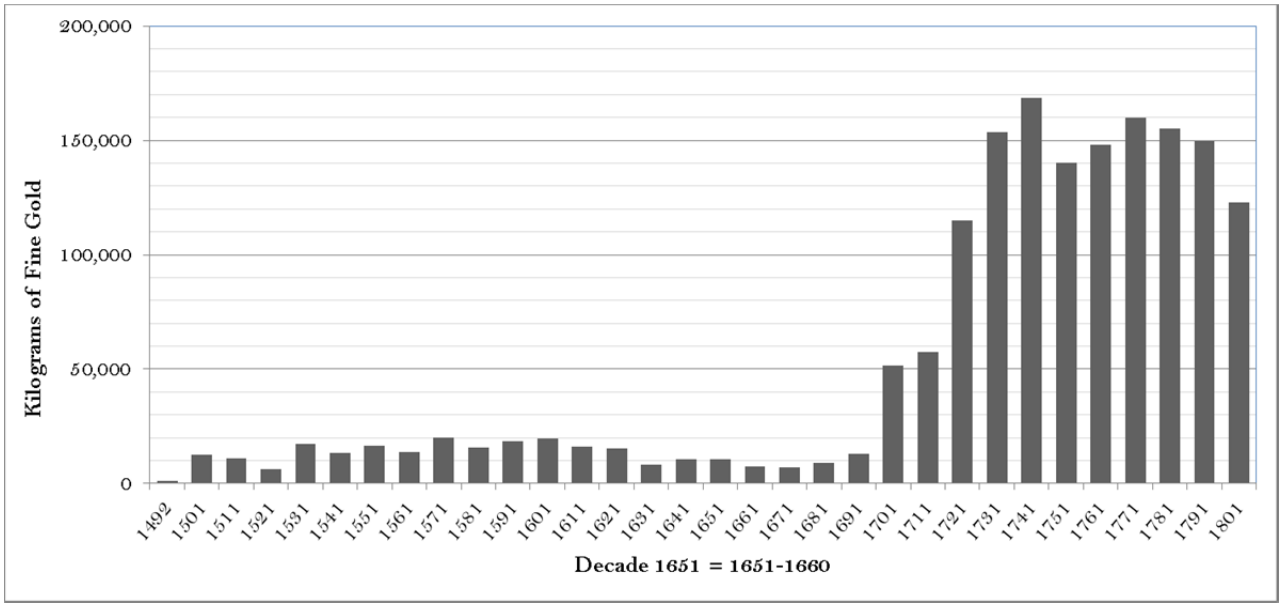


Figure A6. New World Gold output (in kg.), 1492-1810. Source: TePaske (2010, who in turn relies on a combination of other sources).

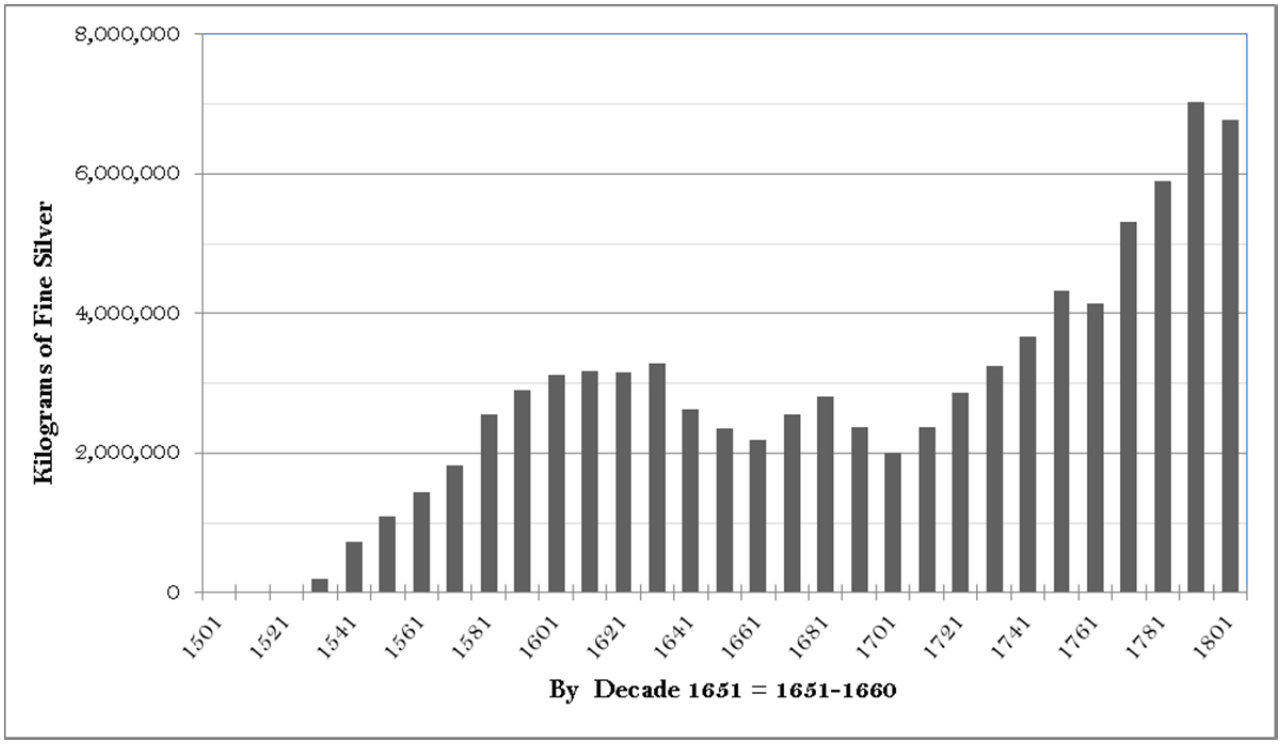


Figure A7. New World Silver output (in kg.), 1492-1810. Source: TePaske (2010, p. 76, who in turn relies on a combination of other sources).

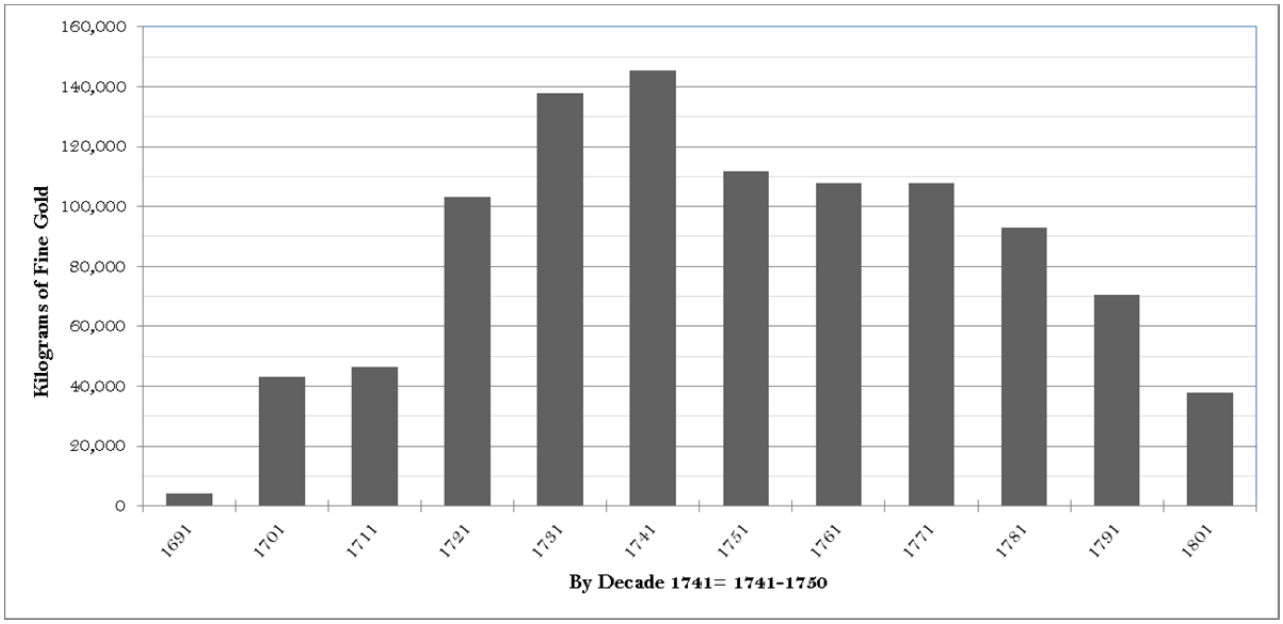


Figure A8. Brazil Gold Production, 1691-1850, in kg. Source: TePaske (2010, p. 47)

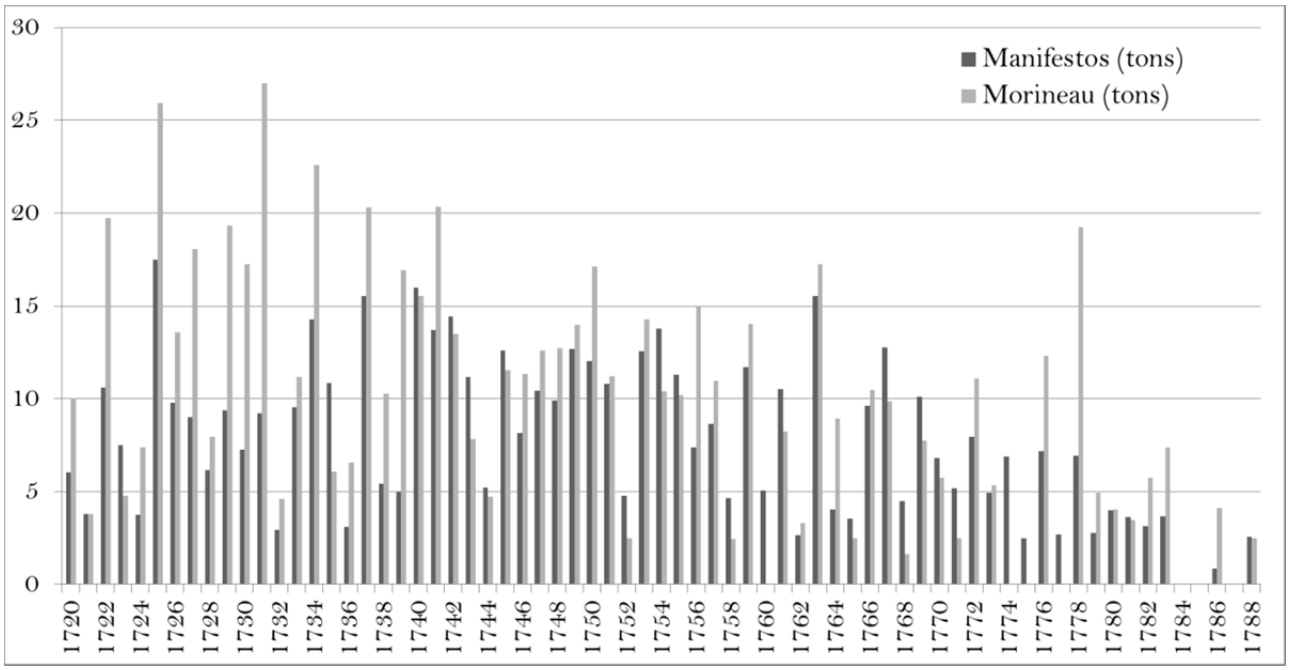


Figure A9. Dealing with endogenous formation of expectations: comparison of the informational higher bound (Manifestos) with the true arrivals (Morineau). Sources: Morineau (1985), Costa, Rocha and Sousa (2013).

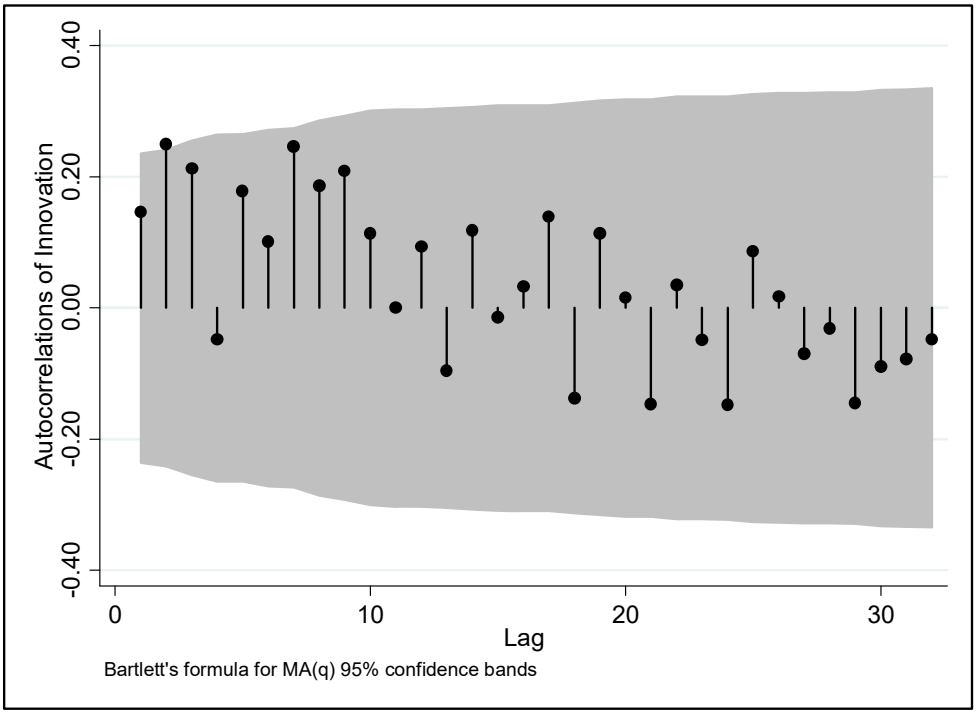


Figure A10.Aucocorrelations of the "innovation" variable in Figure 9 of the main text. 95% confidence bands are shown in grey.

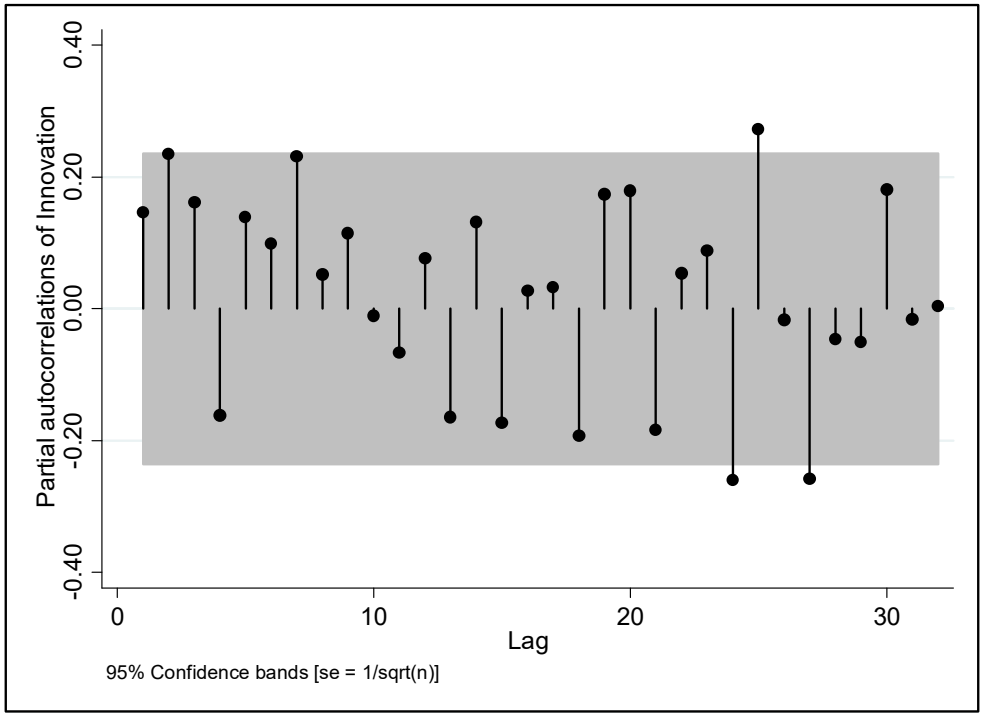


Figure A11. Partial autocorrelations of the "innovation" variable in Figure 9 of the main text. 95% confidence bands are shown in grey.

Sample	Second-order receivers: England, the Netherlands, Sweden and Italy			Second-order receivers, plus Portugal prior to 1690		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Ln of Nominal GDP	Ln of Price level	Ln of Real GDP	Ln of Nominal GDP	Ln of Price level	Ln of Real GDP
Estimator	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)
Constant	.007*	.005**	.002	.006	.001	.001
	(.004)	(.002)	(.004)	(.004)	(.003)	(.003)
First diff. of the ln of precious metals production (-1)	.051*	.013	.038	.053**	.040	.040
	(.028)	(.020)	(.042)	(.023)	(.032)	(.032)
First diff. of the ln of precious metals production (-2)	.089***	.008	.081*	.079***	.067*	.067*
	(.017)	(.036)	(.047)	(.021)	(.039)	(.038)
First diff. of the ln of precious metals production (-3)	.050***	.009	.041	.066***	.045	.045
	(.015)	(.047)	(.053)	(.014)	(.040)	(.040)
First diff. of the ln of precious metals production (-4)	.050	.034***	.016	.022	.014	.014
	(.034)	(.0093848)	(.041)	(.026)	(.031)	(.031)
First diff. of the ln of precious metals production (-5)	.012	.057**	-.044*	-.006	-.038**	-.039**
	(.010)	(.026)	(.020)	(.008)	(.018)	(.018)
First diff. of the ln of precious metals production (-6)	-.046**	.028*	-.074***	-.041	-.059**	-.060**
	(.021)	(.017)	(.027)	(.020)	(.027)	(.027)
DEPENDENT VARIABLE DYNAMICS CONTROLS	YES	YES	YES	YES	YES	YES
WEATHER CONTROLS	YES	YES	YES	YES	YES	YES
R^2	0.0359	0.0298	0.0333	0.0315	0.0317	0.0317
observations	985	985	985	1,138	1,138	1,138

Table A1. Nominal GDP, the price level, or real GDP sample split by receiving order. The "dependent variable dynamics control" include four lags of the dependent corresponding dependent variable. Standard errors (in parentheses) are bootstrapped with 1000 replications. *, ** and *** denote individual statistical significance at the 10, 5, and 1% levels.

Sample	**England and the Netherlands**			**Sweden, Italy, Portugal and Spain**			**Sweden and Italy alone**		
Dependent variable	(1) Ln of Nominal GDP	(2) Ln of Price level	(3) Ln of Real GDP	(4) Ln of Nominal GDP	(5) Ln of Price level	(6) Ln of Real GDP	(7) Ln of Nominal GDP	(8) Ln of Price level	(9) Ln of Real GDP
Estimator	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)	Fixed-effects (within estimator)
Constant	.008 (.0074)	.006 (.005)	.0016 (.008)	.005 (.004)	.004* (.002)	.002 (.002)	.009 (.007)	.006 (.005)	.003 (.003)
First diff. of the ln of prec. metals prod. (-1)	.081*** (.026)	.024 (.040)	.016 (.050)	.037 (.030)	-.008 (.030)	.046 (.030)	.081*** (.026)	.024 (.040)	.058 (.067)
First diff. of the ln of prec. metals prod. (-2)	.102*** (.024)	.023 (.072)	.068*** (.005)	.059** (.030)	.012 (.036)	.047 (.046)	.102*** (.024)	.023 (.072)	.079 (.095)
First diff. of the ln of prec. metals prod. (-3)	.074*** (.012)	-.008 (.107)	.015 (.025)	.065*** (.017)	.010 (.048)	.055 (.051)	.0742*** (.012)	-.008 (.107)	.082 (.107)
First diff. of the ln of prec. metals prod. (-4)	.104** (.049)	.041 (.035)	-.012* (.006)	.036 (.031)	.002 (.012)	.034 (.037)	.104** (.049)	.041 (.035)	.063 (.079)
First diff. of the ln of prec. metals prod. (-5)	.026* (.016)	.070** (.028)	-.046** (.023)	.005 (.014)	.027 (.021)	-.022 (.018)	.026 (.016)	.069** (.028)	-.043* (.025)
First diff. of the ln of prec. metals prod. (-6)	.003 (.034)	.063*** (.015)	-.092*** (.023)	.006 (.0212458)	.039* (.022)	-.033 (.029)	.003 (.034)	.063*** (.015)	-.060 (.045)
DEPENDENT VARIABLE DYNAMICS CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES
WEATHER CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.0244	0.0304	0.1193	0.0114	0.0132	0.0227	0.0244	0.0304	0.0258
observations	479	479	479	985	985	985	479	479	479

Table A2. Nominal GDP, the price level, or real GDP for sample split by type of GDP data. The "dependent variable dynamics control" include four lags of the dependent corresponding dependent variable. Standard errors (in parentheses) are bootstrapped with 1000 replications. *, ** and *** denote individual statistical significance at the 10, 5, and 1% levels.

Chapter 4. Reconstruction of annual money supply over the long run: the case of England, 1279-1870[70]

1. Introduction

In this paper I provide the first annual time series of coin and money supply estimates for about six hundred years of English history. I present a baseline set of estimates, but also consider a variety of alternative scenarios and provide several robustness checks. I concentrate on carefully setting out the details for the data construction, rather than on analysis, but the hope is that these new estimates – the longest such continuous series ever assembled, for any country – will open new vistas to help us understand the complex interaction between the real and the monetary sides of the English economy, at both business-cycle and long-run frequencies. Furthermore, the new methodology which I set out here may serve as a blueprint for a similar reconstruction of coin and money supply series for other economies for which the analogous required data is available.[71]

I propose two new estimation methods. The first, which I call the "direct method", is used to measure the value of government-provided, legal-tender coin supply only. I do not consider broader forms of money such as banknotes, deposits, bills of exchange or private tokens. Notice, however, that these were not as liquid or widely accepted as coin, and it is important not to exaggerate their early importance as a share of the total means of payment: as late as 1790 the monetary base was composed of £44 million of commodity-based coin but only £12 million in notes – £8 million Bank of England notes and £4 million for all other, including bills of exchange (Capie 2004; O'Brien and Palma 2015).

I discuss the results for the 1279-1790 period first, and then in section 4 present an extension until 1870. Additionally, I propose an "indirect method" which relies on a combination of in-

[70] I am thankful to Martin Allen, Jim Bolton, Steve Broadberry, Forrest Capie, Alejandra Irigoin, Pilar Nogues-Marco, Patrick K. O'Brien, Ulrich Pfister, and especially Nick Mayhew, Albrecht Ritschl and Joan R. Rosés, for helpful comments and discussions. The usual disclaimer applies.

[71] Flandreau (2004, p. 75-96 and 220-225) discusses a related method, which requires a different kind of data and makes more restrictive assumptions.

formation about nominal GDP with the value of coin supply or M2 known at certain benchmark periods. This permits estimating the growth of financial intermediation over time.

2. Historical background

In this section I discuss how the English monetary system differed from that of today, both in terms of what constituted money, and how monetary policy was conducted. I start by discussing the role of the government in providing liquidity in the English context.

In modern economies central banks issue fiat currency and engage in monetary policy. In early modern economies including England central banks with these functions did not exist – the Bank of England was created in 1694, but it was a private institution and not a central bank in the modern sense, although it did gradually began to play a public role by providing liquidity to the economy, in particular to other banks and to the government (O'Brien and Palma 2015); still, it took a while until it began to play the "lender of last resort" role (Bordo 2007).

Yet to say that a central banks officially endowed the modern functions did not exist is not the same as saying that governments did not engage in monetary policy. In a nutshell, monetary policy can be for premodern economies helpfully identified with mint policy (Sargent and Velde 2002). Agents were free to take precious metals to the mint and the government chose at which rate these were exchanged for currency, whether to charge a mint fee[72], and, out of a given set that was offered, which denominations to issue.

Given the market price of precious metals and that of minting (in some but not all countries a minting fee was charged), the public decided how many coins to mint and how many to melt or export. In terms of circulation value, there was a premium in low denomination coins due to both cost (lower denominations were proportionally more expensive to produce) and convenience (lower denominations had proportionally higher value due to additional convenience as small change). The low denomination premium meant that coins were valued not just pro-

[72] This is a fixed cost and hence different from the seigniorage fee which is the difference between the market value of the precious metals and the cost to produce the currency which was given in exchange.

portionally to their precious metal content but also by tale, that is, according to their denomination itself (Sargent and Velde 2002, p. 322.)

Since central banks in the modern sense did not exist during this period money, cannot be helpfully defined as liabilities of central banks and credit institutions towards the public. An alternative, if close, definition for M0, M1 and M2 are required. The main point to be realized is that these are progressively less liquid assets, defined as such both in terms of divisibility and general acceptability as well as how quickly redeemable they are.

It is important set out some definitions at the outset. I use the term *coin* referring to official (legal tender) bullion-based coin, regardless of whether it was circulating by tale or not (it usually was). One major distinguishing characteristic of legal tender coin was that, measured in value, the "intrinsic" component was an important part of the overall value, that is, much of it was silver or gold coins (though there was some copper issues as well, but they were worth much less). As for private tokens and other fiat money, these are, conceptually, part of the currency or M0, but are not here defined as "coin".[73] Hence my definition of coin supply is a subset of M0.

Thus coin supply differs from currency supply: it excludes bills of exchange, tokens, and notes in circulation.[74] To avoid confusion, I avoid the term M0 altogether, as doing so would imply excluding notes which would depart from modern practice.[75] However, it is important not to place too much emphasis on anachronistic classifications such as M0 and M2. What for the present purpose does matter is to separate coin (for practical purposes, "quasi-M0") from "everything else", that is, all other assets sufficiently liquid to be potentially classified as "money".

[73] Capie (2004), for instance, defines the monetary base as including banknotes and bank balances at the Bank of England, but also recognizing that "privately issued tokens were at times widespread" (p. 225)

[74] In modern terms, it is usually made clear that only money in circulation counts, that is, we do not include those in the hands of central banks and in the vaults of depository institutions. Since no reserve requirements existed in the period under study, however, no such proviso is not necessary, though it is possible that under some periods some currency was being hoarded as such, instead of circulated.

[75] Unlike what would be true for a modern economy, notes were less liquid than currency, since until quite late they were only issued in high denominations – only in the last decade of the eighteenth century were £1 notes issued by the Bank of England, for instance, only then just low enough to pay a laborer's monthly wage (Schwarz 1985) – but even then, and throughout the nineteenth century, these were less credible than bullion-based currency (often circulating at discount), and of less wide acceptance (especially those issued by provincial banks). Of course, as time goes by, these were increasingly closer substitutes to money, so the boundaries become fuzzier.

3. Baseline estimates

The baseline estimation method relies on information about the value of the coin stock which is known for certain periods. When the type changed (e.g. 1279), or when the hammered coins were demonetized (1696), all the previous coinage still in circulation was called in and we know the value (and the distribution) of the total coin stock quite precisely. In other periods, only earlier coins of good weight would have yielded a profit on recoinage, but painstaking work by monetary historians has led to several secure values for the stocks at several points in time (Table 1, first column).

Evidently, some estimates are more secure than others. The most secure estimate is that of 1870 (Capie and Weber 1985, p. 192-202), but earlier figures that are based on either full or even partial recoinages can also be safely trusted. An example of the latter is the "Great Recoinage" of 1696: it was a partial recoinage because gold was not subject to it, but together with complementary information it leads to what is almost certainly a good approximation (Mayhew 1995, p. 277)

Still reasonably secure are the figures marked as "proxies" in Table 1. These cases are inferred by indirect evidence. The first form of such evidence comes from the dies used to produce the coinage. Coins were struck to completion by placing a blank between two dies and hammering. Surviving coins individually identify their corresponding dies, allowing the number of dies used to estimate the volume of coinage (Allen 2001, p. 597). Another form of indirect evidence used have been archaeological evidence for site finds of coins (hoards). The English civil war produced many coin hoards as a side-effect, which have been put to use in this context, as they indicate which proportions of currency date from which periods (Mayhew 1995, fnt. 4, Mayhew and Viner 1987, Besly 1987, Mayhew 2013, fnt. 38). Finally, the figures marked as "guestimates" are the least secure. There are based on historians' overall understanding of available quantitative and narrative evidence. Unfortunately, there is concentration of these during the Tudor period.

Year	Coin stock value (preferred estimate)	Implied V of coin stock	Type of estimate	Year	Coin stock value (preferred estimate)	Implied V of coin stock	Source of estimate
1279	0.6	6.09	Full recoinage	1548	1.76	3.97	Guestimate
1282	0.835	5.49	Proxies	1549	1.92	4.35	Guestimate
1290	1.0	3.31	Proxies	1551	2.02	5.71	Guestimate
1299	1.1	4.37	Proxies	1560	1.71	6.89	Guestimate
1310	1.5	3.85	Proxies	1561	1.45	8.82	Guestimate
1319	1.5	2.68	Proxies	1600	3.5	6.65	Proxies
1331	1.2	3.16	Proxies	1643	10	3.91	Proxies
1351	0.6	5.98	Partial recoinage plus proxies	1670	12	3.90	Proxies/Guestimate
1377	1.92	2.27	Proxies	1688	10	5.14	Proxies
1422	1.285	2.06	Proxies	1700	10.75	7.07	"Great Recoinage" of 1696-7
1470	0.9	4.53	Full recoinage	1750	18	5.06	Guestimate
1526	1.4	3.5	Guestimate	1790	44	3.88	Guestimate
1546	1.45	5.98	Guestimate	1870	95	10.80	Proxies*

Table 1. Benchmarks for the value of English nominal coin supply and implied velocity, 1270-1870. Sources: For 1279-1470, see Allen (2012). The partial recoinage leading to the figure for 1351 is discussed in Mayhew (1987), and the full recoinage leading to that of 1470 is discussed in Mayhew (1974a), and further improved by Challis (1992, p. 195) and Mayhew (1995, p. 245). For 1526 to 1700, see Mayhew (2013, p. 26-29), where 1551 corresponds to an average of the two available estimates for that year. For 1643, civil war coin hoards were used (Mayhew 1995, 2013). For 1688-1750, these are the estimates of Cameron (1967), endorsed by Mayhew (2013, p. 30). For 1790 and 1870, see Capie (2004, p. 222-225), which in the latter case relies on Capie and Weber (1985, p. 192-202), which in turn largely rely on Jevons (1868). * Despite being based on proxies, the 1870 benchmark is quite secure; see the discussion in Capie and Weber (1985), and the figures in table 3 below.

While the figures discussed so far provide a static snapshot of the value of currency for given years, mint output data provides much useful information about the flows for the in-between years between the stocks in Table 1.[76] Detailed annual estimates exist for the Tower of London mint output (Figure 1) and up to the 1840's it is safe to say that these would have gone directly into circulation (Capie and Weber 1983, 1985).[77] However, simply summing up mint output over time to any given stock from Table 1 would lead to numbers which overestimate the amount of coin in circulation, and hence are inconsistent with the following corresponding stock also observable from Table 1. This is because using that method coin melted down but subsequently again minted is double-counted. Further, much coin was carried abroad in the context of war, diplomatic payments, or trade, and this means that total coin supply at each given moment differed from the accumulated sum of mint output.

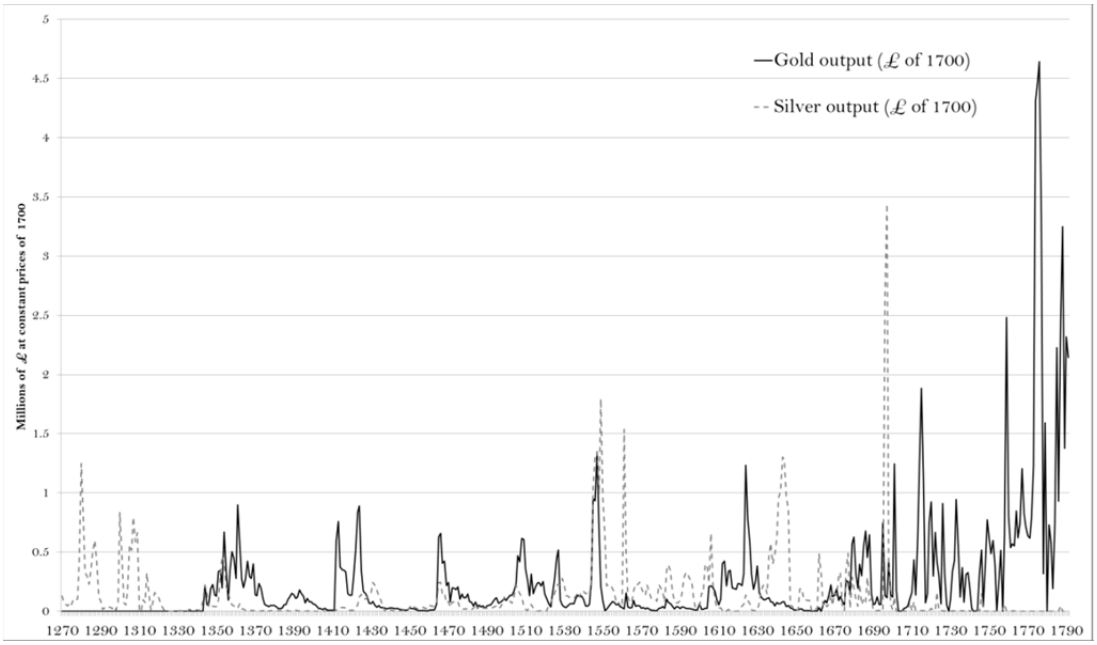


Figure 1. Gross mint output at constant prices of 1700. The peaks in the 1690's and 1770's are correspond to re-coinages; see Horsefield (1960, p. 51-52). Source: Challis (1992); the GDP deflator is from Broadberry et al (2015)

Since the true value of coin supply is known at relatively regular intervals, however, it is possible to "correct" for this bias by factoring out the observed residual from the annual esti-

[76] All stocks are end-of-period stocks (when necessary appropriately annualized to the year on which the majority of the period refers to; after 1660 all variation corresponds exactly to the civil year).
[77] I also consider provincial mints below.

mates. The precise way in which this is done is what distinguishes the "direct method A" from the "direct method B", the latter corresponding to the baseline estimates, which I argue that are the best.

3.1. Previous estimates

In a related piece of work Mayhew (2012b) acknowledges the need to target successive known stocks by estimating annual currency by deducting estimated wastage from known output, alternatively using 2% or 4% assumptions on annual wastage. Notwithstanding the usefulness of Mayhew's attempt, I use a different approach, with the objective of arriving at estimates for which much less true variation is lost. Annual variation in wastage can be estimated with much additional precision for two reasons. First, some components of wastage can be accounted for annually from annual data, as explained in detail below. Second, even after this is controlled for, instead of assuming fixed percentage wastage rate levels over the remainder, it is possible to let these vary endogenously at an arithmetic rate, such that wastage is whatever it needs to be annually such that we arrive at the following available coin supply benchmark as discussed below.

3.2. General methodology

Changes to the value of coin supply are given by

$$dC_t = O_t + P_t + X_t$$

Where dC_t is a flow variable corresponding to the change in the value of coin supply (C_t), O_t stands for net mint output for that year, P_t is the change in hoarding, and X_t is a residual. I now discuss each of these right hand side variables in detail.

O_t is expressed in net terms because gross mint output overstates the annual change in the money stock in years of recoinage or those of net outflows of specie.[78] Hence,

[78] As Glassman and Redish (1985, p.32) notice when discussing the French case, "Balance of payments surpluses were recorded in mint output, at least when settled in coin taken to French mints. Balance of payments deficits, however, caused specie exports not recorded in mint output".

$$O_t = new\ coinage_t - recalls_t$$

Because I estimate the value of coin supply (assumed to be circulating by tale) I do not need to consider clipping or melting down. However, one limitation to the estimation of O_t from mint output data by using the Tower records (reproduced in Challis 1992) is that these only cover the Royal mint, but until 1553 other mints were in operation in several English towns.[79] I have applied a partial correction for this by using the additional information in Munro (1983, p. 127-37), but it must be recognized that much variation in provincial mint output remains unaccounted for at an annual level. However, notice that this will not lead to systematic biases over the long run since the stocks in table 1 above have already corrected for this by using estimates adjusted to the output of provincial mints (Allen 2001, 2012).[80]

The presence of P_t, the change in hoarding, is required because the proportion of precious metals which finds its way into the monetary base changes as agents change how much is held in plate (Mayhew 2012).[81] Much of the value of currency melted down for hoarding purposes can be inferred from the Goldsmiths' company data (Mayhew 2012a), as it had the monopoly over hallmarking – of silverware and jewellery as well as gold, despite the name of the company. Finally, X_t denotes a "wastage" residual that includes coin melted down or exported.

[79] Regional mints opened during some exceptional periods of the early modern period such as the Civil War when a Royalist mint was briefly set up and the Great Recoinage; Challis (1992) includes supplementary information for these periods, which I include in my calculation.

[80] For the medieval period, Allen (2012) provides estimates based on information from the distribution of finds in coin hoards. Until the early modern period, the residual includes undocumented provincial and ecclesiastical mint output from the Bristol, Bury St. Edmunds, Calais, Canterbury, Chester, Coventry, Durham, Lincoln, Norwich and York mints. In the earlier periods, the unrecorded outputs of provincial mints could be substantial – more than one third of total estimated output in three periods between 1279 and 1351 (Allen 2012, p. 312). Hence during the medieval period the money supply must have grown faster than what would be suggested by looking at the (Royal mint) Tower records only. But using my baseline method, the residual between benchmarks will automatically absorb this bias, and only some of the short-term variation associated with between-benchmarks variation in provincial mint output will be lost. Furthermore, this lost variation is always limited since as previously mentioned Tower mint output was never less than two thirds of total mint output, and usually it was a good deal more.

[81] Notice that precious metals melted to be used as plate leave circulation but not those hoarded as coin; when savings increase and people are hoarding currency the circulating fraction of money supply decreases but in an aggregate model this simply corresponds to a decrease in velocity.

3.3. Direct method A: the naïve direct method

Since for some years we know the value of the stock of coin in circulation (Table 1), it is possible to calculate the annual residual as an annually uniform "whatever it needs to be" in the intervening period between benchmarks so that the estimated coin supply at the next period for which we observe it matches the predicted value, that is, after all the intervening $\{O_t\}$ and $\{P_t\}$ have been accounted for.[82] I call this the "direct method A". The resulting annual estimates are shown in the broken grey line of Figure 2.

3.4. Direct estimates B: the baseline direct method

Direct estimates A implicitly assume that recalls were uniformly distributed between the known stocks. This was not the case: recalls were often concentrated in time – usually in the context of full or partial recoinages – and ignoring this would lead to misleading estimates, with predicted but spurious peaks of coin supply, due to double-counting, at the time of recoinages, such as the 1690's and the 1770's, clearly visible in Figure 1.

Hence the estimates can be further improved upon by paying close attention to each of the "suspect" periods which can be identified both from the narrative literature and from informal comparison with the indirect estimates which will be discussed in section 3, and making appropriate adjustments as necessary.[83] I now discuss the periods for which I have done so to improve the credibility of the resulting baseline estimates.

The Tudor debasement period. The Tudor debasement period (1542-1560)[84] constitutes an important period of monetary disruption. The bullion content of the pound sterling fell by 25% in gold and 83% in silver (Ling-Fan 2012, p. 75); even once the fineness was partly restored during Elizabeth's reign, the bullion content of English coin was 25% less than it had been before Henry VIII's Great Debasement (Ling-Fan 2012, p. 88). In practice, this would have

[82] Hence notice that while this residual is unobserved at an annual level, the information contained in stocks which we observe force it to be "correct on average" between these. Using the more complicated alternative method of Chow and Lin (1971) does not lead to significantly different results. (The same is true if this method is applied to the baseline estimation method to be discussed next.)

[83] Since velocity only changes very slowly at best over the long run, a prolonged deviation of the direct estimates from the indirect is a red flag.

[84] There is some debate in the literature concerning wherever the Great Debasement started 1544 or at an earlier date (see Challis 1978 and Munro 2010).

meant that more coin was minted than otherwise would have been possible, but when assuming that money circulated by tale and accounting for money supply *in pounds*, as I am doing here, these developments are automatically accounted. So I make no adjustment to the Tower records.

The great recoinage of 1697-8. The great recoinage was caused by a number of factors including the need to substitute the badly worn out coinage. The intellectual debate surrounding the recoinage has been studied in detail and does not need to be repeated here (see for instance, Horsefield 1960, p. 256 or Sargent and Velde 2002). It is, however, important to understand that because the Locke-Newton position prevailed *vis a vis* that of Lowdes, the money supply may have fallen by up to 40%. According to Craig (2010/1953, p. 193), about £9.6 million in face value was retrieved for recoinage, £4.7 million of which was accepted in face value, being that the rest was only accepted by weight. Clancy (1999, p. 15) writes that "[t]he vast majority, in the region of 10 million, of the old currency was withdrawn over the course of several years and what remained unaccounted for was in any case demonetised in January 1698 … 6.8 million was produced to replace the hammered money, which meant that the resulting silver circulation was reduced by 38 per cent".

Hence I input that in the 1696 and 1697 years the residual has to be Clancy's 10 million (by assumption divided evenly between 1696 and 1697), and otherwise I following the usual methodology as in the previous subsection. This leads to an important – and much more historically realistic – result when compared with the direct A (naïve) estimates of the previous subsection. (The practical difference is illustrated in figure 3.) Hence my direct B (baseline) estimates indicate that the value of the coin stock fell in real terms from 12.4 million in 1695 to 10.2 in 1696 and 9.0 in 1697. Then, it restarted growing.

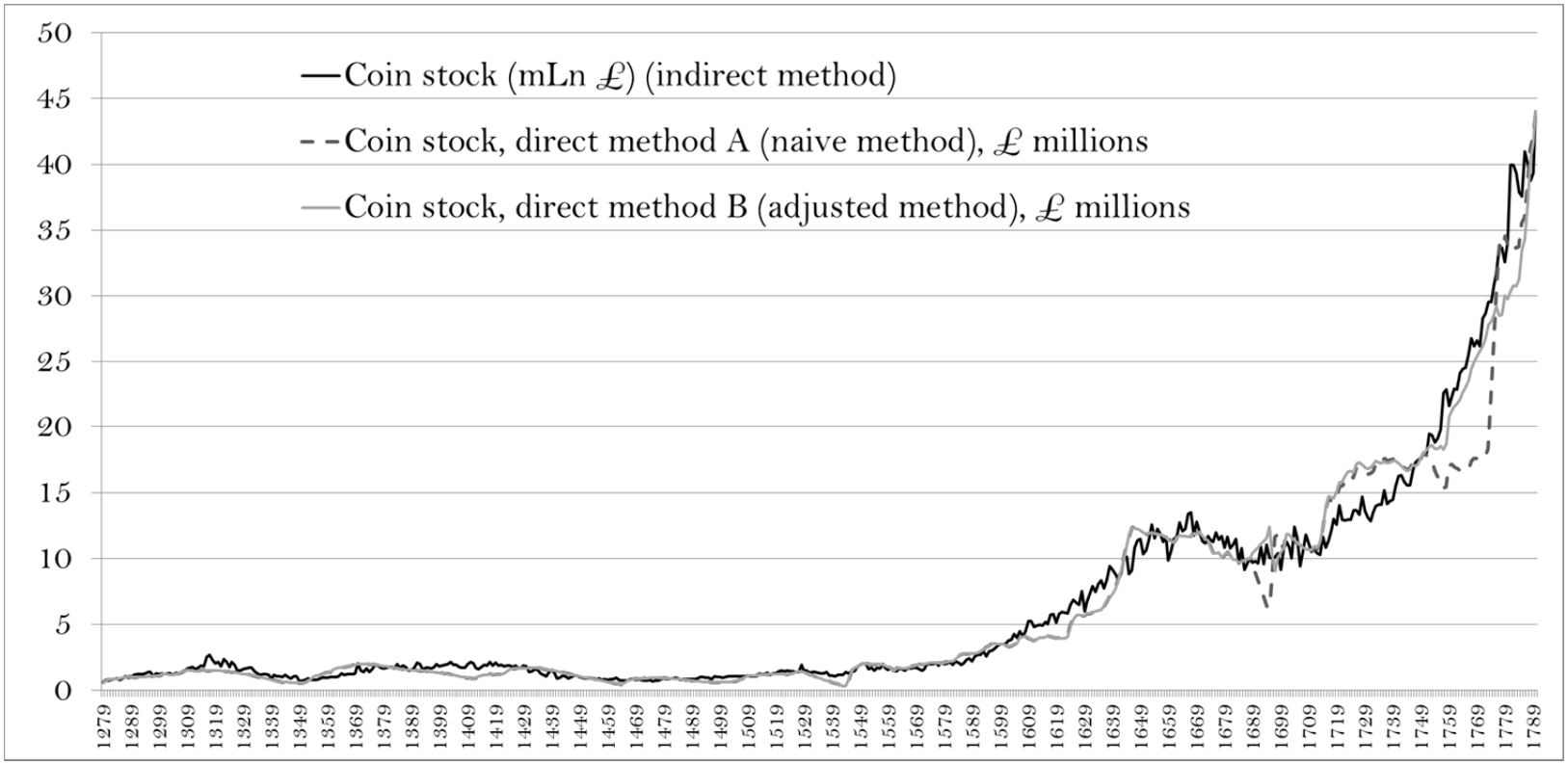


Figure 2. English nominal money supply 1279-1790. Sources: my calculation based on a series of sources; see text for details.

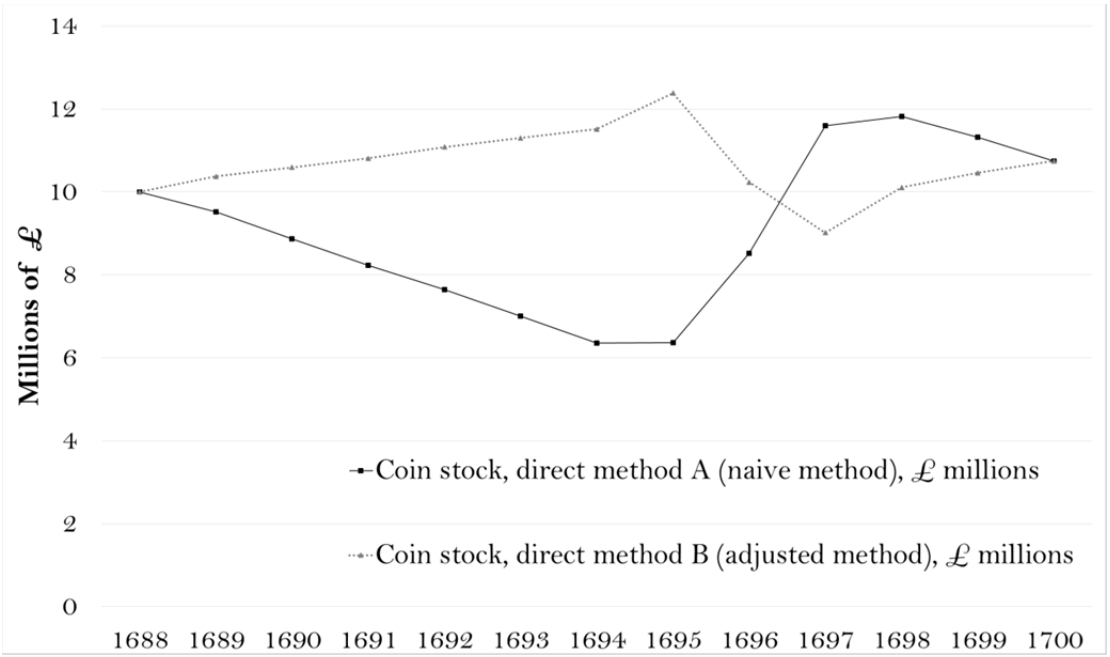


Figure 3. Recalls correction made for the Great Recoinage period.

The 1733-4 recoinage. Challis (1992, p. 439) mentions a partial gold recoinage in these years of "more than 15,500 lb of old hammered coins", which were withdrawn and recoined; cross-checking with the totals in table 63, p. 432, we can see that one lb corresponds to about 46.725 pounds; hence an average of about £362 thousands per year will have been recoined in those two years. These are the additional outflows I assume for those two years in the baseline estimates. (In addition to the 207 thousands estimated residually).

The 1773-7 recoinage. Once the quality of coinage began to be threatened, a gold recoinage took place in the 1770s. Challis (1992, p. 440) suggests the £16.5m in gold minted then represented about 75% of the total gold currency. Also according to the same source, the recoinage took four years to complete, 1773-7. I hence assume an additional outflow of £4.125m per year over this period in the baseline estimates. Adding the regular residual then increases the total to £4.397m over these four years).

4. Robustness: the indirect method estimates

The indirect method estimates do not rely on tower output mint at all, and instead simply linearly interpolate implied velocity between the available benchmarks and exploit annual variation in nominal output to arrive at a measure of annual coin supply. Formally, coin supply can be calculated by writing the equation of exchange as,

$$M = \frac{PY}{V}$$

Where M stands here for coin supply, PY is nominal GDP, and V is the velocity of circulation *of coin*.[85] Nominal GDP is available from Broadberry et al (2015). In order to arrive to a series for V, I proceed as follows. For the years in table 1, I simply write the equation as V=PY/M and apply the figures for M known from the first column of table 1. I then linearly interpolate between those V's, which leads to a series that will map into a series for M.[86] The resulting estimates for V are shown in figure 4, and they suggest that velocity was at times volatile but did not exhibit a long-term trend. (See table A1 in the appendix for some comparative figures.)

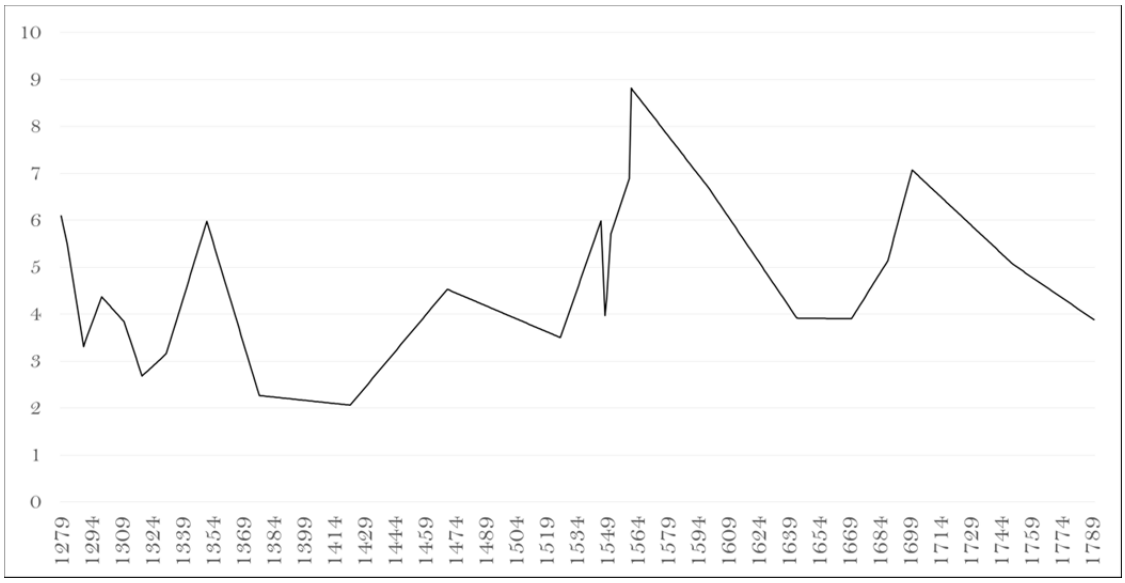


Figure 4. Benchmark velocity estimate used in the indirect method. Sources: see text.

[85] It is possible to define M is as coin supply rather than M2 as long as the definition of V is consistent with it.
[86] Note there is no circularity in this construction: the benchmark years are simply assumed, and all calculations are made for the intervening years only.

I call the resulting estimates the "indirect estimates" and they are shown in the solid black line of Figure 2. The most obvious disadvantage of the indirect method is that it relies on a linear interpolation of velocity between the observed benchmarks. So when calculating the annual estimate, the numerator – nominal GDP – does change in accordance to the "truth", but the volatility of the denominator between benchmarks is underestimated, and hence the estimates for the value of coin supply are more volatile than they should. A second disadvantage is that by relying on income data for its construction, the indirect estimates for coin supply cannot be used in econometric applications which aim to explain variations in income itself. The indirect method does have the advantage that "on average and in the long run", it should be approximately right, since velocity only changes slowly under long horizons (Bordo and Jonung 2004).

5. Discussion

I am now in a position to compare the baseline and the indirect estimates. The baseline estimates, shown in the solid grey line of Figure 2, direct method B, can be compared with the naïve direct method (A) the broken grey line. The comparison suggests considerable improvement, especially at the times where a correction has been applied, such as the late seventeenth century and the 1770's. The baseline estimates are closer to the narrative evidence presented in Sargent and Velde (2002) and Challis (1992). In turn, comparison with the indirect method estimates in black suggests a smoother and also more historically realistic path, which further has the advantage of being independent of any income data in its construction. The fact that output data does not enter in any way in the construction of the direct estimates allows these estimates to be used in econometric work in which output is an outcome variable. Table 2 presents some descriptive statistics for the data produced by the different methodologies.

	Direct method A	Direct method B (baseline estimates)	Indirect method
Sample mean, 1279-1790	5.85	6.06	8.49
Sample standard deviation (standard error), 1279-1790	7.69	7.90	12.11

Table 2. Descriptive statistics for the different methodologies.

5.1. Why are the indirect estimates useful?

The direct method estimates may be biased over a long period of time if no sufficient regular recoinage information is available. Hence, the indirect estimates can be helpful in identifying periods when the direct method estimates may need adjustment using supporting narrative evidence.

I now explain what are the main difficulties associated with extending the methodology to the 1790-1870 period, and these further serve to illustrate the advantages of using the indirect method as a robustness check over the long run levels resulting from the direct method estimates. The basic problem of the 1790-1870 period results from the known benchmark stock estimates being far apart combined with the fact that this period includes several periods which the narrative evidence suggests to be of monetary disruption, as discussed below.

5.2. The 1790-1870 period: what are the difficulties at hand?

It is harder to give precise estimates for coin supply over this period than for earlier periods. An important difficulty is caused by the fact that after the creation of the issue department of the Bank of England with the Bank Charter of 1844, royal mint coin output can no longer be considered to go directly into circulation. It hence becomes more difficult to infer the timing of coin supply increases from mint output data. It also needs to be realized that the gradual growth and increasing complexity of the financial intermediation system means that coin supply increasingly loses relative importance.

The year 1870 is the first for which we have relatively certain data. Table 3 compares the existing competing estimates for the stock in 1870 (Table 3). Annual estimates for both coin and M2/3 under circulation which go as far back as 1833 are available (Huffman and Lothian 1980, Collins 1983). However, as emphasized by Capie and Webber (1985), a key element underlying both is Sheppard's (1971) coin circulation figures for 1880, which Capie and Webber argue persuasively to have been an overestimate – hence the earlier estimates would have been too small.

	Huffman and Lothian (1980)	Collins (1983) (1866-1870 mean of end-of-year figures)	Capie and Webber [1985, tables I(1), I(4) and I(9)]	Capie (2004, p. 222, 224)
Coin stock	95.4	87.5	85.449	95
Monetary Base/High-powered money (M0 or H)	153.4	128.4	134	141.4
Money stock (M2/3)	-	379.7	540	540

Table 3. Value for the several monetary aggregates circa 1870, as proposed by several authors. Unit: £ millions.

I have inflated Huffman and Lothian's (1980, p. 170) figure of £41.4 million by an admittedly arbitrary 20%, and I have done the same with Collins's (1983, p. 384) estimate for £38.8 million for 1846 – which leads to £46.56 million, similar to Huffman and Lothian's £46.2 million for the same year (Figure 5). Clearly, the resulting estimates for this period carry a greater margin of uncertainty than for others, and hence the temporal span of this paper remains fixed at 1279-1790.

However, although I have no intention of settling this debate at present, it needs to be emphasized that while the Capie-Webber critique is not unsubstantial, it needs to be put under some perspective. First, since these series are nonstantionary, for many econometric applications the series will need to be used in first differences. This means that divergences about the exact stocks at each moment are much less important that the timing of growth rates, which we can indeed estimate with a reasonable degree of accuracy.[87] Second, there is agreement about the broad magnitudes at stake, and the divergence is not as large as one might think (Table 3). Indeed, Capie's more recent estimate for both coin and M0 has moved closer to that of Huffman and Lothian (Capie 2004). Third, as before, informal comparison with the indirect method can ensure that the absolute level of the direct method estimates do not fall too much out of line.[88]

[87] Though of course, the absolute levels will still matter if cointegrating or error-correction relationships are involved.
[88] This is where the usefulness of the indirect estimates most clearly comes to light – they put discipline on the long term trends of the direct estimates.

In any case, there is no question that the period after 1790 is one for which there is more fundamental uncertainty about the true value of money supply for both coin and broader forms of money, until the light is turned on again around 1870. Figure 5 illustrates the "double-dip" divergence which results from the baseline and indirect estimates for this period.

5.3. The "bullion crisis" period, approx. 1797-1821

The bullion crisis which goes from approximately the period immediately preceding the bank restriction act (1797) to the formal establishment of the gold standard (1819-21), could have turned into a full-fledged financial crisis and indeed it is one of the "crises which did not happen".[89] For the present purposes, this period is relevant because of the likely negative effect on not just coin output but also possibly hoarding, though massive quantities of export from the country were unlikely due to the ongoing war. As suggested by the direct estimates in figure 5, there was very little minting of coin during this period (Challis 1992). The bullion crisis was due to the sharp divergence of the market price from the official prince of gold (Figure 6).

[89] These are too often ignored by economic historians for that very reason, though in principle we should all agree that from a policy perspective we can learn at least as much from them as from those that did turn sour. The reasons why this crisis did not turn into a full-fledged financial crisis are explored in O'Brien and Palma (2015).

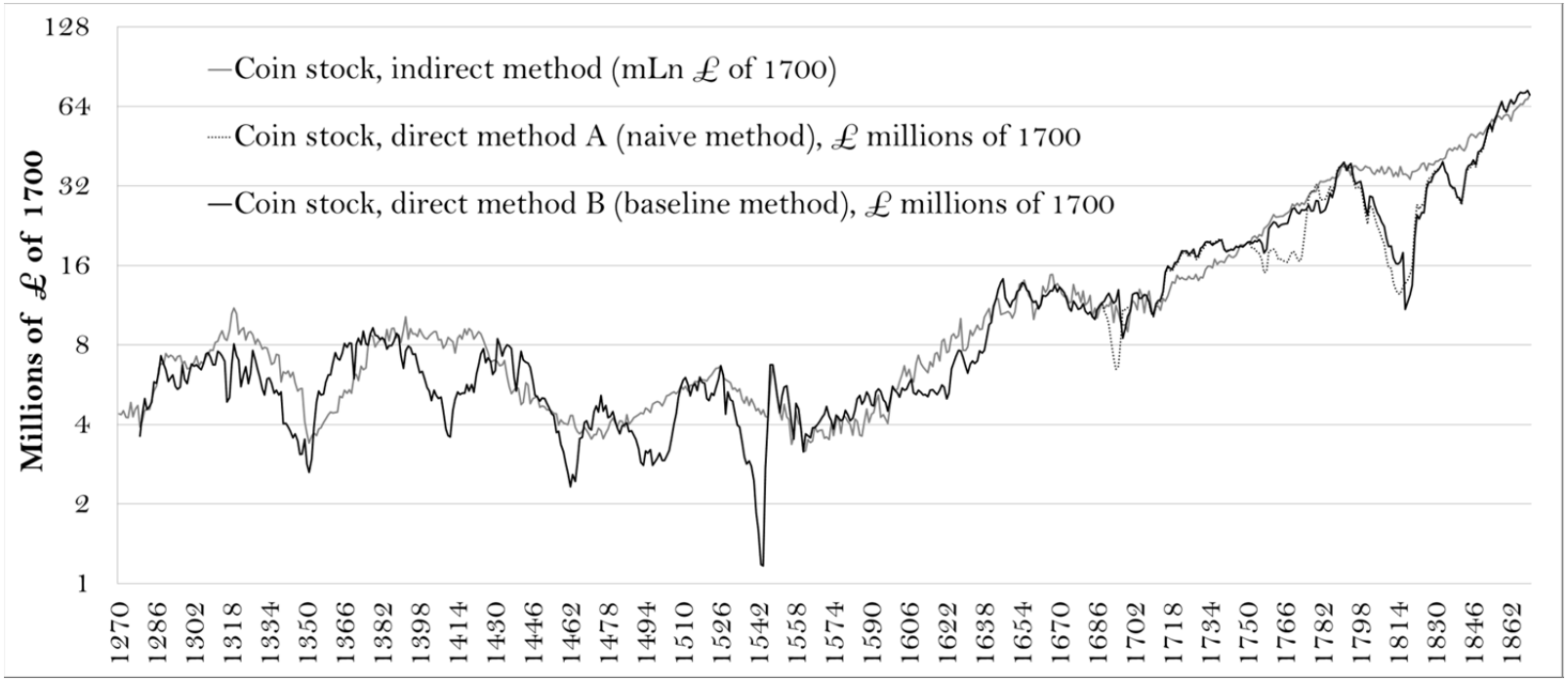


Figure 5. Coin supply estimates for the 1270-1870 period (log scale of base 2). Notice the periods when direct method A cannot be seen means it coincides with the baseline method (aka direct method B).

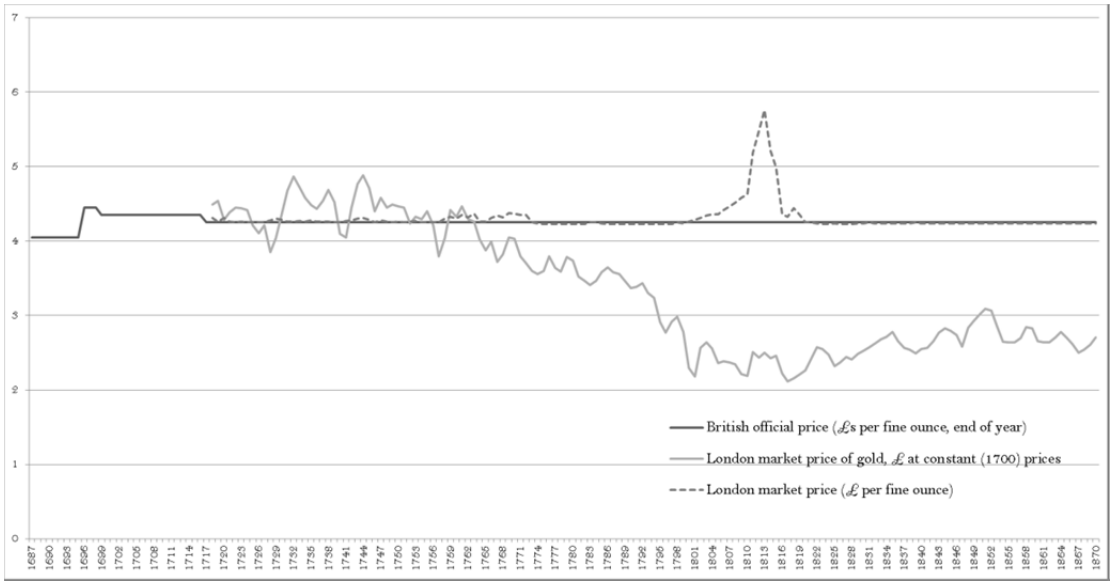


Figure 6. Official and market price of gold. Sources: Officer (2012), Clark (2013)

5.4. The 1816-21 recoinage and exchange

The immediate motivation for the 1816-21 recoinage was the end of the Napoleonic war and the need to pave the way for the Bank of England to return to convertibility, which had been suspended with the restriction act of 1797. It is known that 12.6 million of old silver coin were withdrawn from circulation in 1817 (Clancy 1999, p. 22, 145, and 181-207), and I have accounted for this in the baseline estimate.[90] Still, the "double-dip" behavior of the baseline direct estimates visible in Figure 6 remains suspect, especially in light of the fact that the indirect estimates based on nominal GDP suggest no similar behavior, so there would have needed to have existed sharp changes in velocity at those times. It seems more likely to me that due to capital inflows and other monetary experiments which resulted from the Napoleonic wars the monetary stock around 1815 was much higher than is suggested by the direct method, and much more in line with what is suggested by the indirect method. But without a good estimate of the stock from a source independent of income, the adjustment required by the baseline method cannot be made. The best hope for such a measure would be the 1816-17 "Great Recoinage", but unfortunately Clancy (1999) does not offer an overall figure for the amount withdrawn.

[90] For the crisis of 1847, see Dornbusch and Frenkel (1984).

5.5. The growth of financial intermediation

Using a series of available benchmark data points for the size of M2 (described in table A2 of the appendix), the indirect method can be extended (following a procedure identical to that described in section 4 to allow for the annual estimation of M2. It is then possible to study the growth of financial intermediation, as shown in Figure 7. Using this method, the ratio of M2 to coin supply is 1 until 1470 and 5.75 by 1870, which is broadly consistent, for instance, with the finding by Broadberry et al (2015) that per capita output of financial services increased, in index terms, from 109 in the 1500s to 685 in 1870.

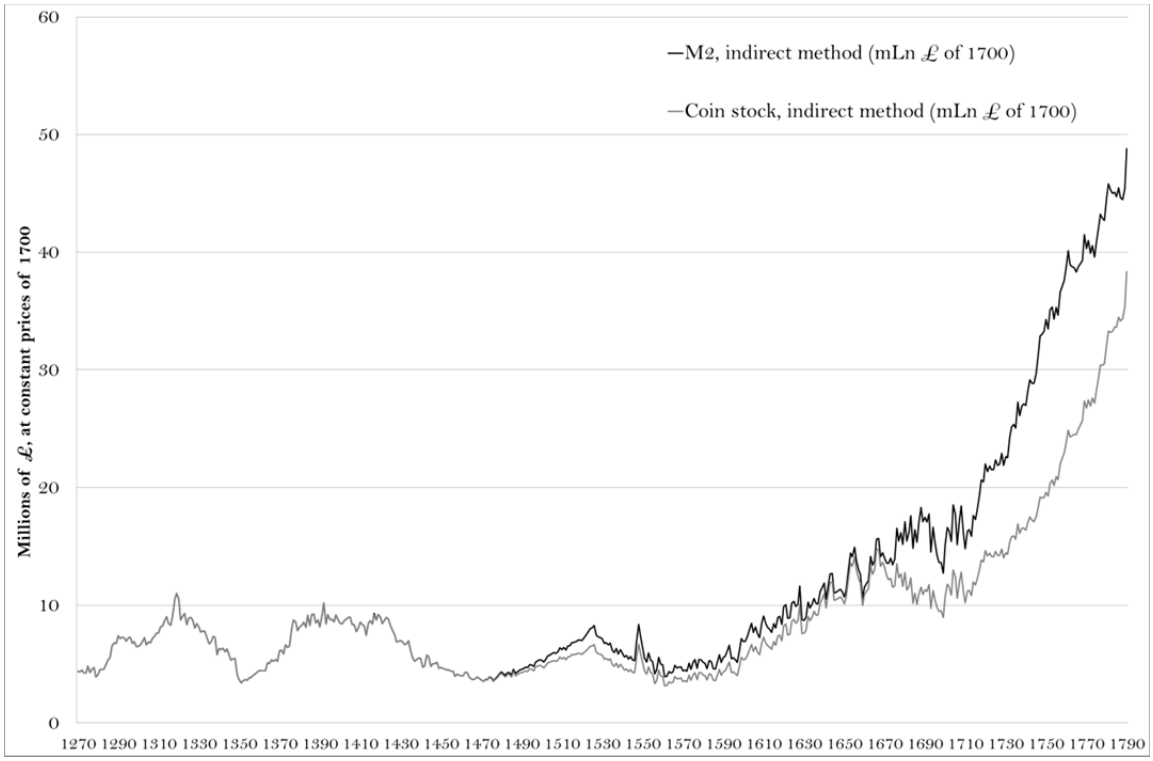


Figure 7 . British per capita coin supply and M2 at constant prices of 1700.

6. Conclusion

As usually in economic history, my estimates are subject to a high degree of uncertainty. I have detailed the assumptions underlying the construction of the series so that anyone can change these as preferred or as new information that I am not aware of may come to light. Furthermore, it is my belief that the methodology that I have here set out can be used for reconstructing coin supply for other premodern economies.

For the reasons set out in section 4, the estimates for the 1790-1870 period carry higher levels of uncertainty than those for other periods. Nonetheless, I have linked my estimates to those of Capie and Webber (1985), which start in 1870, but it seems likely that the estimates for this period can be improved in the future. It is also the case that the sharp drop in nominal and real money supply around the time of the Tudor debasements in the mid-sixteenth century is a little suspect, and it may also be possible to improve on this in the future. For the moment however, the estimates needed for our understanding of first-order variation of English coin and money supply over the long run seem secure.

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Appendix to chapter 4

	Bordo and Jonung (1987)	Capie and Webber (1983)	Capie (2004)	Mayhew (1995)	Mayhew (2013)
England 1300	-	-	-	-	4.91
England 1470	-	-	-	-	4.56
England 1526	-	-	-	-	3.61
England 1546	-	-	-	-	5.95
England 1561	-	-	-	-	8.73
England 1600	-	-	-	-	5.73
England 1643	-	-	-	-	3.81
England 1670	-	-	-	3.40	-
England 1688	-	-	-	-	2.65
England 1700	-	-	4	-	2.64
England 1750	-	-	3	-	2.23
UK 1790	-	-	2.5	-	-
UK 1870	2	1.75	-	-	-

Table A1. Estimates for velocity of circulation.

	Coin supply	Coin supply (preferred estimate)	Implied V of coin supply (preferred)	M2	M2 (preferred estimate)	Implied V of M2 (preferred)
England 1279	0.5 – 0.8	0.6	6.09	0.5 – 0.8	0.6	6.09
England 1282	0.8 – 0.87	0.835	5.49	0.8 – 0.87	0.835	5.49
England 1290	1.0 – 1.3	1.0	3.31	1.0 – 1.3	1.0	3.31
England 1299	1.1. – 1.4.	1.1	4.37	1.1. – 1.4.	1.1	4.37
England 1310	1.5. -1.9	1.5	3.85	1.5. -1.9	1.5	3.85
England 1319	1.8. – 2.3.	1.5	2.68	1.8. – 2.3.	1.5	2.68
England 1331	1.5. – 1.9	1.2	3.16	1.5. – 1.9	1.2	3.16
England 1351	0.6 – 0.95	0.6	5.98	0.6 – 0.95	0.6	5.98
England 1377	1.42 – 2.39	1.92	2.27	1.42 – 2.39	1.92	2.27
England 1422	1.22 – 2.39	1.285	2.06	1.22 – 2.39	1.285	2.06
England 1470	0.75 - 0.95	0.9	4.53	0.75-0.95	0.9	4.53
England 1526	1.4	1.4	3.5	1.4 – 1.71	1.56	2.82
England 1546	1.45	1.45	5.98	1.45 – 1.77	1.61	4.80
England 1548	1.76	1.76	3.97	1.76 - 2.15	1.96	3.18
England 1549	1.92	1.92	4.35	1.92 – 2.35	2.14	3.49
England 1551	2.02	2.02	5.71	2.02 - 2.47	2.25	4.58
England 1560	1.71	1.71	6.89	1.71 - 2.09	1.90	5.52
England 1561	1.45	1.45	8.82	1.45 - 1.77	1.61	7.08
England 1600	3.5	3.5	6.65	4.5	4.5	5.17
England 1643	10	10	3.91	12.22 – 14.07	13.15	3.69
England 1670	12	12	3.90	14.67 – 16.88	15.78	3.68
England 1688	10	10	5.14	11.75 - 20	15.88	3.24
England 1700	7 - 14.5	10.75	7.07	8.5 - 21.75	15.13	5.03
England 1750	15 - 18	18	5.06	23 - 40	31.5	2.89
England 1790	44	44	3.88	56	56	3.05

Table A2. Benchmarks for English nominal money supply, 1270-1790. Sources: For coin supply 1279-1470, Allen (2011, 2012); coin supply from 1526 to 1700 is based on Mayhew (2013, p. 26), where 1551 corresponds to an average of the two available estimates for that year; for the coin supply of 1700, see Mayhew (2013, p. 29). For the 1688-1750 coin supply figures, these are the estimates of Cameron (1967), also endorsed by Mayhew (2013, p. 30). Note that Mayhew's 1688 number in table 3 of page 26 corresponds to Cameron's M1 estimate. For the coin supply estimate see Cameron (1967), also discussed in Mayhew (2013, p. 30). For the M2 preferred estimates: 1279-82, 1377 and 1422 simply the average of both of Allen's bounds. For all other 1290-1470, Mayhew (2013)'s choices. With regards to the bounds to the broader measure of money (M2), the key is to realize Capie's (2004) numbers are more conservative than those of Cameron (1967). For the upper bound during the period before 1600, I use the Mayhew 1600 relative numbers. This bound is hence tantamount to assuming bills of exchange were relatively used as much in the middle ages as in 1600. For sure, this bound should tighten the far back we go in time, but since we know credit was used in the middle ages but have no way to estimate how much of it was transferable or its size, as this is an upper bound there is no harm to assume it all the way it back to 1270. Still in calculating the higher bound, for 1600-1688 I use proportionality with Cameron's 1688 relative M2/coin supply size, and for 1688-1750, Cameron's 1750 M2/ coin supply size. As for the lower bounds, for 1600-1700, use Capie's 1700 relative size (itself a lower bound, as it includes notes but not bills of exchange), and for 1700-1750 use Capie's 1750 relative size, for 1750-1790 use proportionality with Capie's 1790 relative M2/coin supply size.

Chapter 5. Money and modernization: liquidity, specialization, and structural change in early modern England

1. Introduction

Fast structural change is now seen as the main discontinuity associated with the classical period of the English Industrial Revolution (Crafts and Harley 1992). And yet recent research has shown that much of the critical occupational migration from agriculture to industry had already happened even earlier, during the early modern period – in particular, after 1522 (Broadberry et al 2013, p. 369; Leigh Shaw-Taylor and Wrigley 2014, p. 59). In this paper I argue that structural change, market participation and specialization in England were facilitated by large-scale monetary injections which resulted from the discovery of significant amounts of precious metals in America. These injections affected, to different degrees, other European countries as well, but they interacted positively with certain characteristics of the Northwestern European economies.

Figure 1 illustrates the scale of the English monetary injection in aggregate terms. In the figure the price level is given by the GDP deflator of Broadberry et al (2015). The figure shows that prices simply failed to keep up with the enormous increase in per capita coin supply.[91] The long-run evidence for England clearly contradicts a quantity-theory interpretation of the evolution of prices over the long run. Instead, I argue that this large-scale increase in real money supply lead to a significant decrease in the cost of participating in markets.[92] In turn, this led to increased levels of specialization through division of labor, and to labor expansion on both the intensive and extensive margins. The greater ease in making and receiving payments meant that it was then easier for firms to pay the wage bill and for people to work additional days – one feature of the early modern industrious revolution.[93]

[91] Using instead the retail price index of Clark (2014) would lead to the same conclusion.
[92] It may have also made it easier for people to accumulate savings.
[93] My contribution to the study of the industrious revolution does not pretend to substitute the reasons which have been pointed out for this increase, such as demand for new goods (deVries 1994, 2009, Hersh and Voth 2009), but to complement it by pointing out that there was a complementary monetary element. Indeed, many of the "new goods" which led to an increased labor supply depended on the availability of precious metals in order to be imported from Asia (Palma and Silva 2015).

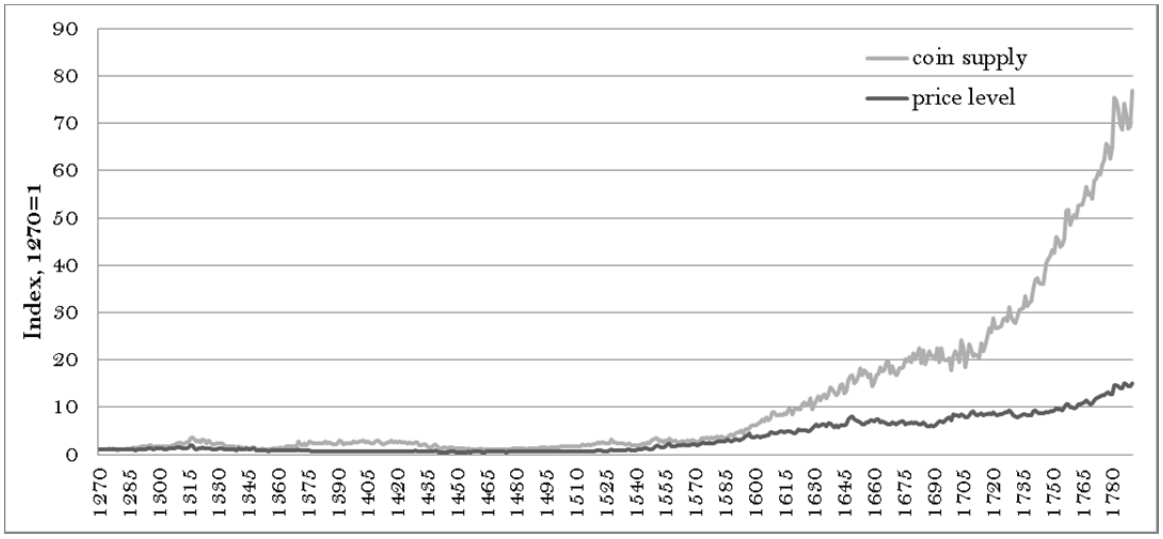

Figure 1. Coin supply and price level, 1270-1790. Source: coin supply from Palma (2015a), and the price level is the GDP deflator of Broadberry et al (2015).

The large reserve of precious metals in America was critical in allowing the European money supply to expand as it did in the early modern period. In the counterfactual absence of these reserves, forms of "inside" money including fiat, bank deposits, bills of exchange or other forms of intermediation could not have compensated for the relative decrease in coin supply anywhere in Europe before 1790.[94] The decrease in transaction costs also encouraged people who were not already involved in the formal market economy – or were only marginally so in rural areas – to become involved, both while staying in the countryside, and, importantly, by moving to cities, hence contributing to rapid structural change and agglomeration returns.

In England only about 40 percent of households lived mainly on wages in 1524-5, a ratio which had been approximately constant since the thirteenth century (Dyer 2002, p. 364).[95] But by the early 1780s few people were not directly involved in the cash economy (Porter 1990, p. 187), an experience at odd with that of continental economies. It is difficult to

[94] Indeed, those higher forms of money would have decreased. This is because, for practical purposes the relationship between them and coin was analogous to a traditional multiplier effect on base or high-powered money (M0). I discuss the reasons in detail below.

[95] The situation in the early sixteenth century corresponded to a long-term stagnation which only American precious metals would break, Indeed, "[i]n 1300 … wage labour may have accounted for about a fifth to a quarter of the total labour expended in producing goods and services. In this respect, however, the world did not change in the direction of capitalism between 1300 and 1525" (Britnell 1993, p. 364; see also Britnell 2009)

imagine how this might have been possible without the enormous increase in money supply. In this paper I document the large-scale increase in the availability of precious metals which followed from the discovery of America, and consider its effects for the English economy. I discuss a variety of channels through which it affected growth. Finally, I present some comparative remarks on the effects on the continental economies.

2. Historical background

I first discuss what we know about the discovery and production of American precious metals, and then focus specifically on the impact on the English economy.

2.1. American precious metals

According to Barret (1990), from about 1500 to 1800, 85% of the world's silver and over 70% of the world's gold came from America (see also TePaske 2010, p. 111, for similar figures). Japan was also a major producer in the 1500s, and it is safe to say the 1500-1800 period was one of unprecedented injections at the global level. The following tables provide some perspective. Table 1 considers bounds for total American production of precious metals in the early modern period, and Table 2 compares arrivals into Europe in comparison with the initial (c. 1500) stock of precious metals. For similar figures see the discussion of Jacob's estimates in Braudel and Spooner (1969, p. p. 444), endorsed by Velde and Webber (2000, p.1230) who also quote other scholars who arrived at similar figures for 1500.[96] These figures are immediately suggestive of the substantial magnitude of the resulting injections.[97]

[96] Braudel and Spooner (1967, p. p. 445) also give estimates for stocks of precious metals in Europe during the early modern period; these are however unusable as they rely on implausible assumptions, in particular they assume that all production of American precious metals came to -- and stayed -- in Europe, thus ignoring the fact that some stayed in America, much went to Asia directly through the Pacific, or, having come to Europe, was subsequently exported to Asia or the Middle East. Also, notice that gold needs to be accounted for because even if it was silver that mattered directly for trade with Asia, the availability of gold as a substitute in Europe meant that more silver was available to be shipped to Asia. The case of 18th century England is illustrative in this respect (Palma 2015c).

[97] Comparative figures are given by Hamilton (1970) for 1503-1660 outflows from the Spanish empire to Spain of 16,886 tons of fine silver, tones, plus 181 tons of gold. Of course, because of the possibility of smuggling, all of the the import figures need to be interpreted as lower bounds.

	lower bound estimate	higher bound estimate
16th c.	17,500	21,000
17th c.	33,800	42,500
18th c.	74,000	84,400
Total	125,300	147,900

Table 1. American production of precious metals (Barret 1990, p. 228). Unit: Silver equivalent tones

	Fine silver, tones	Gold, tones	Total, silver equivalent tones
Initial stock, Europe (1492): Velde-Weber	3 600	297	6913
Imports to Europe			
1500-1600	7 500	150	9173
1601-1700	26 168	158	27891
1701-1800	39 157	1 400	60255
Total imports	72 825	1 708	97320

Table 2. Specie stocks and flows. Sources: Initial stock: Velde and Webber (2000, p. 1230), which rely on Braudel and Spooner (1969, p. p. 444); flows: Morineau (2009), bimetallic ratios and conversion at the London rates from Neal (1990) and McCusker (1978).

Turning briefly to a discussion of the timing of production flows, I now provide a more extensive discussion of transmission flows. There exists complementary information about the timing of production and shipping flows (Hamilton 1970, Morineau 2009, Attman 1986, Phillips 1990, p.84, deVries 2003). These estimates differ in many respects: there is disagreement over the amount of arrivals as well as their timing. While Hamilton presents declining production during the seventeenth century, Barret's European arrivals

data, based on Morineau, show no decline during the seventeenth century (Morineau 2009).[98] I take Barret's (1990) estimates as the benchmark (Table 3).

	European aggregate stock + exports	European per capita stock + exports	European aggregate stock	European per capita stock
1492			6914.5	132.3
1500-1549	14164.5	271. 0	11747.5	224. 8
1550-1599	34664.5	550. 0	27831.5	441. 6
1600-1649	61414.5	832. 4	50164.5	1113. 7
1650-1699	96414.5	1242. 2	82164.5	1058. 6
1700-1749	142164.5	1745. 2	122164.5	1499. 7

Table 3. Europe's holdings of precious metals. Lowercase variables denote per capita values. Sources: see text. The population methodology is the same as in Table 4, but notice Table 4 concerns flows, while here we are concerned with stocks. Population for 1500 used in 1492. Units: Columns one and three in tones, and columns two and four in grams of silver per person.

The Spanish silver debate figures mentioned so far are well known to an audience of economic historians. Less well known is the case of Brazilian gold during the eighteenth century, a case that was of major importance for English monetary developments during that century, despite its comparative neglect in the modern literature. Between 1720 and 1807 alone, about 556 tons of gold were imported, about two thirds of which ended up in England (see Palma 2015c for a systematic study of this episode). Costa, Sousa and Rocha (2013) complement previous sources with information from on-board tax records, *livros do manifesto*. The main reason previous estimates are underestimates is that much currency was minted directly in Brazil (especially during the later periods), so evidence from the Lisbon mint house is incomplete. Their estimates suggest Brazilian gold shipments to

[98] Morineau argues there was no decline during the 17th century as the officially reported decline is cancelled by increased contraband.

Portugal were about 30% higher that the numbers presented by Morineau, having lasted, in decreasing but still significant quantities, into the early nineteenth century.

In a final exercise, I compare per capita American precious metals imports with the wage of Western European laborers (Table 4).[99] All in all, the evidence suggests specie injections were of considerable real magnitude.

	$\frac{New\ World\ production}{European\ population}$	$\frac{Imports\ to\ Europe}{European\ population}$	European wage, unskilled	European wage, skilled
1500-1549	3. 2	2. 8	2.1-4.2	2.8-6.8
1550-1559	8. 4	6. 5	1.9-6.6	3.3-12.5
1600-1649	9. 9	7. 2	3.2.-8.8	5.2-20.1
1650-1699	12. 2	9. 0	2.7-9.7	3.9-15.1
1700-1749	14. 7	11. 2	1.9-10.5	3.0-11.7
1750-1799	16. 4	11. 1	2.9-11.5	3.2-17.8

Table 4. Yearly New World production of precious metals and imports per European person, compared with the range of nominal wages. Sources: Precious metals as above, wages from Allen (2001, p. 416) and population from Maddison (2006, p.636 and 639). Figures are presented after rounding to the nearest decimal.

2.2. English real wages and GDP

Real wage data for England collected over the last two decades suggests that there was no sustained growth until the nineteenth century (Clark 2007).[100] However, there is a conflict between this view and that which emerges from the supply-side GDP data recently put forward by Broadberry et al (2015). GDP shows slow but sustained economic growth

[99] In fact if one sees Europe as "Europe proper plus empire", the exercise surely underestimates the magnitude of the per capita injection because of the amounts of precious metals which never left America or went directly to Asia, compared with Europe's tiny population there.
[100] Using the earlier data of Allen (2001) would lead to the same substantive conclusions.

from the mid-seventeenth century onward (Figure 2). Additionally, it is difficult to square the no-growth view with the evidence put forward by historians of material culture, which strongly suggests that from the mid-seventeenth century onwards there was a significant increase in the consumption of clothing and household goods, not just by the elite but by all except the poorest (e.g. McCants 2007); and the increased variety of available goods must have also had positive welfare consequences (Hersh and Voth 2009).

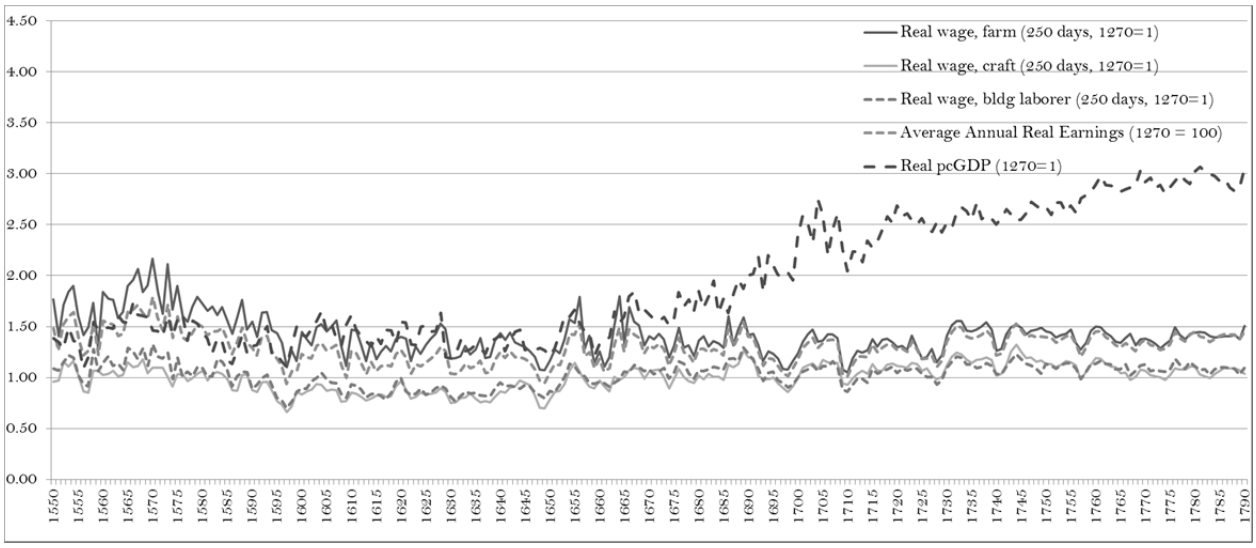

Figure 2. English income and real wages over the long run (1700=1). Sources: Clark (2014), Broadberry et al (2015)

It is in fact possible to conciliate the fact that real wages stagnated with the existence of per capita growth (as emphasized by Broadberry et at (2015) among others). The key is to realize that the nominal wage available from most sources is the day wage, and the annual "real wage" has been computed assuming a fixed working year.[101] But at least from the mid-seventeenth century onwards, people were working more days and hence earning more income[102] (Table 5). The remaining question is: why?

[101] Other assumptions are implicitly made, including that the annual contract is a multiple of the number of days and that the composition of consumption baskets stayed constant in time – which directly contradicts what optimizing behavior in response to changes in relative prices would suggest.
[102] Angeles (2008) shows about two thirds of the divergence is due to an increase in per capita labour input.

Period	Blanchard/Allen and Weisdorf	Clark and van der Werf	Voth
1433	165	-	-
1536	180	-	-
1560-1599	-	257	-
1578-1598	259-260	-	-
1600-1649	-	266	-
1650-1699	-	276	-
1685	-	312	-
1700-1732	-	286	-
1733-1736	-	295	-
1760	-	-	258
1771	-	280	-
1800	-	-	333

Table 5. Days worked per year. Sources: see Broadberry (2013)

2.3. Increase in work time: understanding the industrious revolution

While in traditional economies people enjoy plenty of leisure (perhaps in association with substantial levels of underemployment), the process of economic development initially leads to an increase in working hours as division of labor and structural change take place. Both in cities and in the countryside, more people participate in the market economy for a wage, and those that had already done so did do so more intensively, working more days of the year.

Late medieval Europe was already distinguished by its comparatively well-developed factor markets, and in particular, a high level of market participation and a low level of interest rates (Van Zanden 2009). But days worked would increase considerably in the early modern period (de Vries 1993, 2008). In the case of England, which has been studied in

detail, traditionally people did not work on Mondays – the so-called St Monday was a day on which to recover from the drunkenness of the weekend – and a typical year included about 250 days of work (Allen 2001). During the early modern period days worked progressively increased to the "longest years", which happened around the end of the eighteenth century (Voth 1998, 2001), before declining again in more recent times.[103] Further, there is now substantial evidence that in several other parts of Europe working days also increased during the early modern period (Álvarez-Nogal and Prados de la Escosura 2012, Palma and Reis 2014), though not as much, and with much more limited accompanying structural change.

Two questions can be asked about the industrious revolution. The first is, why does it matter? The second is, why did it happen? With regards to the first question, despite the industrious revolution's prominent center stage in the economic history literature, it really would not have mattered that much if it was just a "one-time" level effect – though even then, as it shifts the timing of the emergence of modern economic growth, it can change our interpretation of what mattered. However, I argue here that there is indeed a relation between the increase in working hours and subsequent continued growth. Second, why did it happen? Why were people working more days? So far, the main candidate seems to have been the increased demand for the "new goods" (deVries 2008, Voth and Hersh 2009). But this was not independent of the availability of silver, which was used to trade with the East, and of gold, which by allowing for an expansion of the means of payment in Europe, also freed more silver for trade with the East, allowing for those "new goods" to be imported.

3. Anglo-Portuguese trade, 1690-1770 and its effects on the English economy

American precious metals were directly received by two countries only: Spain and – after about 1690 – Portugal. But the Iberian economies would not be the ultimate beneficiaries. Instead, Northwestern European countries were: the additional purchasing power of the Iberian economies created demand for the merchandise of the Netherlands and England,

[103] Narrative evidence from travelers to Britain suggest a systematic recording about intensification of work over the Eighteenth century, "from a 'merry England' of frequent feasts, St. Mondays and plenty of time spent drinking [to] the reality and metaphors for lack of leisure and oblivious drinking [which] became established clichés by the early nineteenth century" (Riello and O'Brien 2004, p. 21)

and it had a variety of other effects as well.[104] The following case study of trade between Portugal and England in the eighteenth century illustrates my argument, without the presumption that it would have been necessarily more important than the accumulation of precious metals obtained by trading with Spain (or with regions corresponding to the modern areas of Belgium and the Netherlands which in turn obtained them through interactions with Spain).

3.1. Monetary transmission

During the late seventeenth century, rich gold deposits were found in the Brazilian region we now call *Minas Gerais*. The windfall was substantial and would take over a century to explore and exhaust. England and other foreign nations could not trade directly with Brazil; however, as had happened with the silver from the Spanish empire, most of the gold did not stay in Portugal: two-thirds were exported to England over the course of the eighteenth century. I show that the transfer of gold to the English economy was significant, about £40 million for the 1700-1770 period alone[105], the legal part of which was always in minted form.[106]

This led to an enormous increase in liquidity in England; while traditional estimates place currency circulation as having increased from £9.25 million in 1701 to £26 million in 1780 (Craig 2011, p.214), more recent estimates show a much larger increase from £10.75 million in 1700 to £44 million in 1790 (Mayhew 2013).[107] Gold imports from Portugal during the 1700-1770 period were about 70% of the GDP of 1700 (Broadberry et al 2015). They permitted a massive injection of liquidity, leading Adam Smith, later in the century, to claim that popular opinion was that "Almost all our gold, it is said, comes from Portugal" [Smith 2003 (1776)]

[104] Although direct evidence is not always available, it is clear other countries also benefited, if indirectly; for the case of France, see Morrisson et al (1999).
[105] The nominal 39.9 million correspond in real terms to 39.1 million at constant prices of 1700 using the GDP deflator of Broadberry et al (2015) or 36.9 million using the retail price index of Clark (2014).
[106] Portugal minted coins specifically for export, with a standardized value that could easily be verified. It was a transparent guarantee of the weight and value of the shipments (Sousa 2006). Much of this was sent through Falmouth packet-boats. For instance, £1.5 million were sent in this way in 1757 (Fisher 1971).
[107] The latter figure corresponds to 37.9 million at 1700 prices using the RPI of Clark (2014) and 38.3 million using that of Broadberry et al (2015).

Anglo-Portuguese trade during the eighteenth century was systematically in deficit on Portugal's side, but no long-term trade debt of significant quantities accumulated.[108] Sending gold was the way Portugal financed the trade deficit. Boxer (1969, p.464) articulates this well with a quote from an English consul who wrote in 1721 that "For as the British manufactures imported for the consumption of this kingdom [Portugal] and of its colonies amount to more than five times the value of all the commodities exported from hence, it is evident that the overplus must be remitted in specie".

Hence, between a half and two-thirds of Brazilian gold was exported to England in exchange for manufactures.[109] The increased availability of specie in England meant that English coin output increased significantly as a consequence, and in addition Portuguese coin circulated widely in England and Ireland.[110] Portugal was the main source of gold entering England during the eighteenth century (Fisher 1971). Following Sideri (1969), Fisher writes that gold imports were up to £25 million, but while this figure is mentioned three times, it is never well documented (Alden 1971). In fact, I argue, £45 million is a more accurate nominal estimate for the eighteenth century as a whole, and £40 million for the time period comparable to that of Fisher, 1700-1770.[111] Some of the gold imported went directly into circulation and much was melted to be minted as English coinage. In Figure 3, I show there was a close temporal correlation between Portuguese currency creation and export, especially to England.[112]

[108] The balance of payments was only significantly in deficit if we define payments in gold as "money" other than as a "commodity", as clearly, as a matter of accounting, both sides must always add up.
[109] Fisher (1971), Sideri (1969), Greene and Morgan (2009). Both Boxer (1962, p.157) and Russell-Wood (Russell-Wood 1998, p.144) give a similar figure of between half and three-quarters of all Brazillian gold entering the Tagus, having gone to England shortly thereafter. Boxer documents the primary sources in detail (endnote 66, p. 401).
[110] In England and even Ireland, special scales existed which were designed specifically for Portuguese gold. These have survived in far greater number than for other nations that traded with England. I thank Nick Mayew for this information and for showing me some of these at the Ashmolean. Often, these have the conversion written onto them, for instance 1 moidore = 26 shillings. Moidore, in fact, is an English contraction of the Portuguese expression "moeda de ouro", meaning, literally, gold coin. These coins were alternatively know in England as Joannes because of the name of the Portuguese king written on the coins' face, D. João V.
[111] As with Fisher's figures, this is a sum of nominal quantities without taking into consideration prevailing price levels at each moment in time. In real terms, the cumulative commercial deficit with England peaked at £40 million in 1765, at 1700 prices. Almost all of this was paid in minted gold. It is certain that higher quantities were sent illegally, in bullion form.
[112] In figure A1 of the appendix, I show the cumulative values. Notice the cumulative deficit was always increasing in nominal terms – and smoothly – hence jumps in Figure 5 correspond to variation in the RPI.

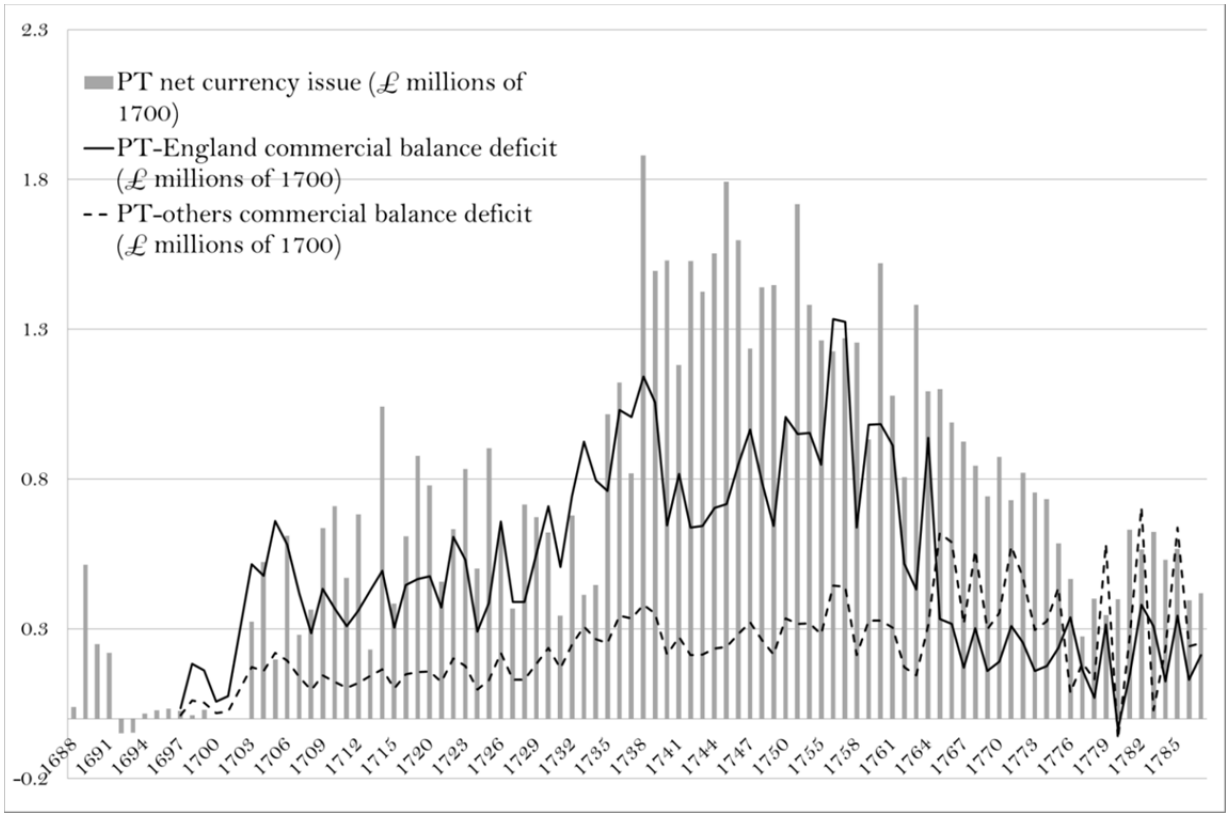

Figure 3. Portuguese net currency issue (includes issues in Brazil and net of re-coinage), and commercial deficit, with England vs. with all other countries bundled. Converted at the exchange rate of £1 million = 3600 contos (Sousa 2006, p.208) and then deflated at 1700 prices. The two commercial balance series are represented continuously for clarity even though they are yearly series. Sources: Sousa (2006), who relies on Fisher (1971), and for the RPI, Clark (2014).

The total nominal value of gold transferred from Portugal to England was on the order of £40 million for the 1700-1770 period, and £45 million up to 1785. In real terms this corresponds, as can be seen in the figure, to a peak of £40 at 1700 prices around 1765, and a slightly lesser value up to around 1785. By the late 1710s, Portugal was England's largest export market, a situation that persisted well into the second half of the eighteenth century (Ormrod 2003, p. 105). Woolen exports to Portugal were booming as mirror image to the gold imports.

Portuguese currency was free to circulate in England and was generally accepted. It could be used as money, and was particularly common in the West of England. For instance, an Exeter man in 1713 noticed that hardly any money was in circulation other than Portu-

guese gold, a remark echoed by the Cornwall Receiver-General in 1737: Practically all payments of taxes in money received were in Portuguese gold (Boxer 1969, p. 469; Fisher 1971, p.153). But according to Fisher, the circulation of Portuguese gold coins was still wider. In 1742, the more common coins in circulation were Portuguese, as in 1750 [de Pinto 2010 (1774)], and 1757 (Craig 1953). Portuguese coin circulated until the end of the century (Craig 1953, p. 215). This can also be seen in a well-known exchange treaty of the early nineteenth century, "Portugal gold coins had formerly a legal and current value, the Moidore of 4800 Rees being fixed at 27 Shillings, the Joanese of 6400 Rees at 36 Shillings, and the smaller coins in proportion; but they are now sold, like other foreign money, according to their weight and fineness, and at the market price of the metal" (Kelly 1811, p. 250).[113]

Most of the money that came into England from Portugal was put in circulation directly by the merchants on whose behalf the transportation was made and by the private banks that bought from them and used the Portuguese coins as money. These banks used the coins directly in daily activities, unlike the Bank of England, which would either pass over any currency to the Mint House to be melted and recoined, or saved it for use in international transactions (Fisher 1971, p. 154).

This trade with Portugal eased the English transition from a bimetallic (and mainly silver-based) to a de-facto gold standard during the eighteenth century. Conduitt, the successor to Newton as master of the mint, claimed in 1730 that "nine parts of ten, or more, of all payments in England are now made in gold" (Challis 1992, p. 431).[114] Further, guineas had, since the Restoration, been increasingly used in commerce and industry, as well as in the payment of taxes (Clancy 1999, p. 20, Feavearyear 1963). Statements such as these were common: "You can see none [other foreign coin among us] in any payments, unless it be Portugal money" (Draper of London 1740, p.14).

But probably the most important contribution of Portuguese gold was not in the form of direct circulation, but gold coins which served as a clear standard of value for the purposes of trade but were then subsequently melted to be minted. Indeed, the London mint coined

[113] Note how "moidore" is a distortion of the Portuguese expression for gold coin (*moeda de ouro*), the same being true of Rees (*reis*), and Joanese (coins which showed the Portuguese king Joao V).
[114] Conduitt also estimated that in 1730 transactions in gold were sevenfold those in silver coin (Craig 2010/1953, p. 256).

"above a million [pound sterling] of Portugal gold" into English currency in the period 1710-1714 alone. Four main denominations in gold were minted: half-guineas, guineas, two-guineas, and five-guineas. Of these, "guineas provided by far the greater part of output" (Challis 1992, p. 431). Given their high face value relative to nominal wages[115], gold coins were often used as a store of value, for international payments, and for paying tax, but they also circulated as means of payment, as evidenced by the recoinages of the 1730s and 1770s, which were in part motivated by the state of deterioration of the coins in use.

3.2. Direct demand and industry stimulation effects

Economic historians [including recently Allen (2009)] have emphasized the role of "new draperies" as a major source of TFP growth in early modern England. Demand for these provided a boost to urbanization and agriculture, through greater demand for food, wool and labor. Portugal was England's second largest commercial partner around the middle of the eighteenth century. In 1736-40 Portugal consumed more than half of English exports of woolen bays, socks, and hats (Fisher 1971, p. 144-145). According to François Crouzet (1981, p.66), "Special attention was paid to the Portuguese trade ... [Many] documents stress the large markets in Portugal for British manufactures ... and the 'prodigious' quantities of English goods which were re-exported to Brazil; still more valuable was the very large favorable balance of trade England enjoyed, and which was settled with gold from Brazil". Crouzet further mentions several memoranda attributing, in varying degrees, the importance of Brazilian gold in supporting English prosperity. Commercial connections related to Brazil are mentioned far more often than those related to the Spanish empire – and incomparably more so than Britain's trade with its own colonies, which were of comparatively minor importance (Crouzet 1981, p. 67).

[115] The nominal wage of an unskilled laborer was 24d per day in London (40p for a skilled craftsman) in 1790 (Allen 2001; see also Stephenson 2016 who argues for even lower values in the construction industry). The value of the guinea was fixed by a Royal Proclamation in 1717 at twenty-one shillings. Half guinea was hence worth ten shillings and sixpence (10s6d).

4. Why was expanding money supply difficult?

The early modern monetary system was a commodity money system.[116] In this system, the government had only two ways to expand the official (legal tender) money supply. The first was to have access to new sources of specie, either through mining or trade.[117] The second policy option was to debase the currency. Yet in using this policy tool governments were constrained by competition with foreign mints. If the currency was much debased, people would start to use foreign currency, and governments' seigniorage revenue could actually diminish in absolute terms. In addition, systematic debasements could lead to a denominational problem related to the physical property of currency as an object intended to serve as an object to facilitate exchange and liquidity.

The very large monetary injections that were the result of the discovery of America, I argue, mattered a great deal in making the English industrious and industrial revolutions possible. In order for this to be the case, two conditions were necessary: First, it must be that money (or its substitutes) would not have expanded anyway, even if precious metals in America were not available. Second, it must be the case that modernization would not have happened anyway, had the money supply not expanded. I now consider the first of these conditions, and in Section 5 I address the second.

4.1. Coin supply

As I mentioned, monetary authorities had only two ways of increasing coin supply, which during the early modern period was by far the most important component of high-powered money supply (M0). The first was to debase currency.[118] This policy tool was constrained by the equilibrium responses of private agents to mint policy, as well as competition with foreign

[116] Other assets which functioned as means of exchange ("inside money") did at times develop. I argue that the two forms were more complementary than substitutes. The discussion in the present section is initially restricted to "outside" money, but higher forms of money will be considered below.

[117] British currency was convertible at fixed rates into silver and gold. It exchanged at virtually fixed rates for other currencies similarly convertible. Hence the value of money in England must have been largely determined by the supply of the precious metals, and the demand for these, in the whole group of nations linked in this way" (Ashton 1972, p.196)

[118] Munro (2011) makes a helpful distinction between aggressive and defensive coinage debasements. The first were undertaken to increase mint profits, both through increased mint output and seigniorage rates, usually to finance warfare, and defensive debasements, made as a response to the aggressive debasements of neighborhood lands, but also as a necessary outcome of the fact that where coins circulated by tale, long-term "wear and tear", clipping, sweating, and counterfeiting diminished the content of precious metals in the coinage, hence legal-tender coins gradually lost their agio over bullion.

mints (Sargent and Velde 2002). The only remaining possibility was to have access to additional precious specie, the critical input in the production of coin. A state could obtain specie either by direct production or on a secondary market. Monetary policy was conducted by means of the monetary authority setting the mint price at which private agents could coin currency from specie, after payment of a seigniorage fee. So specie needed to be available; all in all the options monetary authorities had for monetary expansion were quite limited.

As the major input in the production of money was bullion, and bullion was in inelastic supply during most of the Middle Ages, we would expect money supply to be as well. The limited availability of coinage metals (alloys) meant that governments' monetary policies were restricted by the equilibrium in the specie market. Furthermore, each coin's denominational value had a smaller equilibrium value than that of its metal content, because of the extra exchange service that each coin provided. This restriction, together with the indivisibility problem generated by the physical properties of commodity money (discussed in the next subsection), constrained the issue of low denomination coin made of specie (silver and gold).

Taken together, these restrictions lead to a higher bound in the effective money that can be supplied by a monetary authority at a given moment, a bound that is indexed by the availability of precious metal. From the mid-15th century to about 1520, the exploration of the West African coast by the Portuguese brought to Europe larger quantities of gold at a lower cost than had been previously possible with the trans-Saharan caravan trade. This can reasonably be described as an endogenous development and it is hard to say if the increase in supply through this mean was not offset by relative decline in the North African caravan route previously used to transport the gold to Europe (increased cost efficiency and possibly lower mark-ups due to increased competition notwithstanding). In any case these gold injections were of moderate quantities when measured at a Europe-wide and certainly world-wide level. During the early 15th century there was also increasing production of silver in Burgundy, Saxony and Bohemia and associated technical change made silver available at a lower cost than had been previously possible (Munro 2003; Cipolla 1993, p.174-5). Then between 1492 and the early 19th century, Europe experienced monetary injections of unprecedented magnitude.

4.2. Physical constraints and denominations

Irrespective of the matters of strategic considerations related to competition with foreign mints, debasements had limits. If economic growth was taking place but the supply of precious metals was not increasing, the only way to keep a given denomination proportional to other denominations in weight of precious metal content – than is by keeping the percentage of non-precious alloy component constant – was to make the smaller denominations quite small in physical size.[119] Doing so had obvious disadvantages to trade, and further made verifying the content harder, amplifying the uncertainty of accepting any given coin in a random and non-repeatable transaction where reputation was not an issue.[120] It also amplified the "big problem of small change" (Sargent and Velde 2002), since smaller denominations became even more liquid relative to their value.

Despite these disadvantages, the pressure to introduce currency that could support economic growth in the early modern period was such that this policy was nevertheless sometimes attempted. For instance, a quarter-guinea coin weighing 2 .09 grams was launched in 1718, but failed: "A piece so tiny, and so readily lost, was entirely unacceptable to the British public" (Craig 2011, p.21). Nevertheless, the need for credible small change to support trade was such that essayists in mid-eighteenth century England continued to recommend the minting of this coin (Redish 1990b).

The inherent trade-off of bimetallism was resolved in England in the eighteenth century by adopting gold and accepting that this meant there would be a lack of small change available (see Seglin 2008 for the role of private provision in trying to deal with this shortage). It also meant, however, that the deflationary tendencies were compounded: As Redish (1990b, p. 795) writes, "The political unpopularity of calling down the money and the costs of reminting meant that the adjustment was most frequently made by calling up the undervalued coin. If this were done on an annual basis to correct the coin ratings, however, the currency would have a persistent tendency to depreciate-that is, for the amount of specie per unit of account to

[119] This problem is even more serious for gold than silver, yet silver suffered from the opposite problem; valued by weight coins were too large and cumbersome to carry (Redish 1990b, p.792). This is incidentally what disqualified copper altogether from serving as anything other than a token currency. (Though in some societies it did so, as in China in much of the nineteenth century, with enormous transaction costs.)

[120] These information problems presented a clear limit to debasements – the relative weight of precious metals could not get too small as a percentage of the overall weight of the coin, otherwise it would become difficult to verify. So the only way would be decrease the overall size of the coin, but then policymakers would run up against the previous problem.

decrease". Constrained by the limits of debasement as a policy tool, a government was then limited to finding new sources of precious metals if it wished to expand money supply while maintaining convertibility. Yet the need to provide liquidity to support monetary expansion was such that it was nevertheless discussed in policy circles in the early century. The good fortune of the early modern precious metals discoveries is that they prevented these problems, as well as deflation – and may have encouraged growth in the first place.

4.3. Higher forms of money supply

Fiat money only become prevalent in Europe in the nineteenth century.[121] In England, as late as 1790, the monetary base was composed of £44 million of commodity-based coin and only £12 million in notes (£8 million Bank of England notes and £4 million all other; Capie 2004; Table 6).

The timing of the growth of financial intermediation can be contrasted with that for the size of government. One of the most remarkable aspects of the evolution of the English economy since the mid-seventeenth century is the persistent growth of the government sector, which accelerated during the eighteenth century, more than quadrupling between 1700 and 1790.[122] The growth of government happened through a ratchet effect, with expansion during times of war not fully reversed when peace came along (Brewer 1989, O'Brien 1988).

This ratchet effect was absent in the case of money supply. This is true for both coin supply and higher forms of money supply, either measured by notes of the bank of England or broader measures that include bills of exchange and notes of provincial banks (Figure 4). The fact that until the last decade of the eighteenth century government expanded in tandem with warfare, but money supply did not, tells us much about the fact that in earlier periods, the expansion of coin supply was conditional on the availability of precious metals. The bank of England and other financial intermediaries had the capacity to expand higher forms of money, but, concerned with their reputation and solvability, did not do so (O'Brien and Palma 2015).

[121] Scotland (and North America) did use fiat more regularly than England, but under high transaction costs.
[122] For a recent review, see Broadberry et al (2015).

	1600 (Mayhew)	1688 (Cameron)	1700 (Capie)	1750 (Cameron)	1750 (Capie)	1790 (Capie)	1870 (Capie)
Coin	3.5	10	7	15	18	44	95
Bank of England notes	-	-	1.5	4.3	4	8	35
Other notes (country banknotes)	-	-	0	0.7	1	4	4.9
Bank balances at the bank of England	-	-	-	1.9	-	-	6.5
Other means of payment	1	10	n/a	18.1	n/a	n/a	n/a
Total (M2)	4.5	20	>8.5	40	>23	>56	>141.4

Table 6. Estimates for the components of English nominal money supply. Unit: millions of £. Sources: Mayhew (2013), Capie (2004) and Cameron (1967). The category "other means of payment" includes Cameron's £6m in government tallies and £2 m in inland bills in 1688 and £ 3.1m in deposits in private banks in 1750.

Indeed, all notes of the Bank of England (and of provincial banks) were fully convertible until the Restriction Act of 1797. Only after that period was it possible for the Bank of England to expand notes significantly without running into credibility problems (Figure 4; O'Brien and Palma 2015). The same is true for provincial banks: "the arrival of country banking, combined with the note issues of the Bank of England, was not an answer to the shortage of silver in

England and Wales even by the end of the eighteenth century" (Clancy 1999, p.30); it is hard to conceive how in its absence it would have been.

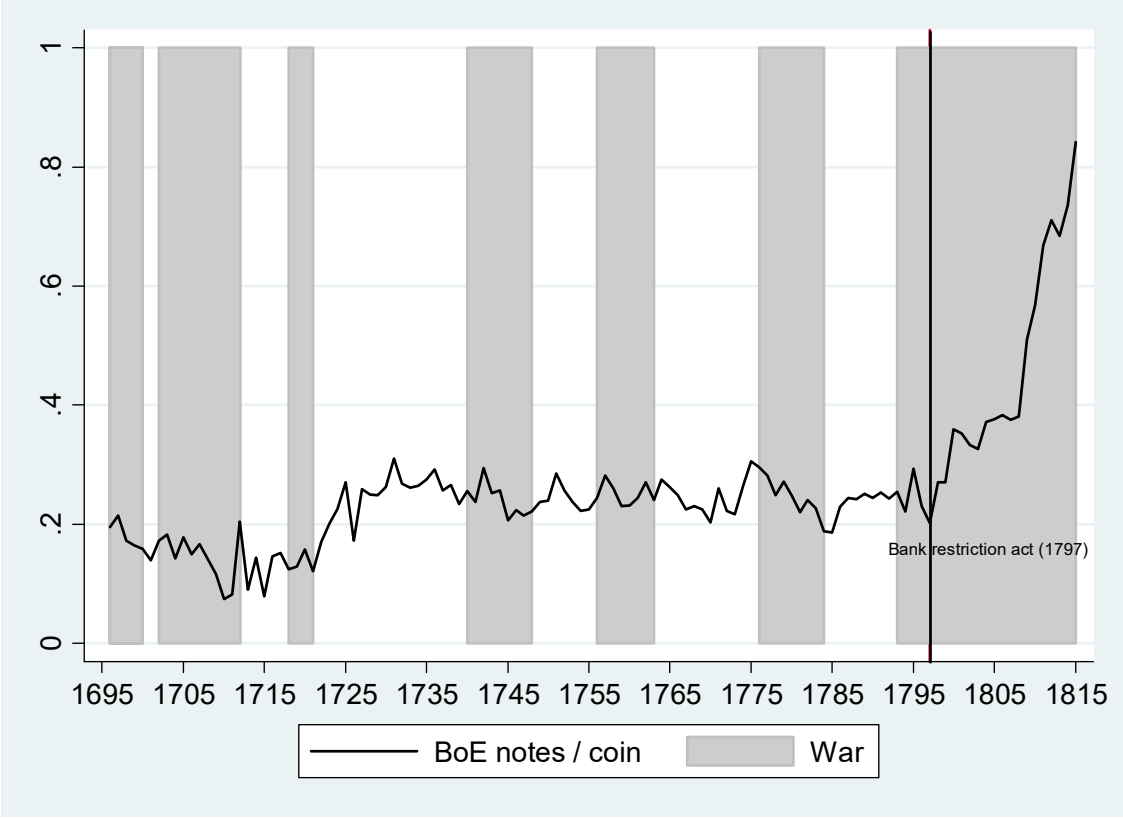

Figure 4. The size of financial intermediation, proxied by the ratio of Bank of England notes over coin supply. Despite the existence of bills of exchange throughout the entire period, growth in the latter period (especially after 1797) is likely to be underestimated because of the spectacular growth of private provincial banking, which here lies unaccounted for. Source: O'Brien and Palma (2015)

Of course another option would be to drop convertibility altogether; but considering that John Law's fiasco in France was very present in people's memory this would have been difficult. It was only under the exceptional threat of a financial panic triggered by imminent French invasion that the Restriction Act was passed in 1797, only for convertibility to be restored as soon as conditions normalized (de facto, 1816, and officially, 1821; see O'Brien and Palma 2015 for details).

Indeed, Angela Redish plainly states that "it was not possible to establish a stable token coinage prior to the nineteenth century" (Redish 1990). Notes both of the Bank of England and of provincial banks enjoyed limited circulation before the last decade of the century; people did

not use these for retail purchases or other regular transactions (Clancy 1999, p. 28-9, Feavearyear 1944, Clapham 1944). According to one estimate by The Board of Stamps, as late as 1812-16 the value of country banknotes annually in circulation was under £16 million" (Clancy 1999, p. 29) Finally, it was also the case that until the last decade of the eighteenth century the lowest denomination for a banknote was £20, which was well above the unskilled wage. Angela Redish goes as far as saying that: "To reduce the problem of counterfeiting, bank notes were generally issued in very large denominations, and until the twentieth century they were not employed at the retail/wage paying level" (Redish 1993, p. 782).

4.4. Currency and credit: substitutes or complements?

It has long been argued that an English "financial revolution" had been in operation at least since the 1660s (Dickson 1993). This consisted of the increased usage of credit instruments such as bills of exchange and promissory notes[123], as well as privately issued tokens (Whiting 1971), and after 1694, bank notes of the Bank of England (O'Brien and Palma 2015) and of provincial banks (Presnell 1956).

It is a fact that in the second half of the seventeenth century, the expansion of the English economy was supported by an expansion of credit. As Table 6 and Figure 5 suggest, however, by the late seventeenth century M2 was still quite close to coin supply. This shows that the seventeenth century's expansion of credit was not sufficient to compensate for the economic growth which was also occurring – at both the extensive (based on population growth) and intensive (per capita) margins – and indeed in the second half of the seventeenth century both measures of per capita money supply actually fell. This trend was only reversed in the eighteenth century – in tandem with an increase in the availability of precious metals, largely due to the discovery of gold in Brazil and to the shifting of mining priorities in the Spanish empire from Peru to Mexico. Further, the conditions of the second half of the seventeenth century in England were special, as they corresponded to what can essentially be described as financial sector catch-up with the best practices of the continent (Coffman, Leonard and Neal 2013).

[123] The Promissory Notes Act of 1704 made all debt instruments negotiable by allowing not just the initial creditor but the holder of any bill to sue the initial debtor (Richards 2012, p. 23)

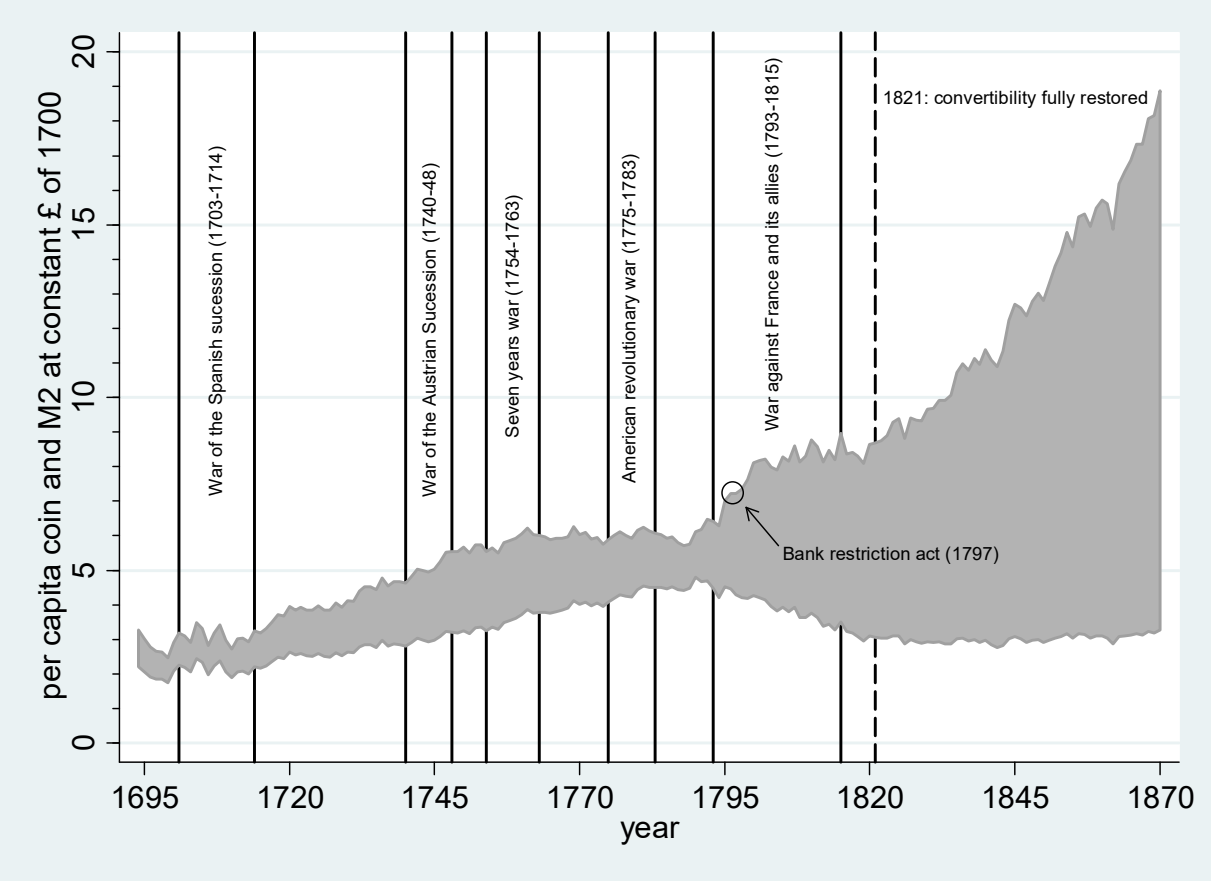

Figure 5. British per capita coin supply and M2 at constant prices of 1700. The area in grey can be interpreted as the approximate size of financial intermediation. Source: O'Brien and Palma (2015), who rely on the indirect method described in Palma (2015a), who in terms of data in turn relies on Broadberry et al (2015), Capie (2004), Mayhew (2013), and others.

While forms of exchange based on informal credit had been developing as a substitute for currency since the sixteenth century, this was inadequate: "the primary hindrance was that personal credit instruments did not circulate, at least not nearly enough to make a real difference. For commerce, agriculture and manufacturing to flourish, new sources of money had to be discovered" (Wennerlind 2011, p. 19).[124] In itself this suggests that under the prevalent system of expectations, commodity-based currency and paper money

[124] As Wennerlind (2011, p. 110) himself recognizes, William Paterson, the intellectual influence behind the creation of the Bank of England, felt that "Credit not founded on the Universal Species of Gold and Silver, is ... impracticable", and that a minimum reserve of 15-25 percent was necessary to make the system secure (Patterson 1694); Godfrey advocated a similar position (Wennerlind 2011, p. 112).

were complementary as much as substitutes.[125] Credit was, additionally, subject to usury restrictions that were binding, and may have prevented access to credit, especially for those without access to significant amounts of collateral (Temin and Voth 2008).

The perceived need for means to expand currency is reflected in several contemporaneous intellectual and political debates revolving around the fact that the commercial expansion of the economy required an accompanying expansion of the money supply. Conventionally classified under the "mercantilist" umbrella, contemporary intellectual thinkers, including authors such as Malynes, Miselden and Mun and their disciples, were unanimous that the scarcity of bullion was a problem, hence the emphasis on access to bullion under a favorable trade balance.[126] In the case of Paterson, Godfrey and Mackworth, paper money was advocated as solution, but always making clear that the extent of expansion was indirectly constrained by access to bullion.[127]

In fact, the common denominator of the "mercantilist" literature seems to have been the preoccupation with the capacity of money to encourage economic growth. I agree with Wennerlind that Adam Smith (and, it could be added, much of modern economic theory which postulates that money must be neutral over the long run) was mistaken in accusing these mercantilists in confusing money with wealth, because in fact the limitations of credit expansion meant that "there was no other way to expand the money stock than to attract silver and gold from abroad" (Wennerlind 2011, p. 40).[128]

Wennerlind subsequently argues that the restriction on endogenous money creation was over once the law allowed the current holder of the debt instrument to sue the initial

[125] Further, the expansion of paper credit was considered by contemporaries complementary to having a positive trade balance and hence access to foreign precious metals (Wennerlind 2011, p. 282 endnote 95).
[126] The state indeed often took action: legislation prohibited the export of bullion. In the non-cooperative world of medieval and early modern Europe, perhaps there was some rationale to these policies which were castigated by Adam Smith and other classical writers. Indeed, it is noticeable that "such bullionist legislation was a constant feature of the work of late medieval parliaments" Mayhew (1974, p. 62)
[127] Other writers such as Hugh Chamberlen and John Briscoe advocated a national land bank, which would expand money based on the security of land, not bullion. The utter failure of the Land Bank United, launched in 1696, to attract capital (in sharp contrast to the Bank of England's oversubscribed issue two years earlier) suggests this foundation was not possible. Only around the time of the restriction act (1797) was it really possible to have monetary expansion independent of bullion (O'Brien and Palma 2015), and as the establishment of the gold standard in 1821 suggests, even those measures were, for the time being, temporary.
[128] With regard to the issue of trade competiveness in connection with deflation, it is noticeable that, at times, it was explicitly recognized that in order for trade to remain completive, the right amount of money was needed to maintain the price level (Wennerlind 2011, p. 40).

debtor. This is where my position differs. Perhaps that eased the constraint a bit, but it would have been unable to support the subsequent eighteenth-century growth. As the end of the seventeenth century approached, the fall of the average silver content of coin to 50% of the official weight meant a serious monetary crisis, in part because silver coin served as security for the notes of the Bank of England (Wennerlind 2011, p.11). This itself suggests that, later on, the lack of gold would have presented an obstacle.

As contemporaries recognized, the feasibility of taking credit was all about reputation. Even though the lack of currency in the face of expanding commerce provided an incentive for the development of forms of "endogenous money", these could only be sustained as long as merchants were convinced of the buyer's "Integrity and Ability for Payment", and more generally, the "honourable Performance of contracts and Covenats" (Defoe 1709).[129] This was, in fact, representative of the position of the intellectual elite of the time. As even Wennerlind (2011, p. 241) recognizes, David Hume, for instance, while open to the notion that under appropriate levels of trust credit could flourish, insisted that currency based on silver and gold was "more practical". Adam Smith advocated a similar position. The situation is analogous to the well-known Magribi traders' case for which reliance on informal networks rather than the legal system to enforce contracts presented limits to commercial expansion (Grief 2006). It was equally so with credit vis-à-vis the much lower transaction costs of using currency at any non-local level (with the possible exception of richer merchants who had the reputation to use bills internationally).[130]

Finally, another argument supports the idea that money and credit were complements. The decision to issue credit was often based on people's anticipation of whether they would be able to have the liquidity to honor the bill, and that in turn depended on the overall availability of money (Nightingale 2010; see also the discussion of "Mayhew's law" in Allen and Coffman 2014).

[129] In an attempt to popularize the notion of credit (and defend his increasingly pro-Tory political position), Defoe used the rhetorical figure of "Lady credit", the younger sister of money, who could take her sister's role in trade, but only as long as "her Sister constantly and punctually relieves her" (Defone 1706). For a recent review of Defoe's role in popularizing the polices of Harley, see Wennerlind (2011, p. 181-189).
[130] In the American colonies, in particular Virginia, in Barbados and even in Scotland, paper money was often used, but it only had the ability to circulate locally and under high transaction costs. Finally, one additional reason change to a fiat system did not happen earlier may have been related to the limited political influence of the groups that would gain from inconvertibility and depreciation (Eichengreen 1992).

In sum, there were only two ways in which people could issue credit, and both critically depended on reputation in the face of repeated relationships. First, richer merchants with established businesses could write bills of exchange, even internationally.[131] Second, at the local village level, people could and did at times informally borrow small amounts from each other (Muldrew 1998). But this required personal and repeated relationships that necessarily limited the scope of credit – it created complications for the advancement of structural change and division of labor, which require the availability of an anonymous and liquid means of exchange for one-off transactions in cities. The lack of an easily accessible liquid means of payment meant that in medieval economies payments often had to be made on a quarterly basis or through the "chalking up by local tradesmen of small debts for later settlement" (Mayhew 1995, p. 239), which surely increased credit risks and transaction costs, leading to a reduced number of equilibrium transactions.

The conclusion is clear: in the middle ages and early modern period, coinage complemented rather than substituted for banking, as emphasized by the following quote by Spufford, who by "money supply" here simply means coin supply: "[B]ank money and other additions to the money supply did not develop where the money supply was generally poor, but, on the contrary, in some of the places where the money supply was already most abundant … [C]ommercial interest rates dropped … in those places where the money supply was most plentiful" (Spufford 2002, p. 42 and p. 44).[132]

5. On the macroeconomics of money and growth

5.1. The doctrine of long-run neutrality

The following words by John Taylor, writing in the *Handbook of Macroeconomics*, summarize economists' standard view on the long-run neutrality of money (Taylor 1999):

> "A change in the money supply cause[s] real output to change in the short run, but not in the long run … as prices and wages gradually rise, real money balances return to their original level and in the long run the real economy is unaffected"

I could choose many other examples. McCallum (2004, p. 1), for instance writes:

[131] In the case of at least one important sovereign borrower, the reputation of the lenders, rather than that of the borrower, determined that the lending could keep happening (Drelichman and Voth 2011).
[132] Evidently, these patters correspond to correlations, which do not necessarily imply causality.

> "At a conference on 'sustained economic growth' held by a central bank, it seems appropriate for me, a monetary economist, to discuss the long-run relationship between monetary policy and real economic growth. One could make this a very short talk without being entirely wrong by just saying that there is no long-run relationship and stopping with that"

The "long-run neutrality" doctrine is one of the cornerstones of modern macroeconomics, and it largely justifies the separation of the field into the study of business cycle fluctuations (a.k.a. "the short run") and economic growth (the "long run").[133] Indeed, this theoretical prior is taken as a given to the extent that it often leads economists to impose, as a maintained exclusion assumption in VAR models, that this long-run exclusion restriction must be true (e.g. Blanchard and Quah 1989).

However, the idea that money must be neutral over growth frequencies is usually justified on theoretical grounds and there is very little empirical work testing it. In fact, the relationship is very hard to test using modern data.[134] First, there are severe identification problems caused by the fact that in modern economies the quantity of money in circulation is endogenous – monetary authorities respond and try to influence the state of the economy. So while some high frequency identification may be at times possible (e.g. Nakamura and Steinsson 2013), that presumably misses most of the action (as only a small fraction of variation will be exogenous), and, given the focus on the short run, is unable to capture growth effects by definition.

These identification problems are further amplified by the insufficient frequency of time-series observations and the lack of variation in monetary institutions and policies themselves during the historically short period for which economists have data. In other words, the standard datasets used by macroeconomists, almost always dating from the post-World War II era, and often from the post-Bretton Woods period, do not work both because they are too short and because monetary policy reacts to the state of the economy,

[133] Notice that in RBC theory and most DSGE models, TFP shocks affect the business cycle, but the direction of causation goes only one way: the way the business cycle is run in no way affects the long-run steady-state or balanced growth path; Money is neutral over the long run. It is also usually super-neutral: not only does the level of money not matter for real allocations in the long run; but the rate of change does not either.

[134] One related influential, but controversial, strand of literature argues that financial development has a causal effect for economic growth (see Levine 2005 for a literature review and Buera et al 2011, Buera and Shin 2013 for recent papers.)

which renders regression analysis uninformative about the causal effects of money in the absence of a source of exogenous variation in money supply.

In an Arrow-Debreu world of complete markets, money is not required, and fiat cash would be worthless. Specifying details about the nature of incompleteness is important in order to understand why and how money matters. In this paper I concentrate on the matter of reduction in the costs of participating in market activity, in association with money's role as a unit of account and means of exchange.

5.2. Some monetary and growth accounting

Consider the familiar equation of exchange: MV=PY, where M stands for aggregate money supply, V is velocity, P is the aggregate price level and Y is aggregate nominal income. As written, this equation is an accounting identity with no theoretical content. (This differs from the quantity theory of money, which corresponds to placing specific assumptions on the behavior of some of these variables.) A log-difference transformation leads to:

$$\Delta M+\Delta V=\Delta P+\Delta Y$$

It immediately follows that for M constant, ΔY implies either $\Delta^{+}V$, or $\Delta^{-}P$, or both: if economic growth is to happen, a fixed money stock implies either continued increases in the velocity of circulation or deflation. While at a secular level velocity could in theory trend a little over a long period of time this would necessarily be second-order in comparison with changes in money, income and prices. Indeed, there is strong empirical evidence that velocity showed no long term trend during the eighteenth century (Palma 2015a, Table 1 and Figure 4).[135]

Hence with a fixed supply of money and at most only moderate increases in V the only way Y could grow fast and consistently – irrespective of the effect it had on the population -- is through continued deflation, $\Delta^{-}P$. This much was already recognized by Braudel and Spooner (1967, p.384), who wrote that "the stock of metal has to be increased regularly for the price level merely to be maintained".

[135] While technological change may lead to moderate increases in velocity over time, this could not have been of the magnitude of British economic growth from the mid-seventeenth century onwards, which was considerable on the extensive margin (ie accompanied by population expansion), and, while slower in this period relative to what was once thought, was still high by previous historical standards even on a per-capita basis (Crafts and Harley 1992, Broadberry et al 2011).

While there was no way that credit could have substituted for coin (Section 4.4., Nightingale 2012), a persistent rise in velocity could not have been a solution either, because transaction costs would have risen prohibitively. As Mayhew (2013) has recently written, summarizing both these points:

> "it is the rise of M, not V, that is characteristic of growing or modernizing economies. Indeed the historical evidence shows that there are real limits to how large V can become without impacting seriously on the economy. The eleventh-century V of around 10 in fact required a large amount of business to be carried out by non-monetary expedients, such as labour services or payments in kind instead of money rents or wages … more through monetization required a growth in M, which thus reduces V … credit cannot grow by an increase in the available money supply".

Indeed, at the aggregate level credit could not at this time grow without an increase in the availability of a complementary means of payment that was both liquid and credible. At the same time, continued deflation does not provide a good foundation for economic growth. But then, since velocity is fixed over long periods of time and continued deflation has negative effects on growth, it follows that continued expansion of the money supply is necessary for economic growth to occur. This should not be too surprising once the role of money is understood: money reduces transaction costs and its availability is required for the possibility of a larger market that permits the continued division of labor.

5.3. Incomplete nominal adjustment

If the price level could adjust immediately to changes in money supply or real economic activity, then any change of unit of account or the overall quantity of money would not matter. As it was, whether due to social norms, menu costs, or other factors, price and wage rigidity was a reality.[136] In early modern England, despite the ongoing "price revolution" which occurred prior to the eighteenth century, customary rents were normally fixed in nominal terms, with contracts often covering a number of generations, and there were substantial benefits to be had for tenants who were able to defeat their lords attempts to raise rents (Holt 2013). Indeed, not only was price adjustment persistently absent or incomplete for long periods of time (Palma 2015b), but it was also the case that it

[136] For a recent review of menu cost models, see Nakamura and Steinsson (2008). Even in modern economies, labor markets often do not clear as nominal wages adjust slowly to changes in economic activity (and do so asymmetrically: they are especially difficult to adjust downwards; see Bewey 2002).

was asymmetric – in eighteenth century France, for instance, upward adjustments were much faster and less penalizing than downward adjustments (Velde 2009).

Several recessionary mechanisms associated with deflation can be posited. Despite the relatively small size of financial intermediation, debt-deflation might have been a serious concern in absence of the monetary injections.[137] As the internal price level falls, the real exchange rate will tend to appreciate and a given economy will tend to become less competitive. Further, even if deflation was avoided for a group of countries as a whole, it may have nonetheless been beneficial for all (Eichengreen and Sachs 1985). Expectations about continued falling prices may also lead people to delay consumption expenditures. More micro-level studies are required for us to conclude which were quantitatively more important.

5.4. Why did the early modern monetary injections matter? A narrative

The discovery of large quantities of specie allowed for systematic increases in the availability of money because specie was the critical input in its production. Europe experienced major monetary injections as a consequence: in the case of England, where minting flows are well known (Challis 1992, Palma 2015a), it is clear that they increased dramatically.

Monetary injections mattered because the additional liquidity avoided persistent deflation and lowered transaction costs, encouraging market participation and structural change.[138] In the Middle Ages, supply of precious metals was quasi-fixed and hence deflation was a persistent phenomenon. It took until the 1530s for the price level to recover to the pre-Black Death level (Figure 6). Indeed, this episode of persistent deflation from the fifteenth century onwards is associated with the late medieval bullion famine (Day 1956; Spufford 1988; see also Dyer 2002, p. 266 and the literature cited there and in p. 384.) Although some elements of the original story were subsequently criticized (Sussman 1998), the lack in the availability of precious metals was in fact at this time an important element in preventing growth (Miskimin 1964, Nightingale 1990, 1997, 2012; Desdan 2014).

[137] Debt-deflation is the fall in the prices of assets, goods or services that raises the real value of debt, which is written down nominally. In turn, this may lead to a negative cycle.
[138] These are the reasons I emphasize in this paper; others may have been at play. In particular, I have here left out associated distributional implications.

The role of precious metals as a binding constraint for growth in late medieval Europe has been emphasized by generations of medieval historians. The period 100-1300, when silver was still available in sufficient quantities, was a period of increased commercialization, which included the establishment of active factor markets for labor, land, and capital (Cambpell 2009). Spufford (2002, p. 12 and 59) considers that the growth in the money supply was a necessary precondition for the thirteenth century European commercial revolution. But it could not last. Indeed, Jaques le Goff writes:

> "What are for me the essential components of capitalism which were not present in medieval Europe? The first is a sufficient and regular supply of either precious metals, making it possible to mint coins, or paper money … [T]he Middle Ages was several time son the brink of monetary famine, and this was still the case at the end of the fifteenth century … The discovery of America meant the regular transfer to Europe of large quantities of precious metals, gold and silver … It was only then that the first demand of capitalism was met". Goff (2012, p. 143)

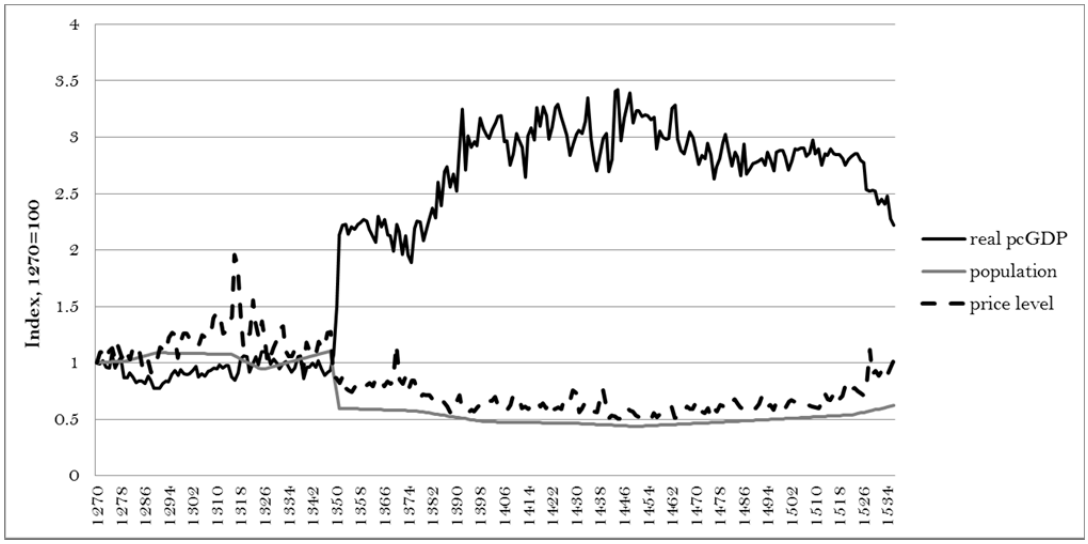

Figure 6. The price level, real GDP, and population, 1270-1540. Source: Broadberry et al (2015).

Different elements associated with the Black Death have been pointed out as an important element to explain not only the evident one-time income increase associated with a rise in the land-labor ratio but also, according to some authors subsequent economic growth much later, during the early modern period (see, for instance, Pamuk 2007 or Voigtlander and Voth 2012). One element which has not been emphasized is that (as with land or other assets) people died, but money did not. The Black Death also functioned, for practical pur-

poses, as a major per capita injection of liquidity (in addition to other less liquid assets). In my view this complements Engel's law and associated demand-side explanations as to why specialization and urbanization subsequently increased. Suddenly, it was easier to conduct trade and specialize since at the prevailing price level it was easier to make and receive payments, more collateral was available, and credit was more likely to be paid in time with reduced risk of running into liquidity problems and having to engage in fire sales. But once a new steady-state was eventually reached, from the late Middle Ages and until to the 1520s the economy ran into persistent deflation – though as always (unlike the converse case which often happens with inflation), prices never decreased too fast. Recent aggregate data suggests that England suffered from persistent secular deflation from the early-fourteenth century to the first decade of the 1530s (Figure 6).[139]

As is well-known, the English population took longer to react to higher levels of income than we would expect under simple-minded Malthusian logic, and by the mid-fifteenth century demographic growth had stopped, though the per capita income level was considerably higher than it had been just before the Black Death. Then the sixteenth century was essentially a century of stagnation, both in terms of per capita real GDP and money supply. John Munro (2003) has emphasized that silver mines from Saxony may have had some effect in the first half of the century, and while silver was arriving from South America into Spain in significant quantities (and by extension, certainly the modern territories of Belgium and the Netherlands, as well as much of modern Italy), it is worthwhile pointing out that it took until the early seventeenth century for precious metals from America to start having a significant effect on England's money supply. Interestingly, this effect slightly predates the very significant (for the standards of the time) growth which then occurs (Figure 7).[140]

[139] Indeed according to some authors, by comparison with both 1000-1300, and much of the early modern period, the 1300-1525 was instead a period of arrested development (Britnell, 1993, 2009).
[140] Notice, however, that the 1600-1643 growth in money supply is conditional on the relatively high figure of £10 for 1643, which is based on a relatively uncertain guesstimate based on civil war coin hoards (Mayhew 1995). If the 1643 figure was lower (see Palma 2015a for details), the rise in per capita money supply would be more contemporaneous to that of per capita GDP.

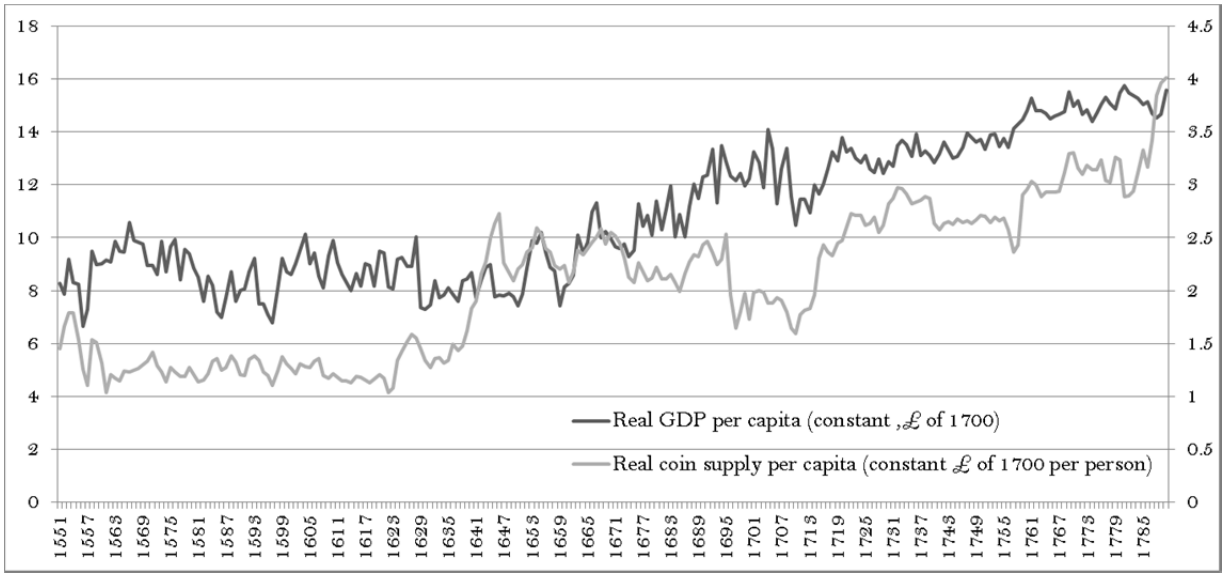

Figure 7. Per capita coin supply and real GDP, at constant prices of 1700. Source: coin supply from Palma (2015a), and the price level is the GDP deflator of Broadberry et al (2015).

In turn, Figure 7 contrasts per capita coin supply and real income, focusing on the period after the Great Debasement of 1542-1552.[141] As we can see, in the second half of the sixteenth century, real per capita coin supply is essentially flat, then steadily rises in the period 1620-40, hence before the Civil War, and then slowly decreases (in per capita terms) but always stays well above the pre-1620 level. Finally, in the eighteenth century in association with the discovery of Brazilian gold (Palma 2015c) and the Spanish Bourbon shift of the American empire towards the Mexican mines, there was a steady rise once more.

A short macroeconomic history of early modern England in relation to monetary history can be told as follows. During the sixteenth century, nominal coin supply increased, but these increases were more or less cancelled by increases in population and the price level. The increase in coin supply did lead to inflation, which is what eventually terminated the previous status-quo of stagnated nominal wages.[142] Inflation may have encouraged wage-labor share growth, and may have had distributional consequences[143], but did not lead to

[141] I focus on the early modern period due to my enphasis on monetization as complementary to other factors. In other words, high coin supply per capita is not a sufficient condition for growth.
[142] Dyer (2013, p. 22) writes that "The daily wage of building workers reached a plateau during the fifteenth century, which persisted until 1520, of 6d per day for a skilled craftsman and 4d for a labourer".
[143] Landes (2003 [1969], p.18) suggests that the long inflation of the sixteenth century, "which "found many peasants holding long-term leases whose burden diminished" was strongly associated with reducing seigneurial authority and enhancing the personal and economic status of the peasantry. See also Whittle (2013, p. 12).

per capita income growth.[144] It was only after the early sixteenth century that the gradual increase in availability of real coin supply per capita allowed for structural change to begin (Broadberry et al 2013)[145], and for income growth to occur. Finally, in the eighteenth century income growth continued, caused factors such a urban agglomeration economies (as illustrated by the rise of London) and related spillovers in the countryside, as well a continued increase in market participation, especially along the intensive margin[146] and in the cities (Allen and Weisdorf 2011).

6. From St. Monday to the long haul

In the interests of breaking down this complex matter, I first consider "level effects" and only next move to "growth effects". In light of standard growth theory, one might expect a one-time decrease in transaction costs to lead to a higher level of commercial transactions, but not to a higher growth rate. The same is true for an increase in labor supply. As I argue in the next section, however, the separation of level and growth effects is to some extent artificial, because certain level effects can generate growth effects. Still, it is nonetheless a useful starting point to discuss "level effects" to break this down.

6.1. Monetization and transaction costs

As discussed in Section 4.4., until late in the early modern period commodity money did not have a viable close substitute in its function of means of exchange for the vast majority of transactions in the economy. An implication is that if availability of precious metals had not been able to expand thanks to the discovery of America, a smaller quantity of money would have been in circulation. In turn, transaction costs would have been higher; it would have been harder to pay and receive wages, both in the cities and in the countryside, but importantly, fewer people would have moved to cities altogether. Without the

[144] This may have been for a number of reasons: decreasing real income of landowners, increased supply of labor having a contrary effect on the equilibrium real wage, and/or the increase in the share of pasture to the expense of arable (as suggested by More's "sheep eating men" *Utopia* metaphor) decreasing agricultural labor demand, even if that was itself partly a response to initially "high" real wages. It is also the case that as long as large reserves of nonwage workers still existed, a continued increase the wage-labor force could proceed without an increase in either real wages or per capita GDP, which by definition only measure market compensation.

[145] Notice that from Broadberry et al (2013), we do not know exactly when did structural change start, other than it must have been between the 1520s and 1700.

[146] The eighteenth century increase in market participation was based primarily on an increase in the average number of days people worked per year (intensive margin) rather than a larger share of the labor force participating in the market, in association with structural employment change (extensive margin).

additional money supply made possible by American precious metals, more transactions would have to have happened through barter, and given the higher cost, fewer transactions would have happened overall.[147] The extent to which this is a level effect rather than a growth effect parallels our understanding of how for long Smithian growth may or may not be viable as a means for continued improvement in welfare (Kelly 1998). Nonetheless, it is helpful not to lose track of the fact that growth over the long run consists of a series of a level effects, which implies that in the context of a given historical period, it may not be easy to distinguish between the two.

6.2. Increased labor supply

Despite the substantial amount of attention given by economic historians to the industrious revolution concept[148], it is important to keep in mind that from a growth theory perspective, an increase in labor supply will lead only to a "level" and not a "growth" effect – it can perhaps explain a higher level of income, relative to that which would exist under a lower labor input per capita, but it cannot on its own explain the take-off towards modern economic growth. Unlike TFP, per capita labor supply is by its nature limited by people's own limited time in life. Furthermore, we know that working time decreased later on, so even that level effect should be reversed (at least for the intensive margin). Hence, while the increased labor input supports the "pessimistic" view of Crafts and Harley (1992) about the eighteenth century (Antras and Voth 2003), it cannot have, on its own, caused the emergence of modern economic growth.

In understanding the industrious revolution, the literature often mentions the phenomena of increasingly commercialized and specialized economies, as indicated at even the macro level by a declining share of agriculture in employment. While not denying the importance of other complementary factors, my emphasis here is that the increased monetary liquidity available must have helped. First, the increased liquidity made it easier for employers to pay employees, and for employees to spend their money. This led to an expansion of equilibrium labor supply (the mechanism is detailed in Palma 2015c).

[147] Money reduces coordination costs associated with barter, but more importantly, allows for intertemporal (and non-billateral) trade in a context of limited contractual enforcement.
[148] For instance, the recent Broadberry et al (2015) volume dedicates a considerable number of pages to the discussion of the concept and its implications for the measurement of GDP, and reviews the literature.

For those who were already participating in the market, the increased liquidity led to more intensive participation (in particular a larger number of days worked, as exemplified by the elimination of St. Monday). Market participation also increased at the extensive level: people who lived in rural areas and were not participating in the market (or were only doing so occasionally), started doing so, either by specializing and selling for the market more systematically while staying in rural areas, or, importantly, by moving to cities.

The "new goods" imported from Asia to Europe stimulated people to work more (de Vries 1993, 2008, Hersh and Voth 2009). Many of these "new goods", including porcelain, silk, and tea, could only be imported to Europe in the quantities which we observed due to the availability of American precious metals (Palma and Silva 2015). This must by itself have been a relatively important effect, as by the middle of the eighteenth century, the Cape-route trade provided an average Western and Central European consumer with Asian goods that cost the equivalent of three days wages of a manual worker in Holland or England (deVries 2003, p. 91). Nonetheless, perhaps the most important role the "new goods" played was that of dynamic spillover effects, discussed in the next section in more detail. Finally, tea also joined coffee in helping to impose the discipline, concentration and effort levels that a modernizing economy required, as exemplified by the mechanization and factory system (Ashton 1997/1948).

7. From the long haul to modernity

It may seem that the effects I have so far discussed could not have had more than a level effect on incomes. Even if they generated a growth spurt during transitional dynamics towards some new steady state or balanced growth path, standard growth models would suggest that the effect should have been necessarily temporary (as it happens with an increase in the savings level in the Solow model for instance.)[149] Of course, all depends on what we mean by "long run".

And yet I argue that instead the fact that market participation and Smithian growth rose before "modern" economic growth took hold does matter to understand why it happened.

[149] Alternatively but similarly, a decrease of the subjective discount factor in the Ramsey-Cass-Koopmans model, in which savings are endogenous.

This in turn increases the importance of understanding why premodern growth took the forms that it did. The point I make here is that, notwithstanding other factors, this was in part a result of the unprecedented increase in money supply that happened in the early modern period.

How should we think about this conditionality? The effects can be broken down as follows. As money supply per person increased, there was, first, a lowering of transaction costs and increasing market thickness effect which led to structural change and consequently agglomeration economies. Second, there were several second-order, indirect effects (which then had a feedback effect on the main effects). These included a long-term "getting used to the market" effect (deVries 2008), learning effects at the firm level, trade and human capital externalities, and importantly, a state-building effect as the collection of taxes became easier (Capie 2004). Naturally, these effects also interacted with each other. Nonetheless, I will now consider each in turn.

7.1. Division of labor, structural change, and agglomeration economies

A more monetized economy permitted greater division of labor because it became easier to obtain the means of exchange to purchase essential goods in an urban context. Hence, moving to cities made more sense, and it was less risky in the sense that one could carry savings in a monetized form to survive while looking for a job. For firms, it also became easier to pay wages, and to invest in a greater variety of products (see Kelly 1997 an exposition of Smithian growth). Thicker markets meant that "horizontal" growth resulting from an expansion in the varieties of available products could flourish.

Structural change in turn led to economic growth resulting from agglomeration economies due to higher levels of urbanization. The modern view about the first industrial revolution is that fast productivity increases were initially limited to a few manufacturing sectors that were too small as a share of the overall economy to matter a great deal in terms of overall growth, which remained unspectacular until the nineteenth century. The remaining discontinuity associated with the eighteenth century is an unusual degree of relatively fast structural change (Crafts and Harley 1992). The spectacular growth of London from the middle of the seventeenth century mirrors the take-off of sustained economic growth since then – as well as the take-off of per capita money supply.

7.2. Trade, human capital externalities, and the dynamics of a "new goods economy"

The direct demand for woolen and manufactured goods from Iberian economies – as well as the second-order demand effects, for instance from the Netherlands, which in turn had more silver and gold brought over in the context or war and trade with Spain – must have meant that English industries got a boost, as illustrated by the case study discussed in Section 3. Indeed, "Through both legal and smuggled imports, effective Spanish demand, sustained by American silver, promoted the economic development of Holland, England, and other European countries" (Cipolla 1993).

I have already discussed the role of the "new goods" in stimulating labor supply, treated as a static effect. The most important effects, however, were dynamic. For convenience these can be separated into technological, learning externalities and industrial expansion effects, and related demand effects, as opposed to general equilibrium effects, particularly in their high-wage economy dimension.

The "new goods" from Asia, a result of Europe's availability of silver for exchange, certainly made people want to participate in the market. But they also induced demand towards import substitutes, which spilled-over into industrial development. In England, it is hard to conceive of important porcelain centers such as Worcester or Derby having appeared if the early modern Euro-Asian trade had not happened – elsewhere in the continent important centers also appeared at Delft, Chantilly, or Sèvres, yet in England the industrial effects were stronger than elsewhere.

Finally, one prominent dynamic consequence of the increased demand for English products was the dynamic general equilibrium effect associated with a high wage economy (Allen 2009). As one early political economist put it:

> [I]f the increase of money in the state comes from a balance of foreign trade ... this annual increase of money will enrich a great number of merchants and entrepreneurs in the state, and will give employment to numerous artisans and workmen who provide the goods sent to the foreigner from whom money is drawn. This will gradually increase the consumption of these industrious inhabitants and will raise the price of land and labor (Cantillon 2010, p.148 [1755], p.150)

The exploration of the American continent was a consequence of the search for precious metals.[150] And while the role of the New World as "ghost acreage" or a mass-emigration escape valve would have to await the nineteenth century, the discovery of the New World mattered in many other ways in addition to the more straightforward trade effects (Palma 2016). It contributed to changing people's mentalities – especially that of the intellectual elite but also ordinary individuals:

"The conclusion is inescapable that the discoveries of America and of the Cape route to the East Indies were highly important factors in the rise of modern capitalism. Changes in trade routes, the widening of markets, contacts with distant lands and strange peoples, and a more perfect knowledge of geography conspired to perturb the minds of men much as does our increasing power over nature to-day. The price revolution set in motion by American gold and silver contributed directly to the progress of capitalism" (Hamilton 1929, p. 355)

At the same time, the increase in monetization must also have helped increase people's basic numeracy skills, as people became more used to handling money and planning as well as performing market transactions. This may have had an impact on human capital accumulation. Perhaps as this process proceeded, in the more monetized economies people's culture also evolved in a more market-friendly direction (McCloskey 2010).

7.3. Monetization, taxes, state capacity and finance

The comparative experience of early modern economies shows that as far as state development is concerned, Britain was well ahead of continental European economies – and even more so relative to other civilizations (Table 7). The monetary injections helped here too as it became much easier for the state to collect taxes in a more monetized economy, and one where an increasingly greater percentage of transactions involved using money (Capie 2004). Under these conditions tax-backed "funded" debt could emerge, which in turn allowed the bank of England to credibly expand paper money gradually, without running into time-inconsistency problems (O'Brien and Palma 2015).[151] Certainly, money was here a necessary but not sufficient condition; there were other (institutional) aspects specific to the English economy which led state capacity to growth faster than elsewhere.

[150] Conversely it is hard to imagine empire-building in the East without silver. Here is, then, another channel in which silver mattered: it largely made possible the intercontinental trade (both with Asia and America) which had important growth-enhancing effects for the countries which engaged in it more intensively (Palma 2016).

[151] This channel is one of several which illustrates how coin and higher forms of money were complements rather than substitutes.

	China	Ottoman empire	Russia	France	Spain	England	Dutch Republic
1650-99	-	1.7	-	8.0	7.7	4.2	13.6
1700-49	2.26	2.6	6.4	6.7	4.6	8.9	24.1
1750-99	1.32	2.0	8.3	11.4	10.0	12.6	22.8
1800-49	1.23	-	-	-	-	17.2	-
1850-99	1.99	-	-	-	-	19.4	-

Table 7. Size of Leviathan: Per capita government revenue in day's wages for unskilled workers. Source: Brandt et al (2014, p. 69)

Finally, the additional liquidity in circulation contributed to the continued decrease in real interest rates, which, despite having medieval origins (Van Zanden 2009), continued during the early modern period, and indeed was particularly strong in Northwestern Europe (Figure 8). In general, we think about an increase in money supply only being able to generate liquidity effects while inflation does not respond. However, as we have seen here, the response of inflation was mild at best (see also Palma 2015b). This is because it was largely real output instead that increased, and it did so permanently. Notice that through arbitrage, the money market could also affect the full term structure of interest rates, and in particular the capital market.[152] For how long, however, is the relevant question; I argue that for this period at least, the answer is: "for much longer than we are used to thinking".

[152] On the relationship between the price revolution and the cost of capital, see Gould (1964). While Gould puts emphasis on inflation, my own view is that, due to contemporary growth, the full monetary effect was larger than that suggested by looking at inflation alone. See Homer and Sylla (2005) for evidence that during the early modern period nominal interest rates fell over all maturities.

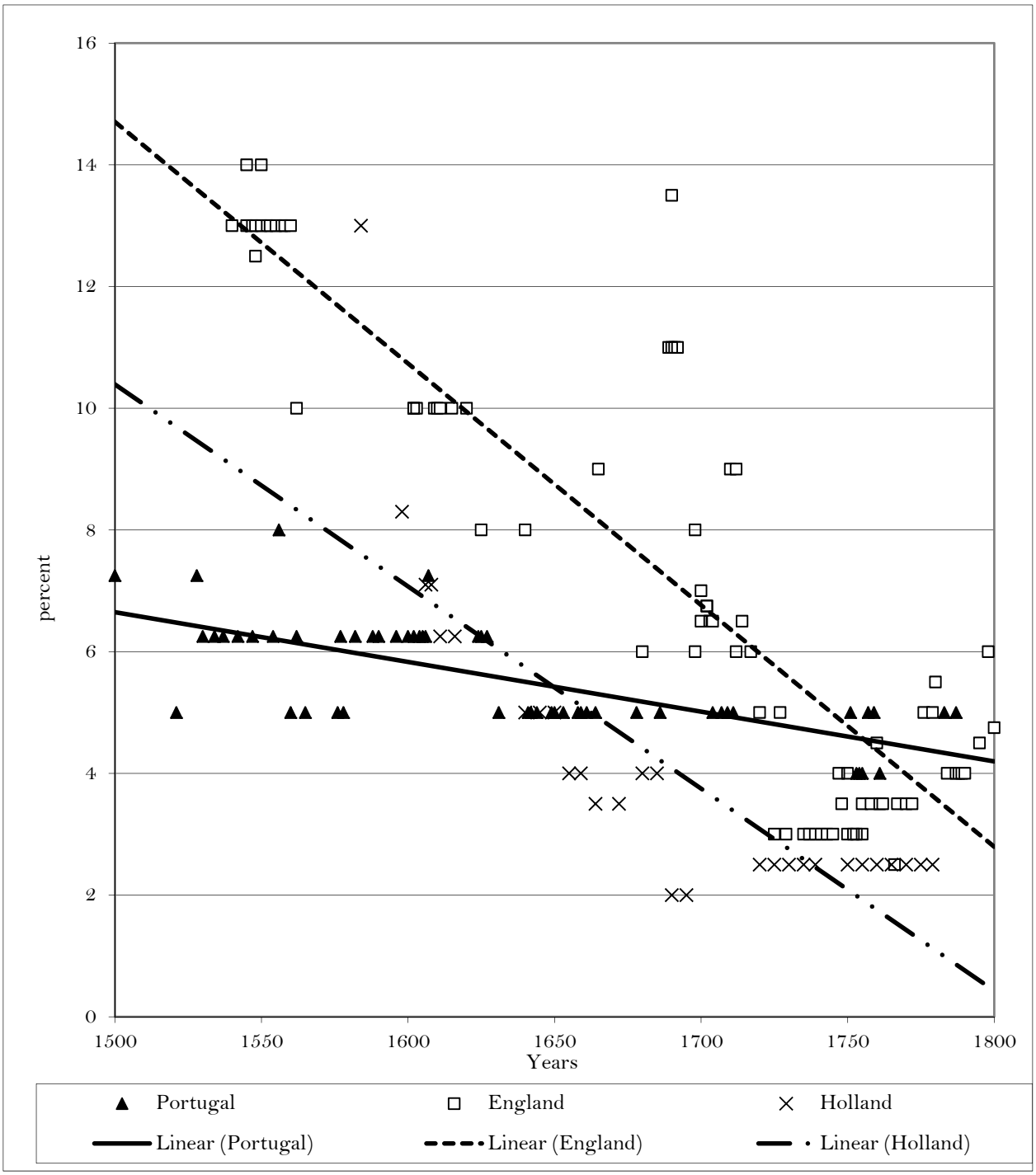

Figure 8. Nominal interest rates in Portugal (new issues of *Juros*), England (new issues of various types of royal debt at corresponding maturities) and Holland (new issues of *Losrenten*) 1500-1800. Source: see Henriques and Palma (2015)

8. Conclusion

American precious metals permitted a dramatic increase in English monetization, which in turn generated Smithian growth, supported state-building, eased the transition to a paper money system (O'Brien and Palma 2015), and facilitated the transition into modern economic growth.[153] From a comparative perspective, one important question is why this did not happen elsewhere, namely in the first-order receiving countries – Spain for the entire early modern period, and Portugal after about 1700. One possibility is that these two countries suffered from the "Dutch disease", or institutional resource curse.[154] (Hamilton 1936, Drelichman 2005a, 2005b).

Even if that was the case, it should not distract us from the possibility that those monetary injections led to a positive – and not only persistent but indeed permanent – long-run effects for other countries. This has not been emphasized in the recent literature, but it did not go unnoticed by some contemporaries:

> "[S]ince the discovery of the mines in America, industry has increased in all the nations of Europe, except in the possessors of those mines; and this may justly be ascribed, amongst other reasons, to the increase of gold and silver … [T]he prices of all things have only risen three, or at most, four times, since the discovery of the West Indies … But will anyone assert, that there is not much more than four times the coin in Europe, that was in the fifteenth century, and the centuries preceding it? … And no other satisfactory reason can be given, why all prices have not risen to a much more exorbitant height, except that which is derived from a change of customs and manners. Besides that more commodities are produced by additional industry, the same commodities come more to market, after men depart from their ancient simplicity of manners." (Hume 1987/1742, p. 33)

[153] For sure, the money-growth causality went both ways – the English economy had the right conditions to grow and this in turn demanded means of exchange (McCloskey and Zecher 1974). My emphasis on the role American precious metals is that at that time they were necessary for monetization to increase, which in turn was necessary (but not sufficient) for economic growth to occur.

[154] In Palma (2015b) I have also documented that liquidity effects were much weaker, or even absent, for first-time receivers, vis-à-vis other European countries for which we have data. It is also useful not to lose the comparative element for other parts of Europe: "[P]eople in central Europe did desire to increase market work and consumption. But elites used the social capital of traditional institutions to oppose new work and consumption practices, especially by women, migrants, and the poor. Although they seldom blocked new practices wholly, they delayed them, limited them socially, and increased their costs" (Ogilvie 2010).

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Appendix to chapter 5

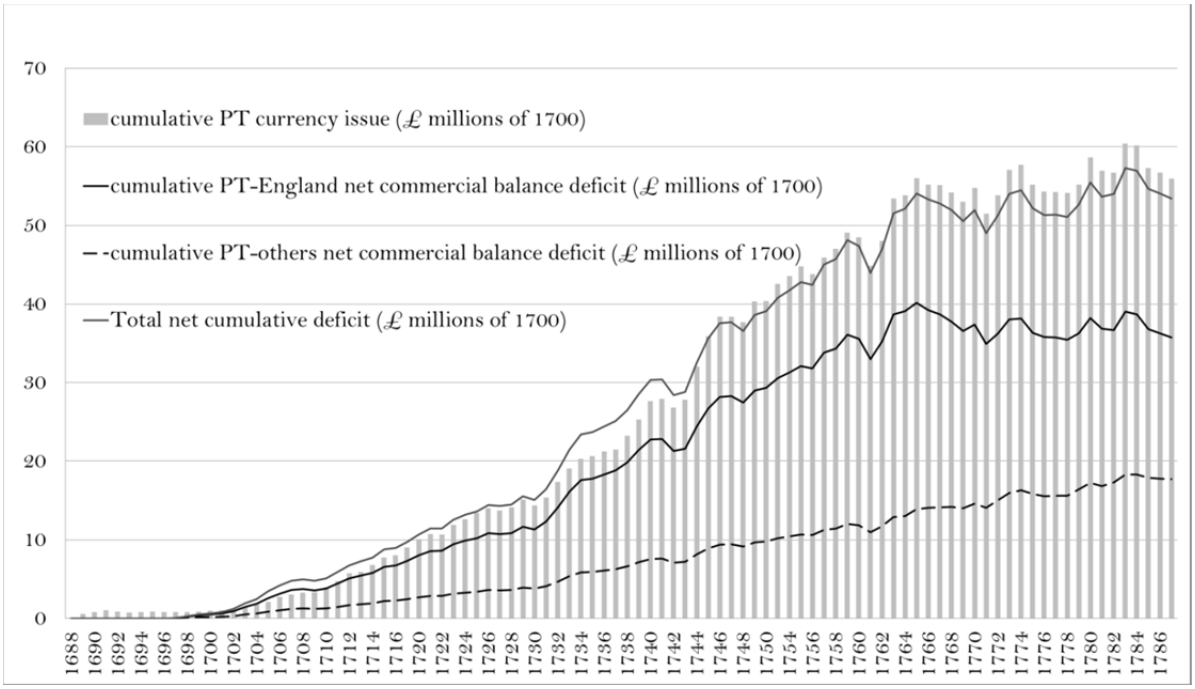

Figure A1. Cumulative values of balance of trade deficit from Portugal to England. The black line gives the total size of the gross real monetary injection into the English economy (not all was minted into currency: see text). Sources: see Figure 3.

Chapter 6. Conclusion

My approach in this thesis has been mostly a "macro-level" analysis, focusing on aggregates such as the money supply, the price level, and GDP. By relying on the longest series of such variables ever assembled, I have been able to conclude that early modern monetary injections caused by the discovery and exploitation of rich mines of precious metals in America had a significant impact in Europe. Hence they matter a great deal for our understanding of the evolution of the early modern European economy. But there is much to be learned through complementary micro and historical studies which can help clarify the precise mechanisms through which money had real, and persistent – indeed, permanent – effects for early modern European economic growth.

The great advantage of the strategy I have pursued in chapter 4 is that the short-to-medium term impact exogenous changes is money supply is likely to be well identified. The trade-off is that I do not wish to push external validity too hard with respect to what monetary policy can or cannot do today, even in the context of developing economies. The main reason today's economies are so different, I think, is not that the size of financial intermediation is much larger than it was for early modern economies, but that for all but the most dysfunctional economies today, the ability of central banks to issue fiat can be taken as given. (That may in itself help us understand one reason why financial intermediation has been able to grow so much.)

While American precious metals provided a series of "one-off" opportunities for the increase of European money supplies, it was the transition to a paper money system (studied in O'Brien and Palma 2015) that allowed economies to keep growing from the nineteenth century onwards, even if initially under a gold or bimetallic standard. It must not be forgotten, however, that the English economy was at that point richer partly as a consequence of the increased monetization.

Today, even economies which have severe credibility problems in central management of the money supply can use the paper money of other economies, as in instances of "dollarization". But taking paper money as a given hides the fundamental role it has played - even during the gold standard period - in allowing for continued economic growth. Indeed, my position in this thesis is not well aligned with either the (new or old) monetarist or the unpleasant monetarist arithmetic or fiscal theory of the price level positions (see Christiano and Fitzgerald

2000 for a review of these debates). Both these viewpoints are missing much of the action at a long-run frequency. Indeed, there is a matter with respect to which "mercantilist" thinking was right: for premodern economies, the overall quantity of money in circulation mattered – this was true of the overall quantity, even in the long-run, and regardless of whether increases were anticipated. Too much focus on fiscally-motivated inflation in modern economies may have blinded us to this. Indeed,

> "Endless books have been written about the dangers of governments printing too much money. But for centuries the opposite problem was just as common: governments often could not mint enough coins … to meet their subject's needs." (Pomeranz and Topik 2013, p. 15)

Despite its importance, the long-term impact of the monetary injections is hard to quantify precisely, and I have not as of yet attempted a growth accounting exercise where I say exactly how much of Northwestern European growth was caused by the monetary injections. Instead, in chapter 3 I have shown that increases in production of precious metals in America lead to temporary increases in growth rates in Europe (and hence to a permanent effect on income levels), and in chapter 5 I have argued that they interacted with features of the English economy to allow for significant levels of growth, by contributing to the decline of transaction costs, and by avoiding a deflationary episode which otherwise would have been inevitable and would have perhaps even killed off growth.

One question left for future work is whether deflation in most of the rich countries of the late nineteenth century, largely caused by a combination of the gold standard with high growth, was prejudicial for growth. Notice this is an open question, because of an identification problem: it may have well be that under the counterfactual of higher monetary growth, those economies would have growth even faster, or that the level of financial intermediation achieved by then would have meant that growth in the base money supply did not matter that much anymore. What can be said for sure, however, is that any conclusion based on using Blanchard-Quah identification assumptions (eg. Bordo, Landon-Lane, and Redish 2010) will necessarily reach tautological conclusions with respect to long-run monetary neutrality.

While new reduced-form empirical results will continue to play a role, as I give more attention to mechanisms my future work will have to be more structural and simulation-based, though always well supported by complementary empirical evidence (see Palma and Silva 2015 for a recent effort along these lines). There are many important open questions for the

future. The most important is perhaps: what was so special about Northwestern Europe? If the "new goods" were as important as Berg (2007) or deVries (2008) argue they were, then why did Portugal, which received them earlier and in greater per capita quantities well into the seventeenth century, not react in the same way as the Northwestern European economies?[155] Taken as a given that the "new goods" mattered for the industrious revolution and for promoting successful import-substitution efforts in the North, the most plausible answer is that they interacted positively with something in Northwestern Europe and/or negatively with something in the South – perhaps "institutions", culture, or human capital. The same question might be asked about China, where much of the precious metals ended up – though here the question seems to me easier to answer in light of early modern China's monetary problems, and the high transaction costs which resulted (Palma 2014).

The long-run neutrality proposition is attractive theoretically. What else other than technology and demographics can really affect the long run? My view is that this conventional wisdom is incomplete, essentially because the evolution of those variables is not orthogonal to the real effects of money.[156] We should not think of money as a mere "veil" with no agency. In the early modern period – and I suspect, today as well – growth over the long run results from a sequence of "short-run" events which are affected by the overall quantity of money in circulation as well as by changes in this quantity (and whether these were anticipated or not is in fact secondary.) In the words of Schumpeter,

> "[T]he trends of our time series are not due to influences distinct from those that create the cyclical fluctuations but simply embody the results of the latter." (Schumpeter 1935).

This thesis has been squarely concerned with events in the past, and the safest interpretation is that the conclusions apply to the past only. Modern economies are different in many ways.

[155] For evidence that Portugal's per capita intercontinental trade was higher than other European countries until the seventeenth century, and remained so during the eighteenth, see Costa, Palma and Reis (2015).
[156] It is not difficult to agree with the view that "Optimal monetary policy maximizes the welfare of a representative agent, given frictions in the economic environment" (Khan et al 2003). But what frictions should be included? While modern DSGE models sometimes include money, their heritage as RBC-type models means they consider the effects of technological change for the business cycle, but the opposite effect is never considered. And yet, for any reasonable discount factor, any policy that is able to affect the rate of growth will surely dominate a different policy simply focused on smoothing short-term fluctuations. Since the typical approach to the determination of optimal monetary policy (as in Khan et al 2003) takes the dichotomy between monetary variables and the long run as a given, it is arguable that by missing growth effects, the most important component of long-term welfare maximization is being left out.

Nevertheless, these results raise doubts over whether for today's economies monetary policy – to the extent that it can control money supply or nominal interest rates – is able to affect not only inflation and the business cycle, as is conventionally believed, but also partly determine the long-run growth process itself.

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