The London School of Economics and Political Science

Infrastructure, market access and trade in developing countries

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To my parents

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 authorisation does not, to the best of my belief, infringe the rights of any third party.

I declare that my thesis consists of 20,967 words.

Statement of conjoint work

I confirm that Chapter 3 was jointly co-authored with Professor Stephane Straub (Toulouse) and Dr Jean-Jacques Dethier (World Bank). I contributed approximately 70% of this work.

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Abstract

International trade is a key driver of development. This thesis contains three chapters concerned with the challenges of, and opportunities for, expanding international trade in developing countries.

The first chapter, "Growth Spillovers and Market Access in Africa", shows that because of increased trade, African countries benefit from the growth of their neighbours. In particular, growth in neighbouring countries increases the size of accessible markets, boosting export demand for local goods. Over the period 1992-2012, this expansion of markets increased domestic growth rates by over 2 percent per year on average. By reducing trade costs, countries can further increase these positive growth spillovers.

The second chapter, "Bad Neighbours as Obstacles to Trade: Evidence from African Civil Wars", considers how the trade of landlocked African countries is affected by neighbouring civil wars. The paper shows that such civil wars increase transport costs and subsequently reduce the international trade of landlocked countries. Calibrating the regression results, I estimate that landlocked trade could have been around 12 percent higher over the period 1975-2005 in the absence of neighbouring civil wars.

The final chapter, "Regulation, Renegotiation and Capital Structure: Theory and Evidence from Latin American Transport Concessions", is joint work with Stephane Straub and Jean-Jacques Dethier. Large transport projects in developing countries are now often delivered through private concessions, and we analyse the financing of such projects. A common argument is that firms use leverage in order to influence regulatory outcomes. Intuitively, firms can extract higher prices by increasing leverage if regulators fear project collapse. We show that under price cap regulation, this mechanism is weakened because prices are less responsive to costs. Consistent with the theory, we find evidence that infrastructure firms in Latin America use less debt when regulated through price cap.

Contents

1 Growth spillovers and market access in Africa

Abstract

How much do countries in Africa benefit from their neighbours' growth, and how can such benefits be maximised? This paper shows that neighbouring growth increases a country's "international market access" – boosting export demand and lowering prices. Using luminosity data to exploit within-country variation, I show that international market access has contributed over 2 percent per year on average to output growth over 1992-2012. By reducing trade costs, countries can increase their international market access, and so increase the spillover of neighbouring growth into domestic growth. Based on the results presented here, we can therefore quantify the expected impact of particular policies on output and growth. I show for example that an expanded West African currency union could increase the aggregate output of the affected countries by around 40 percent.[1]

[1] I am grateful to my supervisor Tim Besley for continued advice and support. I also thank Jane Ansell, Zelda Brutti, Vernon Henderson, Guy Michaels, Adam Storeygard, Silvana Tenreyro and seminar participants at LSE for very helpful feedback.

1.1 Introduction

With African growth averaging over 4 percent a year since the early 1990s, there is increasing hope that much of the continent may have finally achieved 'growth take-off'.[2] The incidence of civil war has declined by most measures, and some post-conflict countries – such as Mozambique and Rwanda – have achieved steady and sustained economic progress.[3] The image of Africa as a 'bad neighbourhood' looks increasingly inaccurate. Indeed, for many countries, the prosperity of their surrounding neighbourhood has increased markedly.

In this paper, I ask to what extent African countries benefit from the growth of their neighbours, and how such benefits can be maximised. I focus on a specific channel: trade. I present a trade model in which domestic regions benefit from their neighbours' growth, as access to foreign markets increases. This boosts export demand and lowers prices, increasing the region's output. To test the predictions of the model, I use luminosity data to create a balanced panel of sub-national regional output over 1992-2012. I calculate each region's 'international market access' (IMA), and investigate to what extent increases in IMA are associated with increases in domestic output.[4]

Following the model, IMA is calculated as a weighted sum of the output in all foreign regions, with weights determined by the cost of trade and the elasticity of trade with respect to (w.r.t.) trade costs. As actual trade costs are unobserved, I first estimate a cross-country gravity model to provide reasonable values for the trade cost parameters. As in much of

[2]Throughout the paper, I use "Africa" to refer to Sub-Saharan Africa. The average growth of real GDP in Africa was 4.1% over 1992-2012, based on World Bank figures.

[3]Based on the UCDP/PRIO Armed Conflict Database for example, there were 7 Sub-Saharan African countries involved in "intense" conflicts - those resulting in at least 1,000 deaths per year - in 1990. By 2012, this dropped to just two (Somalia and Sudan). See also http://www.economist.com/blogs/baobab/2013/11/civil-wars

[4]Throughout, I use "region" to refer to the sub-national Admin level 1 regions. Summary statistics are provided on the regions in Table 2. There are on average 13 regions per country, with a minimum of 3 in Swaziland and a maximum of 40 in Burkina Faso.

the gravity literature, I find that trade declines significantly with distance and international borders, but increases when there is a common language, currency union or free trade agreement (see Head and Mayer 2015 for a meta-analysis). Feeding the gravity estimates into my market access term, I find that increases in IMA are associated with significant increases in domestic output, with an elasticity in the range 0.7 to 0.9.

To put this into context, changes in IMA alone imply average regional output growth of over 2 percent per year over the period. This is a substantial figure, and is at odds with previous work that has found 'growth spillovers' to be small in Africa (World Bank 2009, Roberts and Deichmann 2011). Instead, the evidence here shows that African countries have benefitted significantly from the growth of their neighbours. This is supported by an emerging economic geography literature, demonstrating the importance of access to markets for an area's prosperity (Hanson 2005). Perhaps the most closely related paper to mine is that of Redding and Venables (2004), who show that 'foreign market access' is an important determinant of international inequality. As in this paper, the authors estimate a gravity model to derive estimates of market access, which they then regress on income per capita in a cross-section of countries.[5] Their results suggest that foreign market access alone can explain around 35 percent of the cross-country variation in GDP per capita.

The novel contribution of this paper is to exploit within-country variation. This is done through panel regressions of output (luminosity) on FMA at the region level, including both region and country-year fixed effects. The region fixed effects eliminate institutional and geographic factors, such as the disease environment, that could drive a spurious correlation between output and market access. The country-year fixed effects absorb political and macroeconomic shocks, which have often been so large in Africa as to

[5] The empirical approach of Redding & Venables (2004) is somewhat different, calculating market access based on the fixed effect coefficients from the initial gravity regression. The theoretical approach is also different, leading them to use GDP per capita as the dependent variable. Mayer (2009) extends their methodology to a panel of countries.

dwarf other sources of output variation.[6] These idiosyncratic shocks make it very difficult to identify and estimate growth spillovers at the country-level. Instead, the strategy here is to ask whether those regions *within a country* that have cheaper access to foreign African markets respond more to output changes in those markets than regions within the same country that have more costly access.

The analysis is particularly relevant to Africa, a continent of historically low growth and still home to the majority of the world's very poorest countries. With a third of the population being landlocked, and manufacturing centres continuing to agglomerate in East Asia, penetrating global markets may be unrealistic in the near-term (Radelet & Sachs 1998, Collier 2008). As a result, *African* economic integration is now a top priority of donors and policy makers. The African Development Bank for example has a dedicated Regional Integration & Trade Division, and in November 2014 approved a new Regional Integration Policy and Strategy for 2014-2023.[7] For the landlocked in particular, Collier and O'Connell (2007) argue that "the most obvious growth strategy for such a country is to service the markets of its neighbours" (p.38).

The results here show that reducing trade costs enables a country to pursue such a growth strategy. In particular, reducing trade costs increases IMA and so increases the spillover of neighbouring growth into domestic growth. Based on the gravity results, I can quantify the extent to which specific policies will increase IMA, and so ultimately estimate the impact of such policies on output and growth. To demonstrate this, I consider a specific policy currently under review: an extension of the West African

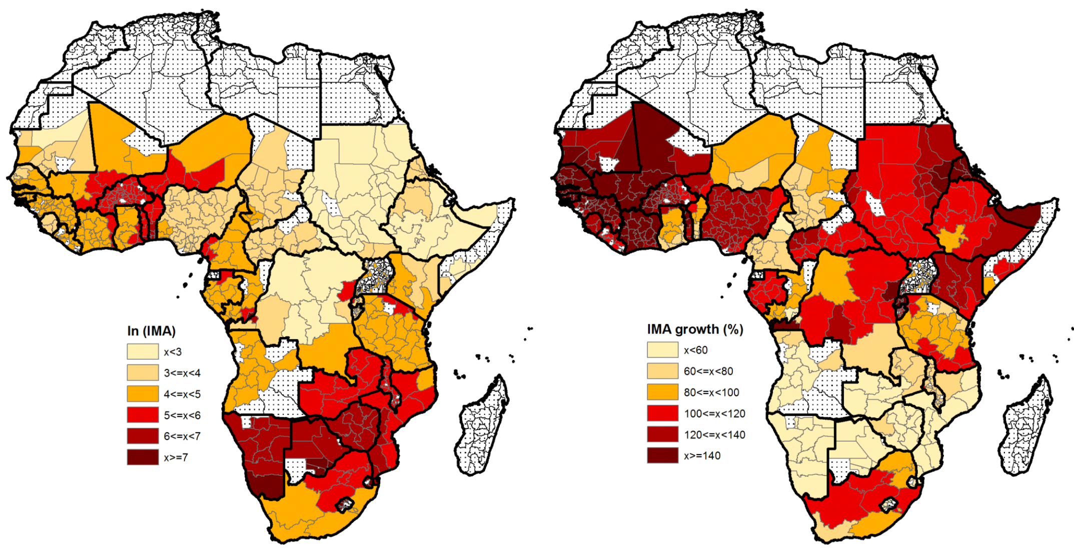
[6] Over the period studied for example, the coefficient of variation (the standard deviation divided by the mean) of real GDP was 0.27 in Sub-Saharan Africa, 0.18 globally and 0.13 in the OECD (based on World Bank WDI figures). Further, 7 Sub-Saharan African countries witnessed a swing in real GDP of over 25 percent from one year to the next at some point during the period.

[7] The President of the Bank recently listed his top priorities for the continent as (i) integration, (ii) institutions and (iii) infrastructure ("Financing Africa's Future: Infrastructure, Investment and Opportunity", speech at LSE on 23rd September 2014).

currency union to include six additional countries. I estimate that such a policy could increase aggregate West African output by around 40 percent, with substantially larger gains for non-members of the existing currency union. Quantifying the (trade-related) gains from such policies can assist policy makers in evaluating expected gains against potential losses (for the currency union case see Santos Silva and Tenreyro 2010 for a discussion).

Figure 1.1 demonstrates the variation in IMA, and its growth, over the period. The regions bordering South Africa and Nigeria benefit from the highest levels of IMA (left-hand map), although growth has been strongest in the far western regions (right-hand map). As a calibration exercise, I document the importance of South Africa and Nigeria – together accounting for half of African GDP – to their immediate neighbours. Due to its impact on IMA, I find that each additional percentage point of growth in South Africa is reflected in at least half a percentage point of growth in each of its neighbours. Nigeria's influence is smaller, due to its higher trade costs, although even here each neighbour would benefit from at least a quarter of a percentage point of additional growth. By lowering trade costs, neighbouring countries can increase their access to these large markets and increase such growth spillovers.

Figure 1.1: International Market Access (IMA), Level (1992) and Growth (1992-2012)



The paper proceeds as follows. Section 1.2 presents the trade model that derives domestic output as a function of market access. Building on this, Section 1.3 presents the empirical framework which proceeds in two stages. First, a gravity model is used to estimate the IMA term. Second, regional output is regressed on this market access term, generating my main results of interest. Section 1.4 discusses the data, in particular the luminosity data and construction of regional output. Section 1.5 presents the results and Section 1.6 considers the growth and policy implications. Section 1.7 concludes.

1.2 Theory

To guide the empirical analysis, I present a trade model based on Eaton and Kortum (2002) and Donaldson and Hornbeck (2013), that derives the output of every region i as a log-linear function of its "market access". Market access is a weighted sum of the output in all other regions, where each region j is weighted by the level of competition for that region, the cost of trading with region i and the elasticity of trade w.r.t. trade costs.

There are many regions, indexed by i when the origin of an export and j when the destination. Regions produce a continuum of goods (indexed by s) using a Cobb-Douglas technology with labour and capital as inputs. The marginal cost of producing a good of variety s in region i is given by:

$$MC_i(s) = \frac{w_i^{\alpha} r^{1-\alpha}}{z_i(s)} \tag{1}$$

where w_i is the wage rate, r is the capital rental rate and $z_i(s)$ is the efficiency with which region i can produce variety s.[8] Following Eaton and Kortum (2002), efficiency $z_i(s)$ is stochastic, and drawn from an extreme value distribution given by $F_i(z) = e^{-T_i z^{-\theta}}$ with $T_i > 0$ and $\theta > 1$. The parameter T_i increases the mean of the distribution, meaning that T_i can be interpreted as region i's level of technology (as average efficiency is higher). A *lower* θ increases the variability of the distribution, such that i will be more efficient in the production of some goods than others. As noted by Eaton and Kortum, T_i is therefore a source of absolute advantage for region i, and θ is a source of comparative advantage.

If labour is mobile, utility levels must be constant across regions in equilibrium:

$$\overline{U} = \frac{w_i}{P_i} \tag{2}$$

where $\overline{U}$ is the constant level of utility across regions and P_i is the consumer price index in region i.[9] Crucially, trading goods across regions is costly. Modelling trade costs using the standard iceberg approach, the price of a good produced in region i and sold in region j is given by $p_{ij}(s) = \tau_{ij} p_{ii}(s)$ where $\tau_{ij} \geq 1$ is the trade cost and $p_{ii}(s)$ is the price of the good sold locally. Region i supplies j with good s if it is the lowest cost supplier,

[8] Capital is assumed to be perfectly mobile, implying a common rental rate r.

[9] This assumption is discussed in detail below.

and so in general, j sources all its goods from the regions from which it can achieve the lowest price.

The expression for the overall price index P_i in region i is solved explicitly in Eaton and Kortum (2002), and is given by:

$$P_i^{-\theta} = a_1 \sum_j T_j w_j^{-\alpha\theta} \tau_{ij}^{-\theta} \tag{3}$$

where a_1 is a constant. Following Donaldson and Hornbeck (2013), this expression can be termed "consumer market access" (CMA), as it captures the access of consumers in i to goods produced elsewhere, with prices in i increasing in the trade cost τ_{ij}. A further expression derived explicitly in Eaton and Kortum (2002) is a gravity equation giving the value of exports (X_{ij}) from i to j:

$$X_{ij} = a_2 T_i w_i^{-\alpha\theta} \tau_{ij}^{-\theta} P_j^{\theta} Y_j \tag{4}$$

where a_2 is a constant and Y_j is the income of region j. Intuitively, i supplies j with the goods for which it is the lowest cost supplier. The likelihood of being this low cost supplier increases in i's level of technology T_i and the overall price level P_j (where a higher price level corresponds to less competition for market j). Higher income Y_j boosts the overall level of demand coming from j. The opposing force is the trade cost τ_{ij}, which reduces i's competitiveness in region j. It can also be seen in (4) that θ captures the elasticity of trade w.r.t. trade costs. This is consistent with the earlier interpretation of θ as the source of comparative advantage: as comparative advantage weakens (higher θ), the importance of geographic barriers increases.[10]

As an accounting identity, the output Y_i of region i is the sum of its

[10] Technically, a higher θ reduces the likelihood of outliers in the efficiency distribution $F_i(z)$ that enable i to produce good s cheaply enough to overcome geographic obstacles captured by τ_{ij}.

exports to all regions j,

$$Y_i = \sum_j X_{ij} \tag{5}$$

where $\sum_j X_{ij}$ includes X_{ii} (i.e. local consumption). Substituting for X_{ij} from the gravity equation (4), and replacing P_j and w_i from (3) and (2) respectively, we can derive an expression for the output of region i as a weighted product of the output of all regions j:

$$Y_i = a_2 T_i \overline{U}^{-\alpha\theta} P_i^{-\alpha\theta} \sum_j \tau_{ij}^{-\theta} CMA_j^{-1} Y_j \tag{6}$$

where $\sum_j \tau_{ij}^{-\theta} CMA_j^{-1} Y_j$ is the "firm market access" (FMA) of region i. This expression shows that the output of region i is increasing in its access to the markets of all regions j: other things equal, output is higher in regions with cheap access ($\tau_{ij}^{-\theta}$) to large markets (Y_j) that have limited sources of cheap supply from elsewhere (CMA_j^{-1}). To see this explicitly, we can take logs of equation (6) to arrive at:

$$\ln(Y_i) = a_3 + \ln(T_i) + \alpha \ln(CMA_i) + \ln(FMA_i) \tag{7}$$

where a_3 is just a constant given by $\ln(a_2) - \alpha\theta \ln(\overline{U})$ and I use the result that $P_i^{-\theta} \equiv CMA_i$.

Donaldson and Hornbeck (2013) show that as $FMA_i = \sum_j \tau_{ij}^{-\theta} CMA_j^{-1} Y_j$ and $CMA_j = \sum_i \tau_{ij}^{-\theta} FMA_i^{-1} Y_i$, any solution to these two equations must satisfy $FMA_i = CMA_i$. That is, the two measures of market access are in fact the same. Substituting this into equation (7), we get a model for the output of region i as a simple log-linear function of its market access (MA_i):

$$\ln(Y_i) = a_3 + \ln(T_i) + (1 + \alpha) \ln(MA_i) \tag{8}$$

where $MA_i = \sum_j \frac{\tau_{ij}^{-\theta} Y_j}{MA_j}$.

Equation (8) states that controlling for a region's level of technology T_i, output increases log-linearly in market access. Market access is the sum of output in all regions j, each Y_j being weighted by (i) the cost of trading with i, and (ii) j's own market access MA_j. This second term captures the degree of competition for market j: if j itself has strong market access, then a smaller share of its imports are sourced from i and hence increases in import demand (coming from increases in Y_j) are muted. Given a panel of observations on regional output, equation (8) therefore provides a testable prediction for the empirical analysis.

1.2.1 Discussion: Mobile labour

The assumption of mobile labour may seem strong in the context of an international trade model. It is used here only to simplify the derivations however; Alder (2015) works with the same underlying model, except that he assumes immobile labour, and notes that "both versions of the model lead to a log-linear relationship between income and market access. The difference is the predicted elasticity, but this is estimated from the data" (p.22). In this paper I also estimate the predicted elasticity from the data, and use the model for its qualitative prediction of a log-linear relationship between output and market access. Hence the assumption of mobile labour does not affect the empirical approach that follows.

Unlike Alder (2015) and Donaldson and Hornbeck (2013) however, both of which work in the context of intra-country trade, this paper is primarily interested in inter-country trade. In the model and the empirical work, intra-country dynamics are ultimately overlooked. (The model itself does not distinguish between domestic and foreign regions, although when it is adapted for the empirical framework, domestic regions are omitted in the calculation of market access.) The paper considers the relative response of domestic regions to changes in their IMA; if there is a shock to a particular region's IMA however, there may be subsequent domestic dynamics, such as migration to/from the affected region, that are not being captured.

To capture these dynamics completely, a mixed regional/international model would be required. Although that exercise is not undertaken here, it is useful to think through the implications qualitatively. Suppose a particular region receives a boost to its IMA due to growth in a nearby region across the border. This not only increases export demand, it also reduces the domestic region's price index; an increase in foreign output Y_j works in the same direction as a fall in trade costs.[11] This fall in the price level temporarily increases the real wage, leading to in-migration. (It is assumed that workers move wherever the real wage is highest, hence the need for a constant real wage in equilibrium.) As the region's workforce increases however, the nominal wage falls due to diminishing returns to labour. Migration therefore restores the domestic equilibrium, but the region that received the initial (positive) IMA shock received an additional output boost due to internal migration.[12] If I was to model internal dynamics explicitly, it is therefore likely that it would reinforce the predictions of the model above. In particular, even if I were to assume immobile labour between domestic and foreign regions, but mobile labour between domestic regions, the model should still predict a positive relationship between output and IMA.

1.3 Empirical Framework

The model has a strong intuitive appeal: higher market access attracts both firms - seeking cheap access to sources of demand - and consumers - seeking cheap access to goods. To implement the model empirically however, there are a number of challenges. Firstly, the market access term from equation (8) includes domestic output, as it is a weighted sum of the output in *all* regions j. This creates a clear endogeneity problem, and would re-

[11] From equation (3), the price index (P_i) is inversely proportional to consumer market access. A fall in trade costs and an increase in foreign output both increase consumer market access, and hence reduce the price index

[12] See Overman et al. (2010) for a more detailed discussion of the spatial implications of an output shock in a particular region.

quire estimates of internal trade costs $\tau_{ii}^{-\theta}$ in order to be implemented. A partial solution to the problem, pursued by Redding and Venables (2004) and Mayer (2009), is to estimate internal trade costs and run the model with both "domestic" and "foreign" market access terms. An alternative approach, also pursued by Mayer (2009) and by Donaldson and Hornbeck (2013), is to drop the inclusion of domestic output from the market access term.[13] As I am interested in *international* spillovers, this is the approach I follow here. Indeed, to concentrate on international spillovers, I include only foreign regions in the calculation of MA_i. I term this "international market access" and denote it by IMA_i.[14]

Secondly, equation (8) remains an implicit function of Y_i even when domestic regions are excluded from the calculation of market access. This is due to the MA_j term in the denominator, which accounts for the degree of competition for the importing region j. Following Donaldson and Hornbeck (2013), I therefore approximate the theoretically correct market access term with a simpler expression given by $MA_i = \sum_j \tau_{ij}^{-\theta} Y_j$. As noted by the authors, the two market access terms are highly correlated in practice but the approximation does not require each market access term to be explicitly derived from the model.[15] As I work with international market access, my

[13]Redding and Venables (2004) outline a similar trade model to the one presented here but with immobile labour. Their model derives the wage rate in country i (w_i) as a log-linear function of the country's market access. They use income per capita as a proxy for w_i and consider various approximations to calculate internal trade costs τ_{ii} for the (domestic) market access term. Mayer (2009) extends the Redding and Venables approach to a panel setting. He presents empirical results both with approximations for τ_{ii}, and with domestic output dropped from the market access term. Both approaches show strongly significant effects of market access on domestic income per capita.

[14]This is consistent with my approach of using cross-country gravity regressions to estimate the trade cost function (below), and I show in robustness checks that my results also hold when domestic regions are included in the market access term.

[15]That is, each MA_i term could be derived from $MA_i = \sum_j \frac{\tau_{ij}^{-\theta} Y_j}{MA_j}$ as this is a system of J unknowns in J equations (taking the $\tau_{ij}^{-\theta}$ terms as given, and where J denotes the number of regions). Donaldson and Hornbeck (2013) find that the results from the approximation adopted in this paper are almost identical to those implemented using the full structural model (columns 1 and 2 in their Table 2).

variable of interest is therefore given by $IMA_i = \sum_{j \in F} \frac{\tau_{ij}^{-\theta} Y_j}{MA_j} \approx \sum_{j \in F} \tau_{ij}^{-\theta} Y_j$, where F denotes the set of foreign regions.

Allowing for randomness in the data and adding a time dimension, equation (8) therefore suggests the following specification:

$$\ln(Y_{it}) = \varphi_0 + \varphi_1 \ln(IMA_{it}) + \delta_i + \delta_{ct} + \eta_{it} \tag{9}$$

where φ_0 is a constant, Y_{it} is the output of region i in year t, $IMA_{it} = \sum_{j \in F} \tau_{ij}^{-\theta} Y_{jt}$, δ_i and δ_{ct} are region and country-year fixed effects respectively (to control for the productivity T_i of region i) and η_{it} is an error term.

Without information on trade costs τ_{ij} and the elasticity of trade w.r.t. trade costs (θ), equation (9) cannot be estimated directly. As an initial step in the empirical work, and departing from Donaldson and Hornbeck (2013), I therefore apply a gravity model to estimate these values.[16] To generate my main results of interest, I then regress regional output Y_{it} on the estimated market access term $\widehat{IMA}_{it}$.

1.3.1 Gravity: constructing $\widehat{IMA}_{it}$

As noted by Anderson and van Wincoop (2004), the trade cost τ_{ij} is typically assumed to be multiplicatively separable in its factors, such that:

$$\tau_{ij} = \prod_{m=1}^{M} (z_{ij}^m)^{\gamma_m} \tag{10}$$

where $z_{ij} = \begin{pmatrix} z_{ij}^1 & \ldots & z_{ij}^m & \ldots & z_{ij}^M \end{pmatrix}$ is the vector of trade cost factors between i and j (e.g. distance, shared language) and γ_m is the elasticity of τ_{ij} w.r.t. factor m. Substituting this expression into the international

[16] For the trade cost τ_{ij} Donaldson and Hornbeck use historical transport cost estimates from the United States. They then apply a value of 3.8 to the trade elasticity θ. I do not have inter-regional transport cost estimates for Sub-Saharan Africa, and also wish to include additional trade costs such as language and border costs.

market access term, we have:

$$IMA_i = \sum_{j \in F} \left[\prod_{m=1}^{M} (z_{ij}^m)^{-\gamma_m \theta} \right] Y_j \tag{11}$$

and from the gravity equation (4) we can get consistent estimates of the $\gamma_m \theta$ terms by running the following regression:[17]

$$\begin{aligned} \ln(X_{ij}) &= \phi_0 - \theta \ln(\tau_{ij}) + \delta_i + \delta_j + \epsilon_{ij} \\ &= \phi_0 - \sum_m \gamma_m \theta \ln(z_{ij}^m) + \delta_i + \delta_j + \epsilon_{ij} \end{aligned} \tag{12}$$

where ϕ_0 is a constant and ϵ_{ij} is the error term. That is, if we observed trade flows between i and j, we could consistently estimate international market access. Although I do not have regional trade data, I can estimate (12) at the country level. A single year of trade data would suffice for consistency, however I include the full set of trade observations over 1992-2012 for greater efficiency. As trade cost factors (z_{ij}) I include distance, a contiguity dummy, common language dummy, regional trade agreement (RTA) and currency union (CU) dummies (Mayer 2009, Head and Mayer 2015). The estimated coefficients allow me to construct international market access as:

$$\widehat{IMA}_{it} = \sum_{j \in F} \left[\prod_{m=1}^{M} (z_{ij}^m)^{-\widehat{\gamma_m \theta}} \right] Y_{jt} \tag{13}$$

where the $\widehat{\gamma_m \theta}$ terms are the estimated coefficients from (12).

Taking a simple example to clarify this procedure, suppose that the only relevant trade cost is the distance between i and j. In this case, we have $\tau_{ij} = dist_{ij}^{\gamma}$ from equation (10) and $\ln(X_{ij}) = \phi_0 - \theta\gamma \ln(dist_{ij}) + \delta_i + \delta_j + \epsilon_{ij}$ from the gravity equation (12). Suppose that from the gravity equation we estimate $-\widehat{\theta\gamma} = -1.1$, the mean estimate from Head and Mayer

[17] The exporter and importer fixed effects δ_i and δ_j control for the $\ln(T_i)$, $\alpha\theta \ln(\overline{U}P_i)$, $\theta \ln(P_j)$ and $\ln(Y_j)$ terms.

(2015). Then from equation (13) the market access term would be given by $\widehat{IMA}_{it} = \sum_{j \in F} dist_{ij}^{-1.1} Y_{jt}$. This example highlights that the market access term used here is a more general form of the well-known Harris (1954) "market potential" term given by $MP_{it} = \sum_j \frac{Y_{jt}}{dist_{ij}}$.

1.3.2 Regional output and market access

Having constructed my market access term, I can turn to my primary question of interest: how do changes in international market access affect domestic (regional) output? To do so, I run the following regression based on (9):

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(\widehat{IMA}_{it}) + \delta_i + \delta_{ct} + \varepsilon_{it} \tag{14}$$

where $\widehat{IMA}_{it}$ is from (13). In alternate specifications I will also include a region-specific linear time trend, to allow for different growth paths of the regions.

1.3.3 Discussion: Empirical Strategy

To clarify the empirical strategy, equation (14) is the main regression of interest, and is estimated across a panel of sub-national regions over 1992-2012. In order to estimate (14) however, we require estimates of the elasticity of trade w.r.t. trade costs (θ) to create the $\widehat{IMA}_{it}$ term. In the absence of region-level trade data, θ is therefore estimated by a gravity regression at the country level - given by equation (12).

$\widehat{IMA}_{it}$ is the sum of output in all foreign regions, with each region weighted by the cost of trade with the domestic region. The cost of trade is assumed to be fixed, and so changes in $\widehat{IMA}_{it}$ are driven exclusively by changes in foreign output. Critically however, an output change in a foreign region has more impact on the IMA of domestic regions with which it has lower trade costs (because IMA is a weighted sum of foreign output). The identification strategy is therefore to test whether those regions within a country that have cheaper access to foreign African markets respond more to output changes in those markets than regions within the same country that have more costly access.

To implement this strategy, equation (14) includes both region and country-year fixed effects. The region fixed effects control for time-invariant factors that could induce a spurious correlation between market access and regional output in the cross-section. In Africa, prominent among such factors are the disease environment and physical geography. The country-year fixed effects control for political and macroeconomic shocks. Such shocks have been frequent and severe in Africa in the recent past: during the period studied for example, 7 African countries witnessed a swing in real GDP of over 25 percent from the previous year. In the presence of these dramatic macro shocks, it is difficult to identify international growth correlations or spillovers when working with country-level data. Zimbabwe is a notable example: between 2002 and 2008, it suffered an overall decline in real GDP of 31 percent, whilst each of its neighbours posted positive growth rates each year. This does not mean that Zimbabwe did not benefit from its neighbours' growth, rather that the domestic macro policies were so disastrous as to completely offset such benefits. Analysing regions within countries therefore allows for a cleaner identification of growth spillovers across countries by controlling for these political and macro shocks.

A limitation of the approach however is that African GDP (and therefore market access) has been growing over time, and so other factors that are also growing over time could drive a correlation between market access and output. The country-year fixed effects control for those factors that affect all regions within the country equally, but there may be some omitted factors for which this is not the case. It is possible for example that lights have been gradually spreading from major cities to hinterland regions that have lower market access. Relative to the major cities, hinterland regions would then have both a larger increase in their lights output and a larger increase in their market access (as, being closer to a border, their market access is more heavily influenced by other hinterland regions just across the border). Although it is not possible to control for such issues completely, it is noted that lights did not grow significantly faster on average in hinterland regions than capital regions over the period considered here.[18] Henderson et al. (2012) find a slightly higher increase in lights growth in hinterland areas of Africa than large cities, although they note that such a difference is extremely small. My preferred set of results also include region-specific time trends, so that I am testing to what extent a region's lights output deviates from trend in response to changes in market access.

1.4 Data

1.4.1 Bilateral trade flows

I construct a panel of bilateral imports using data from the UN Comtrade Database.[19] The dependent variable is the value of imports of country i from country j in year t. The independent variables - the distance between countries i and j (denoted $dist_{ij}$, measured in km), contiguity (denoted $border$), language, CU and RTA dummies - are all taken from the gravity database of Head et al. (2010), available at http://www.cepii.fr/.

1.4.2 Lights data

I exploit luminosity data to create a balanced panel of sub-national regional output over 1992-2012. Described in detail in Henderson et al. (2012), night time light readings have been recorded by the U.S. Defense Meteorological Satellite Program (DMSP) since the 1960s, with a public digital archive beginning in 1992. Before being publicly released, the data are processed to remove most natural sources of light, including moonlight, sunlight, auroral

[18] I denote a "capital region" here as the largest region in each country based on lights output in 2000. Lights output grew in capital regions by 5 percent per year on average. In all other regions, they grew by 4 percent per year on average.

[19] I work with import reports as these are known to be more reliable than export reports (World Trade Organization 2012).

activity and forest fires. The remaining lights are largely artificial, reflecting the use of energy for both consumption and investment purposes. Lights data therefore enable economic activity to be tracked at a local level, where official statistics are either unreliable or non-existent.

Light intensity is provided at the pixel-level, with each 30-arcsecond pixel given an integer light reading between 0 and 63.[20] Constraining light readings to fall within this range reflects the available sensor technology, and in the African case many pixel-year observations omit no recorded light (an issue known as "bottom coding"). There is likely in practice to be some limited activity in such areas, not generating enough light to be captured by the sensors. To check that this is not affecting the main results, I show in the Appendix that the results are robust to restricting the sample to areas that have recorded light readings in every year, as well as dropping 1992 from the sample.[21] Following standard practice (Henderson et al. 2012, Storeygard 2014), I calculate a simple average of light readings for years in which there is more than one satellite. Doing so provides a pixel-year panel of light readings for the entire continent.

As the pixels are so small, I need to aggregate them into economically-meaningful units. I aggregate to administrative level 1 regional units (herein "Admin 1 regions"), with GIS boundaries provided by Natural Earth. Figure A1 in the Appendix provides a map of the regional boundaries. The use of Admin 1 regions provides adequate within-country variation, whilst ensuring that the model remains plausible and tractable.

Prior to aggregating, I clean the raw lights data by making use of the "urban extents" dataset provided by the Global Rural Urban Mapping Project (GRUMP).[22] The GRUMP dataset classifies the globe into areas of "urban"

[20] A 30-arcsecond pixel has an area of approx. 0.86 square km at the equator.

[21] There is an abnormally large proportion of observations with a light reading of zero in 1992. Thirty percent of regions have a light reading of zero in 1992, dropping to 20 percent in 1993 and falling gradually to 7 percent by 2012.

[22] Center for International Earth Science Information Network - CIESIN - Columbia University, International Food Policy Research Institute - IFPRI, The World Bank, and Centro Internacional de Agricultura Tropical - CIAT (2011), Global

and "rural", also at a spatial resolution of 30-arcseconds. The classification of an urban area is based on population estimates; contiguous urban areas should consist of at least 5,000 persons.[23] In aggregating to Admin 1 regions, I sum only across lights in urban areas. Doing so enables me to include only areas where people actually live and economic activity takes place, excluding extremely small settlements and random noise in the data (such as lights from gas flares and lights that spill across borders).[24] A further advantage is that I can always classify contiguous urban cells, essentially the same city, as belonging to the same region.[25]

Lights and economic output

As discussed in Pinkovsky (2013), a number of empirical papers have now used luminosity data as a proxy for output. The first paper to investigate this relationship systematically was Henderson et al. (2012), who demonstrated a robust correlation between luminosity readings and official GDP estimates in a panel of countries. The authors show that this relationship holds both with and without a country time-trend, and also when estimated in "long differences". Their baseline results suggest an elasticity of real GDP w.r.t. lights of around 0.3.

Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H4GH9FVG accessed 28/10/2014. See also Balk et al (2006).

[23] CIESIN also provide a "settlement points" dataset, which provides coordinates of known settlements of over 1,000 persons. Each urban extent should therefore correspond to at least one settlement point (due to the higher populaton threshold). I drop any contiguous urban extent pixels that do not have a settlement point associated with them. This also ensures that any foreign urban areas that spill across the border are not (incorrectly) included in a domestic region.

[24] Indeed, my approach shows a substantial and significant correlation between the regional lights data and official GDP estimates on the South African sub-sample below. Simply aggregating across lights within regions does not (even nearly) pass this "sense check".

[25] I take the centroid of each contiguous block and assign the region according to the location of the centroid. The advantage of this approach is that a "city", an economic unit, is not split into two if its lights cross an Admin boundary.

The principal advantage of using lights is that they enable estimates of economic activity in local areas for which official figures are unavailable. In Africa, Michalopoulos and Papaioannou (2013) use luminosity data as a proxy for income per capita across ethnic territories. To justify this, they first show that across different "enumeration areas" (typically villages or small towns), lights output is highly correlated with a wealth index created using Demographic and Health Surveys data. More recently, Storeygard (2014) uses lights output as a measure of city-level output across a number of African countries. He tests that light output approximates official GDP at the sub-national level by running regressions of GDP on luminosity for Chinese prefectures (over 1992-2005) and South African magisterial districts (over 1996-2001). The relationship is highly significant in both cases, with elasticities in the range 0.2 to 0.3.

Following these previous papers, I also test to what extent the luminosity data used here correlates with official GDP figures. Figure A2 provides a visual illustration, plotting the light output of Rwanda - a country that has grown steadily since the late-1990s, and Zimbabwe - a country where output has declined slightly over the period.[26] The contrast is clear from the lights output, with growth in Rwanda notable in all areas of the country. To check the correlation between GDP and lights explicitly, I sum the regional lights figures above within each country, and run the following regression (as in Henderson et al. 2012):

$$\ln(z_{ct}) = \zeta \ln(y_{ct}) + \delta_c + \delta_t + w_c t + \nu_{ct} \tag{15}$$

where z_{ct} is the real GDP of country c in year t (from the World Bank *World Development Indicators*), y_{ct} is the light reading of country c in year t, δ_c and δ_t are country and year fixed effects respectively, $w_c t$ is a linear country time-trend, and ν_{ct} is an error term. The regression is run

[26] Output in Rwanda declined by around 50% as a result of the genocide in 1994, and this is also visible in the lights output (see Henderson et al 2012).

at country-level due to the paucity of African GDP estimates at the sub-national level (which is the primary motivation for using lights). However, Statistics South Africa have been producing annual GDP estimates for Admin 1 regions since 1995, and so I am able to run the regression at the regional level on this small sub-sample.

Results are provided in Table 1.1. Columns (1) and (2) are run at the country-level over 1992-2012, and columns (3) and (4) are run for the South African regions over 1995-2012. Columns (2) and (4) include the linear time trend $w_c t$, and thus measure correlations in terms of deviations from trend. All columns indicate a significant correlation between official GDP and lights, with an elasticity of around 0.5 when the time trend is excluded. The level of significance is somewhat weaker when using the South African regional data, although with such a limited sample the results are encouraging.

Table 1.1: The elasticity of GDP w.r.t. lights

			SAF (regions)	
	(1)	(2)	(3)	(4)
$\ln(y_{ct})$	0.506***	0.329***	0.468*	0.145*
	(0.059)	(0.070)	(0.229)	(0.073)
Time trend	No	Yes	No	Yes
Obs.	819	819	162	162
Countries/Regions	39	39	9	9
R-Squared	0.83	0.94	0.58	0.76

Robust standard errors (clustered by country) in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The results in Table 1.1 support those presented in Storeygard (2014), and suggest that luminosity data can be used as a proxy for economic output at the local level in Africa. This justifies the use of lights as a proxy for regional output in the estimation of equation (14). Ultimately however, I would like to use the results of (14) to make inferences regarding the response of domestic output to changes in foreign output. That is, I am ultimately interested in the response of GDP in region i (denoted z_i) to changes in GDP in region j (denoted z_j), rather than the response of *lights* in i (denoted y_i) to lights in j (denoted y_j).

It can be shown that the two elasticities are the same. Denote the "GDP elasticity" by $\varepsilon_1 \equiv \frac{dz_i}{dz_j}\frac{z_j}{z_i}$ and the "lights elasticity" by $\varepsilon_2 \equiv \frac{dy_i}{dy_j}\frac{y_j}{y_i}$. We have also estimated the elasticity of GDP to lights in Table 1.1, denoted by $\varepsilon_3 \equiv \frac{dz_i}{dy_i}\frac{y_i}{z_i}$. From the chain rule, $\frac{dz_i}{dz_j} = \frac{dz_i}{dy_i}\frac{dy_i}{dy_j}\frac{dy_j}{dz_j}$ and so, multiplying by $\frac{z_j}{z_i}$,

$$\begin{aligned}\varepsilon_1 &= \frac{dz_i}{dz_j}\frac{z_j}{z_i} = \underbrace{\left(\frac{dz_i}{dy_i}\frac{y_i}{z_i}\right)}_{\varepsilon_3}\underbrace{\left(\frac{dy_i}{dy_j}\frac{y_j}{y_i}\right)}_{\varepsilon_2}\underbrace{\left(\frac{dy_j}{dz_j}\frac{z_j}{y_j}\right)}_{\varepsilon_3^{-1}} \\ &= \varepsilon_2.\end{aligned}$$

I use this result in section 1.6 to analyse the implications of changes in IMA for changes in domestic output.

Issues and limitations

As discussed in Michalopoulos and Papaioannou (2013), luminosity data suffers from saturation and "blooming". Saturation occurs due to the sensor technology, which only registers light output up to a certain level. This results in top-coding, such that all lights bright enough to reach the upper bound are coded with a value of 63. In reality however, such a level of luminosity generally occurs within wealthy urban centres. (As discussed above, there is also an issue of bottom-coding.) In Africa, top-coding is extremely rare; Michalopoulos and Papaioannou (2013) note that in their

African sample less than 0.0001 percent of pixels are top-coded.

A more pertinent issue with the lights data is "blooming" or "overglow". Blooming occurs when a source of light is bright enough that some of its glare is captured in the readings of neighbouring pixels. This is a geocoding error, that could generate a manual correlation between lights growth in neighbouring areas. Reassuringly however, Michalopoulos and Papaioannou (2013) find that because luminosity is generally low in Africa, blooming is not a major concern in this sample. More concretely, Pinkovsky (2013) finds that the effect of blooming on measured light output is insignificant beyond a 10 km buffer. For my baseline results, I therefore buffer all country borders by 10 km to account for blooming.[27]

1.4.3 Market access

To construct the $\widehat{IMA}_{it}$ term, I calculate the distance from each region i to each foreign region j. Distances are calculated using the great circle distance from the largest city in each region, based on lights output in 2000.[28] In calculating $\widehat{IMA}_{it}$, I restrict the set of foreign regions j to lie within the same UNECA "sub-region" as i - these consist of West Africa, Central Africa, Eastern Africa and Southern Africa.[29] The motivation for this is that (i) the vast majority of international trade takes place within the same sub-region, and (ii) when considering trade flows across sub-regions,

[27]Because borders are buffered by 10 km on each side, there is a minimum of 20 km between light readings either side of country borders. In practice, buffering country borders makes very little difference to the results. In the Appendix I show that my results are almost identical if no buffer is used, and I have also experimented with other buffer distances, again with very little effect.

[28]I take the centroid of the largest city (contiguous block of urban cells) based on light output in 2000. To accurately calculate distance, I then project these points to the African Sinusoidal (projected) coordinate system. Geodesic distances, that take into account the curvature of the globe, are then calculated using the Generate Near Table tool. All steps are done in ArcMap 10.2.1.

[29]See http://www.uneca.org/pages/subregional-offices. The Admin 1 regions of any immediate neighbour that is not in the same UNECA "sub-region" are also included in the calculation of $\widehat{IMA}_{it}$.

the relative locations of regions within the same country becomes trivial relative to the overall distance between domestic and foreign regions. Running equation (14) including two $\widehat{IMA}_{it}$ terms, one calculated from foreign regions within the same UNECA sub-region as i, and one calculated from foreign regions outside the UNECA sub-region, shows that only the first is significant. In addition, the main results of interest (presented in Table 1.4) remain strongly significant if $\widehat{IMA}_{it}$ is calculated using *all* foreign regions.

For the baseline results in Table 1.4, I exclude all observations from countries that are in conflict according to the UCDP/PRIO Armed Conflict Database.[30] Conflicts tend to be concentrated in particular regions within a country, and so some regions suffer large falls in output regardless of changes in their market access. It therefore seems sensible to exclude all regions of a country for years in which the country is in conflict. In Appendix A.2 I show that the results are robust to including all observations, including conflict years.

Summary statistics are shown in Table 1.2. As the lights data are available over 1992-2012, the summary statistics and all subsequent analysis covers this period. All mainland Sub-Saharan African countries are included except for Equatorial Guinea, which is dropped (as in Henderson et al. 2012) because almost all of the light output is from gas flares. As a tiny country, it also has only one mainland region.

[30] Only "intense" conflict years are excluded, which are those that result in a minimum of 1,000 battle-related deaths.

Table 1.2: Summary Statistics

	Mean	Median	s.d.	Min	Max
Countries	40				
Regions	530				
Observations	11,130				
Regions per country	13.25	10.50	10.66	3	40
Region growth (lights)	0.05	0.04	0.07	-1.00	0.24
Country growth (lights)	0.04	0.04	0.02	0.00	0.10
Country growth (GDP)	0.04	0.04	0.02	-0.01	0.09
Partner regions	140.17	129	55.72	46	218
Distance (km)	1,248.64	1,164.91	659.00	68.10	2,927.13

Growth rates are compound annual averages, and must be multiplied by 100 for a percentage figure.

1.5 Results

1.5.1 Gravity model

Table 1.3 presents the results of running equation (12), a structural gravity model, for the Sub-Saharan African sample over 1992-2012. The set of control variables follows Mayer (2009), and consists of distance (km), contiguity (denoted *border*), common language, RTA membership and CU membership. This is a standard set of controls in the gravity literature (see e.g. Head and Mayer 2015), although in alternate columns I exclude the potentially endogenous RTA and CU variables. Columns (1) and (2) include importer and exporter fixed effects and columns (3) to (6) include a full-set of importer-year and exporter-year fixed effects. This is now best practice in the literature (Anderson and van Wincoop 2004), as it most closely follows the theoretical gravity model (equation (4)). Finally, columns (5) to (6) are estimated using a Poisson pseudo-maximum-likelihood (PPML) estimator

(Santos Silva and Tenreyro 2006) instead of ordinary least squares (OLS).

The variables enter significantly throughout, with each taking the expected sign. Perhaps the most striking results are the magnitudes of the distance and RTA variables. Although estimates of RTA effects vary widely, Head and Mayer's (2015) meta-analysis finds a median estimate of just 0.28. The large coefficients in Table 1.3 are particularly surprising given the common view that African RTAs are less effective than average (see e.g. Roberts and Deichmann 2011). A satisfactory explanation for this finding would require further research, although I note here that the main results of interest for this paper - the impact of market access on output - are not sensitive to the particular coefficients in Table 1.3.[31]

As with the RTA dummy, the coefficient on distance in the OLS regressions is slightly larger than typical estimates.[32] This is less surprising than the RTA effect however, as the poor state of African infrastructure (Limao and Venables 2001) and logistics services (Arvis et al. 2012) both suggest that transport costs rise rapidly with distance. In practice, it is likely that African trade is even more geographically concentrated than the estimates here suggest. Survey evidence shows that informal cross-border trade occurs on a substantial scale across the continent, with volumes in some areas comparable to official trade (Lesser & Moisé-Leeman 2009, Afrika and Ajumbo 2012). Much of this trade is in food, agriculture and low quality manufactures, meaning that much of it is concentrated around border regions (Lesser and Moisé-Leeman 2009, Golub (forthcoming)). Hence overall trade likely declines more rapidly in distance than official trade: the estimates here may in fact *underestimate* the true effect of distance on trade in Africa.

[31] In Table 1.4 I show that the effect of market access on output is robust to the different gravity specifications in Table 1.3, and in robustness checks I show that this further extends to using the median gravity estimates from Head and Mayer (2015).

[32] Head and Mayer (2015) find a median coefficient on distance of -1.1 from structural gravity regressions with a standard deviation of 0.4.

Table 1.3: Gravity results (1992-2012)

	OLS (CFE)		OLS (CYFE)		PPML (CYFE)	
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(dist)$	-1.992***	-1.489***	-2.001***	-1.438***	-1.683***	-1.191***
	(0.103)	(0.126)	(0.108)	(0.138)	(0.180)	(0.192)
$border$	0.908***	0.958***	0.909***	0.968***	0.287	0.477**
	(0.201)	(0.193)	(0.209)	(0.200)	(0.234)	(0.228)
$lang.$	0.854***	0.566***	0.864***	0.580***	0.680***	0.509*
	(0.118)	(0.141)	(0.123)	(0.146)	(0.207)	(0.289)
RTA		0.993***		1.132***		0.816***
		(0.160)		(0.190)		(0.236)
CU		0.845***		0.827**		0.666*
		(0.318)		(0.331)		(0.404)
Obs.	13,710	13,710	13,710	13,710	13,711	13,711
R-squared	0.56	0.57	0.60	0.61	0.91	0.92

Robust standard errors (clustered by country) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

1.5.2 Regional output and market access

Having generated estimates for the trade cost parameters, I can now consider the effect of IMA on regional output. To do so I substitute the coefficients from Table 1.3 into my expression for market access, $\widehat{IMA}_{it}$ from equation (13), and regress regional output on this estimated market access term - equation (14).

The results from equation (14) are presented in Table 1.4. I consider three alternative estimates of market access: $\widehat{IMA}_1$ is calculated using column (2) from Table 1.3, $\widehat{IMA}_2$ uses column (4) from Table 1.3 and $\widehat{IMA}_3$ uses column (6) from Table 1.3. That is, the different market access terms are calculated from (13) using estimates from the three different specifications in Table 1.3: OLS (CFE), OLS (CYFE) and Poisson (CYFE).

In all columns of Table 1.4, IMA has a positive and highly significant effect on regional output. I consider the results in columns (4) and (6) to be the best estimates, and will work with these estimates in the calibration below. In both cases the parameters of the $\widehat{IMA}$ term are estimated using a full set of CYFE, and any long-term regional growth paths are controlled for with the time trend. These estimates put the elasticity of regional output w.r.t. IMA in the range 0.7 to 0.9.

These estimates suggest that regional output responds strongly to changes in IMA. Previous work, estimated at country-level, has produced comparable albeit slightly smaller estimates. Mayer (2009) regresses income per capita on a measure of "foreign market potential" over 1960-2003, finding an elasticity of 0.88 from a random effects model and 0.57 when including country fixed effects.[33] In earlier work, Redding and Venables (2004) apply the same approach as Mayer on a single cross-section of countries in 1996, and find an elasticity of 0.48 on "foreign market access".

[33] Mayer's (2009) "foreign market potential" term is, from his model, very similar to that used here. His empirical approach is quite different however. Rather than including a measure of market potential directly, he demonstrates that it can be captured by the country fixed effect coefficients from an initial gravity regression. That approach is not applicable here because I am calculating market access for sub-national units.

Table 1.4: Regional output and market access (1992-2012)

	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\widehat{IMA}_1)$	0.940***	0.639**				
	(0.341)	(0.258)				
$\ln(\widehat{IMA}_2)$			0.980***	0.665**		
			(0.364)	(0.273)		
$\ln(\widehat{IMA}_3)$					1.355**	0.892**
					(0.527)	(0.391)
Time trend	No	Yes	No	Yes	No	Yes
Obs.	8,956	8,956	8,956	8,956	8,956	8,956
Regions	508	508	508	508	508	508
R-Squared	0.58	0.75	0.58	0.75	0.58	0.75

Robust standard errors (clustered by region) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

1.5.3 Identification and robustness

The results presented in Table 1.4 show that there is a robust correlation between changes in a region's IMA and changes in its own output. Based on the model presented in Section 1.2, I argue that this is driven by trade: as IMA increases, demand for local goods increases which drives increases in local production. In this sub-section I aim to establish both that trade is indeed the driving mechanism, and that this is a causal relationship. To do so, I present a number of falsification and robustness checks in Table 1.5.[34]

Firstly, if the effect of IMA is working through trade, we would expect to find a smaller effect between countries that do not have trading relationships with each other.[35] To test this, I gather data on diplomatic

[34] Each column in Table 1.5 includes the region-specific linear time trend.

[35] The effect would not necessarily be zero, as informal cross-border trade takes place on a substantial scale across the continent (Lesser and Moisé-Leeman 2009). This is likely the case even amongst countries with poor official relations.

relations from the Correlates of War's *Diplomatic Exchange Database*, and classify countries based on whether they had diplomatic relations with each other over the period (1992-2012). For each region, I then calculate two $\widehat{IMA}$ terms: one across countries with which it had diplomatic relations ($\widehat{IMA}\_D$), and another across regions in countries with which it did not ($\widehat{IMA}\_ND$). Reassuringly, in column (1) we see that the $\widehat{IMA}$ term is significant only amongst countries with diplomatic relations.

Secondly, there may be localised shocks, such as higher commodity prices or cross-border investment projects, that simultaneously benefit neighbouring regions. This would generate a positive correlation between output and market access, but not due to the trade channel posited here. To reduce such concerns, column (2) excludes all regions within 100 km of the domestic region when calculating $\widehat{IMA}$.[36] Column (3) drops the closest foreign region, so that any localised shock would have to cover a number of regions to drive the correlation between IMA and domestic output. In both cases, the $\widehat{IMA}$ term remains highly significant.

Column (4) controls for neighbouring conflicts, which can spill across national borders through refugee flows, direct violence or destruction of infrastructure. This acts like a specific localised shock, generating a simultaneous (negative) shock to both IMA and domestic output. To control for this, I create a dummy variable (denoted $conflict\_neigh$) that equals 1 if a region's nearest neighbour is in conflict in year t.[37] In column (4) this variable enters negatively but insignificantly, whereas the coefficient on $\widehat{IMA}$ remains largely unchanged and highly significant.

Finally, columns (5) and (6) address potential reverse causality from domestic output to IMA. This occurs because an increase in domestic output increases every foreign region's IMA, increasing their output, which in turn increases the domestic region's IMA. In practice this concern is reduced

[36] That is 100 km between the "capital" of each region.

[37] Neighbouring conflicts are defined in the same way as domestic conflicts (Section 1.4), as a year in which there are 1,000 or more battle-related deaths according to the UCDP/PRIO Armed Conflicts Database.

because every region's IMA is calculated based on the output of a large number of regions (140 on average, see Table 1.2). Still, it may be the case that some regions are large enough to individually affect output in the wider area in a meaningful way. To account for this possibility, column (5) drops all observations from the economically largest region of each country. Column (6) drops all observations from the largest country in each UNECA sub-region. Hence even when equation (14) is run only with economically small regions, the $\widehat{IMA}$ term remains positive and significant.[38]

[38] The exception is the $\ln(\widehat{IMA_3})$ term in column (5) which becomes insignificant. The coefficient remains economically substantial however, and is significant if the regional time-trend is not included.

Table 1.5: Identification and robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: OLS ($\widehat{IMA}_2$)						
$\ln(\widehat{IMA}_2)$		0.661*	0.856**	0.640**	0.459*	0.607**
		(0.388)	(0.411)	(0.268)	(0.276)	(0.277)
$\ln(\widehat{IMA\_D})$	0.574**					
	(0.271)					
$\ln(\widehat{IMA\_ND})$	0.515					
	(0.405)					
Conflict_neigh				-0.058		
				(0.036)		
Obs.	8,164	8,956	8,956	8,956	8,172	7,633
Regions	470	508	508	508	468	445
R-squared	0.74	0.74	0.75	0.75	0.75	0.75
Panel B: PPML ($\widehat{IMA}_3$)						
$\ln(\widehat{IMA}_3)$		1.021**	1.285**	0.870**	0.599	0.827**
		(0.517)	(0.556)	(0.385)	(0.408)	(0.397)
$\ln(\widehat{IMA\_D})$	0.809**					
	(0.390)					
$\ln(\widehat{IMA\_ND})$	0.542					
	(0.500)					
Conflict_neigh				-0.056		
				(0.036)		
Obs.	8,164	8,956	8,956	8,956	8,172	7,633
Regions	470	508	508	508	468	445
R-squared	0.74	0.74	0.75	0.75	0.75	0.75

The results in Table 1.5 support the claim that there is a causal link between $\widehat{IMA}$ and domestic output, and that this relationship is driven by trade. In Appendix A.2 I provide a number of more general robustness checks. I remove the 10 km buffers around country borders; include domestic conflict years; include domestic regions in the calculation of $\widehat{IMA}$; include North African regions in the calculation of $\widehat{IMA}$; recalculate $\widehat{IMA}$ using the gravity estimates of Head and Mayer (2015); restrict the sample to regions that have a positive light reading in every year; drop all observations from 1992; and drop countries with a population below 5 million in 2000. In all cases the $\widehat{IMA}$ term remains positive and significant.

1.6 Growth and Policy Implications

1.6.1 Implied growth due to IMA

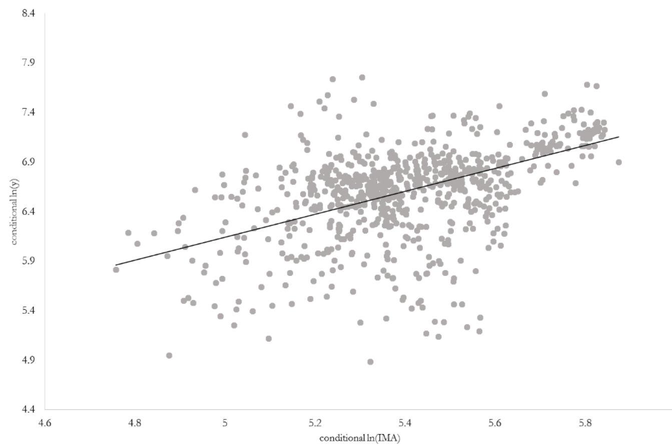
Reflecting a general improvement in Africa's macroeconomic performance, the average region's IMA grew by almost 4 percent a year during 1992-2012. As the results in Table 1.4 show that output increases log-linearly with IMA, we can calculate the implied increase in regional output resulting from this increase in IMA. To do so, note that the log-linear relationship implies that $\Delta \ln(Y_{it}) = \widehat{\beta}\Delta \ln(\widehat{IMA}_{it})$, which in turn implies that

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} = \left(\frac{\widehat{IMA}_{it}}{\widehat{IMA}_{it-1}}\right)^{\widehat{\beta}} - 1 \tag{16}$$

where $\frac{Y_{it}-Y_{it-1}}{Y_{it-1}}$ is the growth of Y_i between $t-1$ and t. Based on my preferred estimates of $\widehat{\beta}$ from Table 1.4, from columns (4) and (6), I can calculate the implied change in regional output over 1992-2012 as a direct result of changes to $\widehat{IMA}_{it}$ using equation (16).

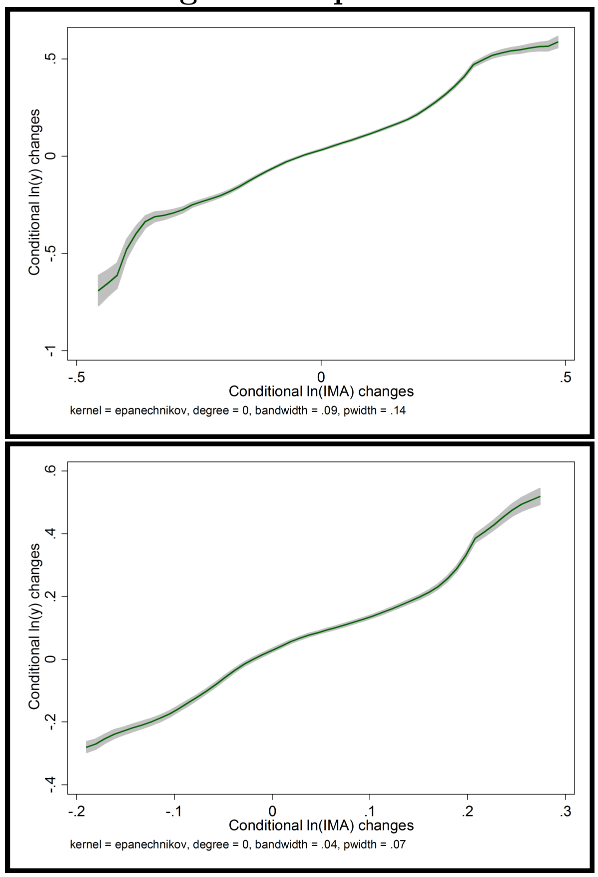
A similar exercise to this is undertaken by Donaldson and Hornbeck (2013), who use their reduced form market access results to calculate the implied effect of US railways on historical land values. To justify the approach, the authors first demonstrate that the relationship between land values (in my case output) and market access is indeed log-linear. I follow this approach here. First, in Figure 1.2, I plot the fitted values of $\ln(Y_{it})$ and $\ln(\widehat{IMA}_{it})$, having first regressed both variables on the set of region and country-year fixed effects. Although there is still a reasonable amount of variation, the conditional relationship between the two variables does appear to be log-linear.

Figure 1.2: Output and market access



In Figure 1.3, I provide evidence that the relationship between changes in output and market access is log-linear. Following Donaldson and Hornbeck (2013), I plot a kernel-weighted local polynomial of changes in $\ln(Y_{it})$ and $\ln(\widehat{IMA}_{it})$, again using the fitted values after regressing both variables on region and country-year fixed effects. The first chart presents results for the full sample, and the second excludes outliers by restricting changes in market access to within 2 standard deviations of the mean. There appears to be an approximately linear relationship between changes in log output and log market access, particularly in the lower chart that excludes outliers. As noted in Donaldson and Hornbeck (2013), the log-linear relationship is also a prediction of the model, which strengthens the case for using this functional form for the calculations that follow.

Figure 1.3: Changes in output and market access



As equation (16) is based on reduced form regressions of output on market access, an additional concern is whether the market access term is truly exogenous. Section 1.5.3 undertakes some robustness tests for this, but it is noted again here that two potential sources of endogeneity are localised shocks and reverse causality. In general we would expect both sources of endogeneity to result in an upward bias, meaning that the calculations here might overstate the true impact of IMA on growth over the period. I therefore present the growth implications using both the baseline estimates of $\widehat{\beta}$ and the lowest estimate from the robustness tests in Table 1.5 - estimated using economically small regions only, to account for reverse causality.

The results of equation (16) are summarised in Table 1.6, which provides simple means and standard deviations across regions (using weighted means produces very similar results). Using the baseline results, from Table 1.4, changes in $\widehat{IMA}$ alone imply growth in regional output of around 62 to 87 percent over the period 1992-2012. This equates to an average annual growth rate in the range 2.3 to 3.0 percent. The lower robustness result, in the final column, implies average annual growth of 1.6 percent. These estimates are substantial, and challenge the view that spillover effects are small in Africa (World Bank 2009). In fact, based on the evidence here, developments in neighbouring countries have sizeable effects on the domestic economy.

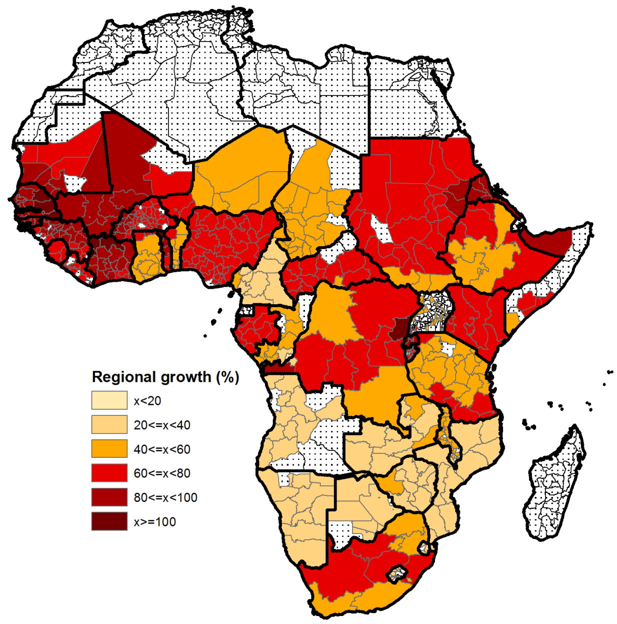
Table 1.6: Implied regional growth due to $\widehat{IMA}$

	(1)	(2)	(3)
	OLS	$PPML$	Robust.
	$\widehat{\beta} = 0.665$	$\widehat{\beta} = 0.892$	$\widehat{\beta} = 0.459$
Total growth, 1992-2012 (%)	61.85	86.60	39.20
	(19.66)	(26.36)	(11.73)
Annual average growth (%)	2.30	2.99	1.58
	(0.69)	(0.84)	(0.47)

Entries are simple means across regions, standard deviation in parentheses.

The geographic variation in growth due to $\widehat{IMA}$ is shown in Figure 1.4 (using the estimates from column 1 of Table 1.6). The largest gains are in West Africa, where in a number of regions growth in $\widehat{IMA}$ alone implies a doubling of domestic output over the period. In the south, the regions bordering South Africa enjoy the highest *levels* of IMA, but have been adversely affected by comparatively weak South African growth. This is particularly true for Botswana, southern Namibia and southern Mozambique, highlighting the importance of South Africa for the wider region's prosperity (Arora and Vamvakidis 2005).

Figure 1.4: Implied regional growth (%)



1.6.2 Case studies: South Africa and Nigeria

In this sub-section I quantify the importance of South Africa to the wider Southern region, as well as Nigeria's importance to West Africa. The two countries dominate the Sub-Saharan economy, together accounting for over half of total output and almost a quarter of intra-African imports in 2012.[39] Here I demonstrate how their fortunes affect their immediate neighbours, by calculating the change in each of their neighbours' growth rates resulting from a 1 percentage point annual increase in South African and Nigerian growth.[40]

The results are presented in Table 1.7. The "previous" column shows the annual average growth rate in each country based on equation (16), as in Table 1.6 (using column (1), $\widehat{\beta} = 0.665$), and the "new" column repeats the calculation but with higher Y_{jt} figures for the South African and Nigerian

[39] Using GDP figures from the World Bank and import figures from Comtrade.

[40] I increase the annual growth of each South African and Nigerian region by 1% point.

regions in $\widehat{IMA}_{it}$. For South Africa the largest gains accrue, as expected, to Lesotho and Swaziland, where growth in each country expands by more than 0.6 percentage points per year. Mozambique gains the least of all the neighbours, as South Africa is less important to the market access of its northern regions. Even here though, each addtional percentage point of growth in South Africa's regions contributes an additional 0.5 percentage points of growth in Mozambique.

The impact of Nigerian growth is lower than that of South Africa owing both to its smaller economy and its higher trade costs with its neighbours.[41] Its economic impact is still considerable however, with a 1 percentage point increase in growth reflected in at least a quarter of a percentage point of growth amongst each of its immediate neighbours.

[41] South Africa is a member of an RTA with all of its neighbours, and shares a currency with Lesotho, Namibia Swaziland; Nigeria shares a currency with none of its neighbours and is in an RTA with only Benin and Niger. In addition, South Africa shares a common language with all of its neighbours except Mozambique, whereas Nigeria shares a common language only with Cameroon.

Table 1.7: **Effect of higher South African & Nigerian growth**

Annual average growth rates	Previous (%)	New (%)	Difference
South African effect			
Botswana	1.11	1.71	0.60
Lesotho	1.07	1.73	0.65
Mozambique	1.23	1.73	0.50
Namibia	1.20	1.81	0.61
Swaziland	1.14	1.78	0.64
Zimbabwe	1.46	1.97	0.51
Nigerian effect			
Benin	1.78	2.17	0.40
Cameroon	1.64	1.98	0.34
Chad	1.89	2.13	0.25
Niger	2.52	2.81	0.29

Based on a 1% point annual increase in growth in each South African and Nigerian region.

1.6.3 Policy evaluation: West African currency union

It is argued above that Nigeria's high trade costs reduce the extent to which its growth benefits its neighbours. More generally, any policy that lowers trade costs increases IMA and thus increases both growth spillovers and domestic output. Based on the gravity results, we can quantify the extent to which specific policies will increase IMA, and then based on the results in Table 1.4, we can estimate the impact of this policy on output.

In this sub-section I calibrate the impact of a specific policy with implications for both Nigeria and the surrounding neighbourhood. Specifically, six West African countries - Gambia, Ghana, Guinea, Liberia, Nigeria and Sierra Leone - are proposing to enter into a CU, sharing a new currency called the eco.[42] Ultimately, this CU will expand to incorporate the existing

[42] See http://www.economist.com/news/finance-and-economics/21591246-continent-

West African Economic and Monetary Union (WAEMU). As the primary motivation for a CU is to boost trade, in this section I calibrate the extent to which this proposed CU would increase market access, and in turn increase output. I ask the following: how much higher would predicted output be in 2012 if the CU was in place?

The implied output change for each country is provided in Table 1.8. As the output change is very sensitive to how much a CU boosts trade, I consider a range of estimates from the literature. That is, in each column I re-estimate $\widehat{IMA}$ (in both the actual and counterfactual worlds), replacing the CU coefficient from Table 1.3 with previous estimates from the literature. Column (1) uses my estimate from Table 1.3 (column 4), column (2) uses the estimate of Tsangarides et al. (2008) as this is also based on African trade flows, and column (3) uses the median estimate from Head and Mayer's (2015) gravity meta-analysis. Columns (4) to (6) are based on papers that have explicitly addressed the potential endogeneity of CUs: Barro and Tenreyro (2007), estimated using instrumental variables; Rose (2001), estimated with pair fixed effects; and Rose (2001) estimated using a matching technique.

My baseline estimate in column (1) is that the proposed CU would boost aggregate West African output by almost 40 percent, based on the predicted increase in trade. The biggest winners are the countries that are not members of the current CU, the WAEMU, as their trade costs with the entire WAEMU block are lowered. Based on the CU effect estimated by Barro and Tenreyro (2007), the output of such countries would more than double. Such dramatic output gains are driven by their estimate that a CU increases trade by over 500 percent. At the other extreme, the estimates in column (6), based on Rose's matching technique, imply that such countries would gain an output boost of only around 15 percent. As the precise impact of a CU on trade is still debated, quantifying the output gains from

mulls-merging-currencies-ever-closer

such policies remains possible only within wide bounds.

Table 1.8: Output change from CU expansion

	(1) OLS	(2) Tsangarides	(3) H & M	(4) B & T	(5) Rose	(6) Rose
All	38.4	19.7	45.6	85.2	34.3	8.5
Benin	41.7	21.4	49.4	89.8	37.3	9.3
Burkina Faso	16.7	9.6	19.0	28.4	15.3	4.5
Cote d'Ivoire	34.0	18.0	39.8	67.6	30.6	8.0
Gambia, The	72.8	32.9	91.3	252.1	63.2	13.4
Ghana	73.3	33.1	91.8	253.4	63.5	13.5
Guinea-Bissau	13.3	7.8	15.1	22.2	12.3	3.7
Guinea	73.1	33.0	91.7	253.0	63.4	13.4
Liberia	73.2	33.0	91.7	253.2	63.5	13.4
Mali	9.2	5.4	10.4	14.9	8.5	2.6
Niger	39.9	20.6	47.1	84.1	35.7	9.0
Nigeria	59.6	26.6	74.9	210.5	51.6	10.8
Senegal	23.1	12.4	26.9	44.6	20.9	5.5
Sierra Leone	73.0	33.0	91.5	252.6	63.3	13.4
Togo	29.7	16.1	34.5	56.4	26.9	7.2
CU coefficient	0.85	0.43	0.98	1.90	0.74	0.19
Sample	Africa	Africa	Global	Global	Global	Global

1.7 Conclusion

This paper considers how African countries are affected by the growth of their neighbours, and how they can increase the spillover of neighbouring growth into domestic growth. I present a trade model that derives domestic output as a function of the output in all other regions, with each region weighted by the cost of trade. That is, a region's output is a function of its "market access". Higher growth elsewhere increases market access, increasing the demand for local goods. Lower trade costs work in the same direction. Thus, lowering trade costs further increases the gains that an area receives from higher growth amongst its neighbours.

To concentrate on international spillovers, I include only foreign regions in the calculation of market access for the empirical work. I am able to conduct the empirical work at the sub-national level by exploiting luminosity data to generate a panel of regional output over 1992-2012. This advances both previous work on spillovers in Africa (Collier and O'Connell 2007, Roberts and Deichmann 2011) and the related market access literature (Redding and Venables 2004, Mayer 2009), which work with country-level data. My empirical work shows that international market access is an important determinant of the growth of domestic regions: increases in international market access are reflected in significant regional growth, with an elasticity between 0.7 and 0.9.

I noted in the introduction that African economic integration is now a top priority of policy makers. In large part, this stems from the difficulty that most countries face in penetrating global markets. Agglomeration forces have clustered manufacturing activity in East Asia, generating concerns that many African countries have "missed the boat" of globalisation (see World Bank 2002, Collier 2008). For the landlocked countries, higher freight and insurance costs multiply this challenge (Limao and Venables 2001, Faye et al. 2004). The World Bank (2009) argues that "for small countries far from world markets but close to a large developing country [such as South Africa or Nigeria], their best prospects often lie in growth in the dominant economy" (p.272). In this paper, I show that by reducing trade costs and increasing integration, such prospects are substantially improved.

2 Bad neighbours as obstacles to trade: Evidence from African civil wars

Abstract

I analyse a cost unique to landlocked countries: access to the sea requires passage through neighbouring countries. What happens to transport costs and trade when these neighbours are in conflict? Based on data for landlocked African countries over 1975-2005, I show a sizeable effect on both transport costs and international trade flows. My results imply an elasticity of trade with respect to transport costs in the range -3 to -6. For the group of landlocked countries, I find that trade could have been around 12 percent higher in the absence of such shocks. Even then however, per capita trade would still have been half that of the coastal countries.[43]

[43] I am grateful to my supervisor Tim Besley for continued advice and support. I also thank Jane Ansell, Jean-Francois Arvis, Uwe Deichmann, Olivier Hartmann, Guy Michaels, Gael Raballand, Marcia Schafgans, Silvana Tenreyro and Benedict Wall for their time and input. Finally I thank seminar participants at LSE, Oxford, the Annual FIW International Economics Conference and the Annual CSAE Conference for many useful suggestions.

2.1 Introduction

The plight of landlocked countries is one of the most striking – and enduring – features of the developing world. As demonstrated in Table 2.1, per capita income and trade figures are just half that of coastal countries. In Africa, where the majority of the world's landlocked population lives, these figures drop to just a third. The success of landlocked countries in the developed world is equally notable however. Particularly in western Europe, landlocked countries have prospered. Seemingly there is a substantial cost to being landlocked in some regions, but not in others.

Landlocked countries face a unique development obstacle: they must transit neighbouring countries to access seaborne trade. In Africa, such transit is characterised by limited infrastructure (Limao and Venables 2001), inefficient services (Arvis et al. 2010), frequent road blocks (USAID 2010) and security concerns (Faye et al. 2004). The gulf between landlocked and coastal trade volumes remains vast, and overseas exports are overwhelmingly concentrated in primary commodities. Collier (2008) argues that being *landlocked with bad neighbours* is a development trap.

Table 2.1: Landlocked GDP and trade in 2012 (relative to coastal)

	Developing		High-income		Global
	All	Africa	All	W. Europe	
GDP per capita	0.47	0.34	1.00	1.31	0.39
Trade per capita	0.48	0.30	1.99	1.60	0.65
LL population (mil.)	471	275	33	17	504
LL population (fraction of total)	0.08	0.30	0.03	0.09	0.07

Based on data from the World Bank *World Development Indicators*. Trade is the mean of exports and imports. High-income countries are those as defined in the World Bank country classification 2013: those with a (2012) GNI per capita of $12,616 or more. Developing countries are defined here as all non-high income countries. Africa refers to sub-Saharan Africa only, again as defined in the World Bank country classifications 2013. Western Europe is as defined in the United Nations geoscheme, which includes continental Europe only.

Just how important are neighbours to the success of landlocked countries? Despite suggestive evidence, we know little regarding magnitudes or the precise channels through which neighbours are important. The figures in Table 2.1 for example might be largely explained by distance; landlocked countries are more disadvantaged relative to coastal countries in Africa than they are in Europe, because the relative distances to major markets are so much greater. Alternatively, any apparent "landlocked effect" may be largely spurious. Borchert et al. (2012) for example question the view that landlocked countries are "victims of geography", finding that they often have more restrictive trade policies than coastal countries. They find that this is particularly true in Africa, and that this can be partially explained by weak institutions.

The aim of this paper is therefore to provide causal, quantitative, evidence that neighbours are important to the prosperity of landlocked countries. I focus on the channel that is unique to landlocked countries: neighbours are obstacles to seaborne trade. I use civil wars in neighbouring countries as natural experiments, increasing the size of these obstacles.[44] Applying this strategy to Africa over 1975-2005, I show that by obstructing the shortest route to the coast, neighbouring civil wars (i) increase transport costs and (ii) reduce the overseas trade of landlocked countries.

There are two principal contributions of the paper. The first is to provide causal, quantitative, evidence that "neighbours matter". Bad neighbours impose a cost on landlocked countries because they obstruct their access to the coast; this cost is unique to landlocked countries and helps to explain the "landlocked penalty" shown in Table 2.1. Calibrating the regression results shows that the international trade of landlocked countries could have been 12 percent higher during the period in the absence of neighbouring civil wars. The results further suggest that neighbouring civil wars account for around 10 percent of the difference between (per capita) landlocked and coastal trade volumes over the period. Landlocked African countries therefore face additional barriers to development, being dependent on others for access to the coast.[45]

The second contribution of the paper is to provide rare evidence on the importance of transport costs to international trade. Despite the obvious policy implications, such evidence is sparse because transport costs are typically endogenous. For landlocked countries however, neighbouring civil wars act as natural experiments – increasing the distance to the coast

[44] The most closely related work is that of Qureshi (2013), which provides strong evidence that neighbouring conflicts reduce international trade. The advance in this paper is to concentrate on a particular mechanism: transport costs. Doing so enables me to calibrate the importance of transport costs to trade, an issue of particular importance to international trade models. I also focus specifically on developing landlocked countries, i.e. those that are most likely to be vulnerable to regional instability and those with the lowest levels of international trade.

[45] The "landlocked penalty" in Table 1 can partly be explained by distance; landlocked countries are further from overseas trading partners and therefore are expected to trade less. This paper shows however that there are costs associated with being landlocked itself; for a given distance, landlocked countries are disadvantaged because they are reliant on passage through other countries. In related, earlier work, Limao & Venables (2001) show that landlocked countries have higher transport costs even conditioning on distance.

and thus creating an exogenous shock to transport costs. The identification strategy of the paper is therefore to treat neighbouring civil wars as exogenous shocks to transport costs, and estimate the response of trade to these shocks. (I first demonstrate in section 2.4 that neighbouring civil wars do indeed increase transport costs.) I estimate an elasticity of trade w.r.t. transport costs in the range -3 to -6, which is slightly larger than previous available estimates (see Table 2.6).

I argue that this large trade response is due to the export profiles of landlocked African countries, being primarily concentrated in primary commodities. It is possible however that there are other conflict-related spillovers, besides higher transport costs, that also disrupt trade. This might produce an over-estimate of the importance of transport costs, as these other factors (such as an increase in domestic unrest and military spending) could also explain the link between neighbouring conflicts and reduced trade.[46] To try and isolate the effects of transport disruptions alone, I explicitly map the transit routes of the landlocked countries and exploit GPS data on the location of neighbouring civil wars. Further, I rule out a number of other spillover effects from conflicts that could plausibly drive the results. Finally, I find no evidence that conflicts in "non-transit" neighbours reduce trade, or that the trade of coastal countries is affected by neighbouring conflicts. Both results support the view that the underlying mechanism is indeed a transport cost shock.

The paper is organised as follows. Section 2.2 reviews the related literature, section 2.3 discusses the sample and the creation of the dataset, section 2.4 estimates the response of transport costs to neighbouring conflicts, section 2.5 estimates the response of international trade, and section 2.6 calibrates the results. Section 2.7 concludes.

[46] When analysing trade flows, I consider overseas trade only as it is only these partners with whom distance has increased. Therefore any mechanical reduction in aggregate trade, due to lower trade with the neighbour itself, would not affect the results.

2.2 Related Literature

2.2.1 The costs of being landlocked

As highlighted in the introduction, there is a substantial penalty to being landlocked in Africa and in the developing world more widely. Access to markets is the most plausible explanation for this finding. Collier (2006) for example disaggregates landlocked and coastal countries according to whether they are resource-rich or resource-scarce. He notes that amongst resource-rich countries, there is no significant penalty to being landlocked. If resources are sufficiently valuable – as in the case of Botswana – any additional costs of being landlocked are surmountable. Botswana's diamond exports for example – which constitute the vast majority of its exports (Deaton 1999) – are valuable enough to be transported by air (Faye et al. 2004). Amongst the resource-scarce countries however, there is a dramatic divergence between coastal and landlocked groups: the world's most successful countries tend to belong to the former group, and the least successful to the latter. Switzerland and Austria are exceptions because being landlocked has not constrained their access to markets; indeed their geographical position places them at the centre of a successful regional economy.

In the African case, being landlocked has constrained access to markets because the main trading partners are predominantly overseas: intra-African trade is comparatively small. As argued by Collier and Gunning (1999), "Africa's landlocked economies trade with Europe, so that neighbouring countries are an obstacle rather than a market" (p.15). A sense of this obstacle is provided by Limao and Venables (2001), who consider the determinants of international transport costs using data on the cost of shipping a 40-foot container from Baltimore, Maryland, to various cities around the world. Not only do they find that land distance is substantially more costly than sea distance – an extra 1,000 km by land adding $1,380 to the shipping cost compared to just $190 by sea – but shipping to landlocked countries is significantly more costly even controlling for land distance.[47] The authors postulate several reasons for this "excess" landlocked cost – border delays, coordination problems, higher insurance costs, and direct charges made by the transit country. As the cost of sea distance has been declining over time, it is possible that the landlocked penalty will become even more significant in the future (Arvis et al. 2010).

2.2.2 Transport costs and trade

How do these additional transport costs impact on international trade? Although the gravity model has established a robust correlation between *distance* and trade flows, the relationship between distance and transport costs is far less clear. Consequently, so is the relationship between transport costs and trade.

Head and Mayer (2015) undertake a meta-analysis of gravity estimates and find a mean elasticity of trade w.r.t. distance of -1.1. That is, a 10 percent increase in distance between countries leads to an 11 percent reduction in bilateral trade. As argued by Feyrer (2009) however, distance captures not only transport costs but also a range of unobservables such as tastes and cultural differences. A good example of this is provided by Blum and Goldfarb (2006), who find large distance effects for goods consumed over the internet (i.e. where the transport cost is zero).

Due to a general paucity of transport cost data, gravity models typically include only estimates of distance effects. A notable exception is that of Limao and Venables (2001), who combine distance estimates from a gravity model with the transport cost data discussed above, as well as transport data inferred from CIF/FOB comparisons. By combining the different sources of data, the authors are able to estimate both (i) the elasticity of transport costs w.r.t. distance, and (ii) the elasticity of imports w.r.t. dis-

[47] Without controlling for distance, the mean cost of shipping to a coastal country is \$4,620 and being landlocked adds \$3,450. When controlling for distance, being landlocked still adds \$2,170.

tance. This gives them an implied elasticity of imports w.r.t. transport costs of around -6.5, implying a large role for transport costs.

A novel approach to estimating the impact of transport costs on trade is provided by Feyrer (2009), who uses the closure of the Suez canal between 1967 and 1975 as a natural experiment. Although he does not measure transport costs per se, his methodology exploits changes in distance and so removes time-invariant factors such as culture. In effect, he provides an estimate of distance on trade that is more relevant for transport costs. His estimates are around half that of Head and Mayer (2015).

2.2.3 Conflicts and trade

Post-independence Africa has been blighted by civil war, the disastrous consequences of which for economic prosperity are well documented (see e.g. Collier and Hoeffler 2007). Bayer and Rupert (2004) estimate the effects of civil war on international trade (in a global sample) using a gravity model over the period 1950-1992. The authors find a substantial impact of civil war, estimating a reduction in bilateral trade of around a third if either partner is involved in a civil war. A similar exercise for international conflicts is undertaken by Glick and Taylor (2010), who extend their coverage back to 1870 to include the effects of both World Wars. The authors find substantially negative and persistent effects of conflicts on trade, enduring for many years after conflict has ended.

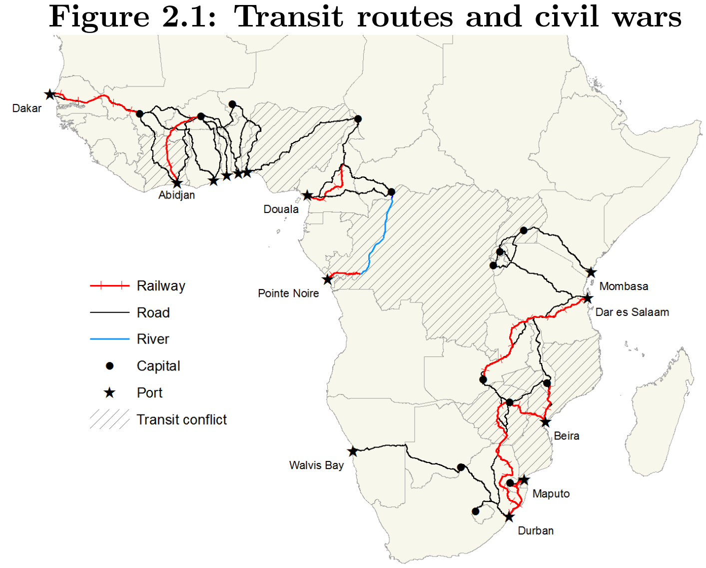
Compared to the sizeable literature regarding domestic civil wars, research on the externalities of conflicts on neighbouring countries is somewhat limited. An early attempt to measure these externalities is that of Ades and Chua (1997), who run cross-section regressions of economic growth over the period 1960-1985. The authors find that high regional instability, measured by the number of revolutions and coups per year, has a significant and negative impact on growth. In terms of mechanisms, the authors find that regional instability leads to higher military outlays and reduced trade flows. In related work, Murdoch and Sandler (2004) examine the effect of civil wars in neighbouring countries on domestic economic growth, in the context of a Solow growth model. They find that countries in a region with 3 or more civil wars may be equally damaged by the conflict (in economic growth terms) as the country experiencing the civil war. Interestingly however, countries are generally able to limit the impact of neighbouring civil wars after a couple of years, whereas the host country experiences increasing harm as the conflict continues.

The papers most closely related to mine are those of Milner and Zgovu (2006) and Qureshi (2013). Milner and Zgovu estimate the relative effects of trade policy and transport costs on the exports of Malawi, exploiting the civil war in Mozambique as a natural experiment. The authors estimate an export supply function for Malawi, and find transport costs to be a more significant determinant of exports than trade policy. Although this is a useful case study however, it is interesting to consider to what extent the Malawian experience generalises, and whether instability on transit routes has negatively affected landlocked countries in the aggregate. Qureshi (2013) estimates the effect of conflicts in neighbouring countries on international trade in a global sample, using a gravity model over the period 1948-2006. The author finds significant negative effects of neighbouring conflicts on bilateral trade, with his principal estimate being that conflict in a neighbouring country reduces international trade of the domestic country by around 8 percent. Despite postulating that transport costs are one of the key mechanisms driving his results however, the author does not test the underlying mechanisms. In this paper I specifically consider the role of transport costs and use conflicts as a means of deriving estimates for the effect of transport costs on trade.

2.3 The Sample

Figure 2.1 maps the major transit routes of each landlocked country.[48] To identify such routes I have consulted a wide literature, and details of both routes and disruptions are provided in Appendix B.1. Mapping the routes explicitly provides me with a measure of distance to coast for each alternative, and will enable me to exploit data on the specific location of civil wars. For the base road and rail networks I use the Food and Agricultural Organisation's *Relational World Database II*, and navigable rivers are taken from *Natural Earth*.[49] After identifying the ports and transport modes used by each landlocked country, detailed in Appendix B.1, I calculate the shortest route from capital to port using the Network Analyst extension in ArcGIS.

Figure 2.1: Transit routes and civil wars



Throughout the paper I use data on civil wars from two datasets. The first is the Correlates of War (COW) database, the most widely used dataset in the study of conflict and economic activity (e.g. Bayer and Rupert 2004,

[48] Ethiopia and Souh Sudan are not included as they became landlocked countries during the sample period.

[49] Available online at http://www.fao.org/geonetwork/srv/en/main.home and http://www.naturalearthdata.com/downloads/50m-physical-vectors/

Murdoch and Sandler 2004, Collier and Hoeffler 2007). For inclusion in the COW database, each year of a conflict must result in a minimum of 1,000 battle-related deaths, and there must be "effective opposition" from both sides. This coding rule ensures that I am capturing only years in which there is significant unrest in the affected country.

As a second measure of civil war, I use the PRIO-GRID dataset of the Peace Research Institute of Oslo (PRIO) (Tollefsen et al. 2012).[50] PRIO-GRID geocodes the UCDP/PRIO Armed Conflict Dataset, based on the location of fighting in each calendar year. Specifically, PRIO-GRID divides the globe into square cells at a resolution of 0.5 x 0.5 decimal degrees, and conflict data is processed at the cell-level rather than country-level.[51] This provides me with a potentially cleaner treatment strategy: when using the PRIO-GRID data, I can exclude conflicts that occur in areas of the transit country that routes do not pass through.[52]

Table 2.2 provides details on the frequency and duration of civil wars in both datasets over the period 1975-2005.[53] From the table, it is clear that civil wars have been extremely common over the period, with the majority of landlocked countries experiencing a conflict on at least one of their major transit routes. Such conflicts are less common in the PRIO-GRID data, partly as a result of using cell-level data, but largely due to measurement and methodological differences between the two datasets. As an example, Cote d'Ivoire is coded as being in civil war from 2002-2004 in the COW dataset, based on 1,000 or more deaths per year, but not in the PRIO-GRID dataset. As shown in the table, on average there are an

[50] For consistency with the COW, I include all episodes from PRIO-GRID classified as "intense", i.e. those involving 1,000 or more deaths per year.

[51] Conflicts are however constrained to take place in the country listed in the master UCDP/PRIO Armed Conflict Dataset.

[52] I use the "intersect" tool in ArcGIS to intersect the PRIO-GRID civil war coordinates with the transit network shown in Figure 2.1.

[53] This is the period over which data is available in all the datasets used. In particular, the transport cost data used in Section 2.4 begins in the early 1970s, with very little data pre-1975. In the PRIO-GRID dataset I use the *confold* variable, for which the latest year is 2005.

additional two years of transit conflicts per landlocked country in the COW data.

Table 2.2: Summary statistics - conflicts (1975-2005)

	Correlates of War	PRIO-GRID
# countries	14	14
# years	31	31
# countries with a conflict on a transit route	10	7
# countries with a conflict on shortest route	5	4
Mean years with conflict on a transit route (s.d.)	7.86 (7.67)	5.71 (6.38)
Mean duration of transit conflict (s.d.)	4.55 (4.03)	3.60 (3.69)

2.4 Transport Costs

Do civil wars in transit countries increase transport costs? Figure 2.2 provides an illustration that they might, by plotting the overseas trade of Burkina Faso and Malawi transiting through Cote d'Ivoire and Mozambique (respectively).[54] As a result of civil war in Cote d'Ivoire, the border with Burkina Faso was closed for an entire year in September 2002. During the closure merchandise was blocked in the port of Abidjan, and throughout the conflict exporters struggled to insure goods passing through Cote d'Ivoire (OECD 2006). Prior to the crisis, Abidjan had also served as the principal port for Malian exporters, many of whom now transited through Burkina Faso to ports in Ghana and Togo. The increase in distance alone was estimated to cost Mali an additional $12 million per year in freight costs (Briceno-Garmendia et al. 2011).

The 1980s conflict in Mozambique disrupted the transit routes of Malawi, Swaziland, Zambia and Zimbabwe. As demonstrated in Figure 2.2, Malawi's

[54] I am grateful to Olivier Hartmann at the World Bank for providing the Burkina Faso data.

access to both its ports in Mozambique was completely blocked during the crisis and diversion to South Africa (via Zimbabwe) increased distances by almost 2,500 km. Freight costs on the South African route were around 3 times higher than those through Mozambique (World Bank 1988), and Kennedy (1988) estimates additional transport costs in the region of $100 million per year. For the other landlocked countries, passage through Mozambique was still possible although subject to terrorist attacks, derailments, long closures, and a reduction in rail and port capacity (Kennedy 1988, World Bank 1989). Zimbabwean and Zambian transit was guarded by government troops, although sabotage still occurred and access to the southern port of Maputo was closed completely in 1984. In the case of Zambia, access to ports in Mozambique had also been completely blocked during the civil war in Zimbabwe (1973-1979), in which the border between Zambia and Zimbabwe was closed (Hoyle and Charlier 1995).

Figure 2.2: Transport disruptions, Burkina Faso and Malawi

To quantify the aggregate effect of civil wars on transport costs, I collect data on freight and insurance expenditure from IMF Balance of Payments (BOP) statistics. As noted by Hummels (2007), international trade economists typically measure transport costs in ad valorem terms: the cost of freight and insurance relative to the value of the good. Recent research has demonstrated however that non-pecuniary transport costs – delays and unreliability – may be just as important for trade (Arvis et al. 2010, Djankov et al. 2006). The examples above demonstrate that conflicts on transit routes are likely to influence both types of cost, although quantifying the non-pecuniary effects is challenging. To the extent that delays and unreliability are reflected in higher insurance premiums, the ad valorem transport cost will capture such effects. It is likely nevertheless that the ad valorem cost may be underestimating the overall impact of conflicts on the costs of transport.

I approximate an ad valorem transport cost for country i in time t by dividing payments on foreign freight and insurance services by the combined value of imports and exports of goods. To clarify, the numerator consists of expenditure by domestic residents on both "freight services" and "insurance services" provided by foreign residents. The latter includes not only freight insurance, but also life, health and other types of insurance. If conflicts in transit countries increase expenditures on types of insurance other than freight, this will bias the effect of conflict on transport costs upwards. I therefore present results for both the combined transport cost measure (freight services and insurance services), and for both types of service separately.

As noted by Anderson and van Wincoop (2004), transport costs are almost always assumed to be log-linear in distance. I present results for both linear and log-level forms in Appendix B.2, but in the log-linear case we have:

$$\ln(t_{it}) = \alpha + \beta_1 T_{it} + \beta_2 \ln(dist_{it}) + \delta_i + \delta_t + \varepsilon_{it} \tag{17}$$

where t_{it} is the ad valorem transport cost of country i at time t, T_{it} is a dummy equal to 1 if there is a conflict on a major transit route, $dist_{it}$ is the distance (km) to the nearest port, and δ_i and δ_t are country and time fixed-effects.[55] Due to the country fixed effects, all variation in distance

[55] When using COW data, T_{it} =1 if there is a civil war in any neighbouring country that the landlocked country's transit routes cross. When using PRIO-GRID data, T_{it} =1 if there is a civil war in any of the 0.5 x 0.5 decimal degree cells (in neighbouring

is caused by conflicts on transit routes. Specifically, changes in distance are calculated as the difference in distance (if any) between the route on which there is a conflict and the next-shortest alternative. This difference is non-negative: a conflict may increase the distance to coast, or leave it unchanged.

The regression includes both a conflict dummy T_{it}, and the continuous distance variable $dist_{it}$. The two variables are correlated over time because $dist_{it}$ changes only when $T_{it} = 1$. The rationale for including both variables is that T_{it} captures the *incidence* of conflict on a transit route, and $dist_{it}$ captures the *intensity* of conflict on a transit route. It is not clear ex ante whether all conflicts are damaging, or only those that increase the distance to coast. The incidence variable T_{it} tests for this in the regressions, because it picks up the effect of conflict when distance is controlled for (by the inclusion of the $dist_{it}$ variable). The results in fact show that it is distance that is the important variable rather than T_{it}: conflicts that do not increase the distance to coast do not appear to damage landlocked countries' transport costs or trade.[56]

In practice, conflicts do not necessarily block transit routes completely. Even when there is a conflict on the shortest route to coast, there is generally still some transit traffic. Distance is therefore to some extent capturing the shortest optimal route rather than the shortest possible route. Further, even if transit through a conflict zone is feasible, there are good reasons to expect both freight and insurance costs to increase in the distance variable. Firstly, we know from the examples above that many firms do change route as a result of conflicts, and for such firms freight costs will be higher when the outside option is further away (due to variable costs such as fuel and labour). Secondly, a more distant alternative port makes it more likely that firms will continue to transit via the original route (if possible), thus

countries) that the landlocked country's transit routes cross.

[56] The inclusion of T in the regressions has little effect on the $dist$ coefficients, although they generally become more significant if T is excluded. Similarly, T remains insignificant if $dist$ is omitted.

increasing insurance costs.

A general issue with the empirical strategy is that there is limited variation in the $dist_{it}$ variable. As shown in Table 2.2, 5 countries suffered a conflict on their shortest route during the period. These were Malawi (1979-1992), Mali (2002-2004), Swaziland (1979-1992), Zambia (1972-1992) and Zimbabwe (1979-1992). The Mozambique conflict accounts for a number of these cases; Malawi, Swaziland, Zambia and Zimbabwe (although Zambia was also affected by the earlier conflict in Zimbabwe). As a number of countries suffered from the same conflict, there may be common unobserved effects that are not captured. To account for this I have experimented with clustering standard errors at the regional level, as suggested in Cameron et al. (2015), although there is little effect on the main results (in which standard errors are clustered by country).[57] The general lack of variation in the dataset however means that the regressions are based on a rather limited number of cases, and the results should therefore be interpreted with some caution.

Table 2.3 presents the results of equation (17) for the landlocked countries over 1975-2005. Columns (1) to (3) use the COW conflict dates and columns (4) to (6) use those from PRIO-GRID. As transport costs are generally declining over the period, I include a country-specific time trend in Panel B. The time trend substantially reduces a number of the coefficients, although the effect of distance on transport costs remains positive and significant in both panels. It is notable that the incidence of civil war (T_{it}) is insignificant in all specifications, whereas the "intensity" of civil war - cap-

[57] As a given conflict affects a number of landlocked countries within the region, this could be viewed as a situation in which there is a regional level treatment, but country-level data. Cameron et al (2015) suggest clustering standard errors at the regional level in such cases. I have experimented with this by creating 4 regional groups - West, East, Central and South. Most of the main results are not affected, although some of the coefficients in the regressions including a time-trend become insignificant. In the main results I have clustered at country level as the treatment is not truly regional - even if a number of countries are affected by the same conflict, the changes in distance to the coast are very different across different countries.

tured by $\ln(dist_{it})$ - is positive and highly significant. This suggests that the impact of transit country civil wars is limited provided that the landlocked country has good outside options. If the outside options are weak, and civil wars cause a diversion to much longer routes, transport costs will rise significantly.

With the time-trend, the coefficients in columns (1) and (4) suggest an elasticity of transport costs w.r.t. distance in the range 0.27 to 0.42. The upper bound is pulled up somewhat by the large increases in insurance premiums; using freight charges alone suggests an upper bound of 0.34. Such estimates are strikingly similar to those of Hummels (2001), often used as benchmark figures (e.g. Anderson and van Wincoop 2004). Hummels finds elasticities of 0.39 for rail distances and 0.28 for road distances using US Census Bureau data.

Table 2.3: Transport costs and conflict (1975-2005)

Panel A: No time trend

	Correlates of War			PRIO-GRID		
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(t)	ln(fr.)	ln(ins.)	ln(t)	ln(fr.)	ln(ins.)
T	-0.152	-0.225	0.069	0.137	0.027	0.376
	(0.211)	(0.205)	(0.307)	(0.148)	(0.138)	(0.381)
ln(dist)	0.787***	0.779***	1.289***	0.452***	0.513***	0.847***
	(0.163)	(0.166)	(0.307)	(0.106)	(0.104)	(0.274)
Obs.	342	359	342	342	359	342
Countries	14	14	14	14	14	14
R-Sq.	0.28	0.19	0.38	0.22	0.15	0.34

Panel B: Linear time trend

	Correlates of War			PRIO-GRID		
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(t)	ln(fr.)	ln(ins.)	ln(t)	ln(fr.)	ln(ins.)
T	-0.159	-0.255	0.078	-0.052	-0.181	0.173
	(0.181)	(0.197)	(0.265)	(0.176)	(0.195)	(0.356)
ln(dist)	0.416**	0.342*	0.854**	0.265**	0.287**	0.564*
	(0.151)	(0.168)	(0.285)	(0.121)	(0.130)	(0.277)
Obs.	342	359	342	342	359	342
Countries	14	14	14	14	14	14
R-Sq.	0.48	0.39	0.50	0.47	0.38	0.47

Robust standard errors in parentheses. All regressions include country and year fixed effects.
The dependent variables are ad valorem transport costs (columns 1 and 4), ad valorem freight costs (columns 2 and 5) and ad valorem insurance costs (columns 3 and 6). Constants are included but not reported.
*** p<0.01, ** p<0.05, * p<0.1

2.5 Trade

Having established the effect of transit civil wars on transport costs, and the central role that distance plays in this relationship, it is natural to apply this to a gravity model of trade. Africa provides a suitable environment for this strategy, as most external trade is conducted with countries outside the continent. As noted by Collier and Gunning (1999) above, Africa is unique in that neighbouring countries are as much an obstacle as a market; I now investigate what happens to trade when these obstacles increase. I run a gravity equation given by:

$$\ln(trade_{ijt}) = \gamma_0 + \gamma_1 T_{it} + \gamma_2 \ln(dist_{ijt}) + X'_{ijt}\theta + \delta_{ij} + \delta_t + u_{ijt} \qquad (18)$$

where $trade_{ijt}$ is the average value of trade between countries i and j in year t, T_{it} is defined as before, $dist_{ijt}$ is the distance between i and j in year t, X_{ijt} is a vector of controls (GDP of i and j; a dummy = 1 if either i or j is at civil war in year t; plus a lag of this variable), and δ_{ij} is a fixed effect for each pair. Inclusion of the fixed effect controls for time-invariant factors that are known to affect trade flows including common language and colonial ties. Inclusion of this term also means that all variation in distance is caused by conflicts on transit routes: changes in distance to coast are calculated exactly as in Section 2.4, and to generate bilateral distances I add the sea distance between country i and country j using data from www.sea-distances.org. The strategy in equation (18) is thus to treat changes in distance, resulting from neighbouring civil wars, as exogenous shocks and estimate the response of trade. Having also estimated the response of transport costs to these shocks, I can then back-out (in section 2.6) the implied elasticity of trade w.r.t. transport costs.

Equation (18) is run over the period 1975-2005 using IMF Direction of Trade (DOT) statistics. This dataset provides annual bilateral trade flows in nominal \$US, which I normalise to \$1985 using the US CPI deflator. I include all observations for which one member of the pair is an African landlocked country and the other is located outside Sub-Saharan Africa. Because I use sea distances, all partner countries are coastal. To exclude very small economies, whose trade reports are extremely volatile, I exclude all partner countries with populations below 1 million in 1990. The results are not sensitive to this decision, and in Appendix B.3 I present a number of robustness checks: modifying the list of transit routes; adding measures of "openness"; including very small partner countries; and using great circle instead of sea distances.

Table 2.4 presents the results of equation (18). Columns (1) and (2) are based on the full sample, and columns (3) and (4) are essentially robustness checks ((5) to (8) replicate (1) to (4) using the PRIO-GRID data). To check that extreme distances are not driving the results, column (3) excludes all observations in which bilateral distance is greater than two standard deviations above or below the mean. Because most of the variation in distance is caused by the Mozambican conflict of the 1980s, column (4) limits the sample to a shorter period by excluding observations beyond 2000. In all specifications except columns (5) and (8), the distance term enters negatively and significantly.[58] It is notable that - particularly for the COW estimates - the coefficient is slightly larger than previous estimates. In their meta-analysis of gravity models, Head and Mayer (2015) find a mean effect of -1.1, although in the related literature somewhat higher upper estimates are common: -1.69 (Limao and Venables 2001), -1.38 (Glick and Taylor 2010) and -1.36 (Qureshi 2013).

[58] The term is highly significant in both columns if small partner countries are not excluded.

Table 2.4: Trade and conflict (1975-2005)

	Correlates of War				PRIO-GRID			
	(1) ln(trade)	(2) ln(trade)	(3) ln(trade)	(4) ln(trade)	(5) ln(trade)	(6) ln(trade)	(7) ln(trade)	(8) ln(trade)
T	-0.028	0.015	-0.019	0.039	0.034	0.065	0.022	0.082
	(0.079)	(0.081)	(0.083)	(0.088)	(0.097)	(0.097)	(0.099)	(0.100)
ln(dist)	-1.606*	-1.980**	-1.670**	-1.420**	-1.225	-1.628**	-1.305*	-0.921
	(0.832)	(0.783)	(0.780)	(0.692)	(0.791)	(0.724)	(0.721)	(0.656)
$\ln(Y_{it})$		-0.016	0.003	-0.083		-0.036	-0.018	-0.083
		(0.115)	(0.114)	(0.118)		(0.115)	(0.114)	(0.119)
$\ln(Y_{jt})$		0.393***	0.397***	0.292**		0.372***	0.372***	0.309**
		(0.132)	(0.133)	(0.144)		(0.132)	(0.133)	(0.144)
Conflict		-0.277***	-0.311***	-0.296***		-0.283***	-0.314***	-0.301***
		(0.086)	(0.089)	(0.091)		(0.085)	(0.088)	(0.090)
Conflict+1		-0.457***	-0.493***	-0.419***		-0.454***	-0.499***	-0.420***
		(0.089)	(0.091)	(0.100)		(0.089)	(0.092)	(0.100)
Obs.	23,972	21,405	20,285	16,871	23,972	21,403	20,283	16,874
Pairs	1,101	1,046	983	979	1,101	1,047	984	979
R-sq.	0.02	0.03	0.03	0.02	0.02	0.03	0.03	0.02

Robust standard errors in parentheses. All regressions include pair and year fixed effects.
Column (3) excludes very short and long distances, and column (4) covers only 1975-2000. Columns (5) to (8) replicate (1) to (4) using the PRIO-GRID definition of conflicts. Constants are included but not reported.
*** p<0.01, ** p<0.05, * p<0.1

2.5.1 Spillovers

A limitation of the empirical approach is that there may be other spillovers from neighbouring conflicts - in addition to higher transport costs - that also reduce trade. This would bias the results, as we would be attributing the impact of such factors to transport costs. Ades and Chua (1997) for example find that regional instability increases domestic military spending. If such spending is financed through higher taxation, or (more generally) raises domestic interest rates, this could reduce investment and hurt exports. Alternatively it may be the case the violence itself spills across the border, provoking domestic unrest and reducing economic activity. Such factors would also generate a correlation between neighbouring conflicts and trade, but not due to the transport cost channel that is of particular interest here.

The fact that my results are driven by the *dist* variable, rather than the incidence of neighbouring conflicts (T) per se, limits such concerns. The results suggest that trade declines significantly only when the distance to the coast increases. This result supports the view that an increase in transport costs is the causal mechanism. Nevertheless, in Table 2.5 I explicitly check for these "crowding out" spillovers. Columns (1) to (4) present results from regressions of government consumption, military spending, tax revenues and the real interest rate on the transit conflict (T) and *dist* variables used above.[59] It can be seen in each of the four columns that any crowding out effects are largely absent (although the tax data is extremely limited).

As a further test that transport costs are driving the results, I check (i) whether the trade of coastal countries is affected by these neighbouring civil wars, and (ii) whether landlocked trade is affected by civil wars in "non-transit" neighbouring countries. The results are presented in columns (5) and (6). Although the incidence of neighbouring conflicts (T) enters negatively, it is extremely small and insignificant in both columns. The results do not rule out the importance of other spillovers altogether, but they do provide further evidence that the trade effects work via transport shocks rather than other trade-related spillovers.

[59] Government spending (general government final consumption expenditure), tax revenues and the real interest rate are all from the World Bank *World Development Indicators*. Tax revenue data is not available pre-1990. Military spending is from the Stockholm International Peace Research Institute (SIPRI) and is available from 1988.

Table 2.5: Other conflict spillovers

	(1) ln(gov.)	(2) ln(mil.)	(3) ln(tax)	(4) r	(5) ln(trade)	(6) ln(trade)
T	0.159	0.077	-0.699	0.000	-0.026	-0.075
	(0.146)	(0.163)	(0.518)	(0.063)	(0.049)	(0.059)
ln(dist)	0.093	0.013	-2.651	-0.084		
	(0.126)	(0.192)	(2.814)	(0.122)		
Obs.	424	214	75	313	67,243	27,423
Countries	14	14	10	13	3,305	1,374
R-Sq.	0.139	0.189	0.782	0.194	0.01	0.02

Robust standard errors in parentheses. Columns (1) to (4) include country and year fixed effects, columns (5) and (6) include bilateral pair and year fixed effects.
The dependent variables are general government consumption (column 1), military spending (column 2), tax revenues (column 3), the real interest rate (column 4), and bilateral trade (columns 4 and 5).
Constants are included but not reported.

2.6 Calibration

2.6.1 Implied elasticities

It is useful to bring together the results of the previous two sections, to consider their implications for the responsiveness of trade to transport costs. Table 2.6 collects my estimates of the elasticities of transport costs and trade to distance, from Tables 2.3 and 2.4 respectively. I can then calculate the elasticity of trade with respect to transport costs as the ratio of the two (column 2 / column 1). For comparison, I provide estimates from elsewhere that are often used as benchmark figures. Head and Mayer (2015) is based on an extensive meta-analysis of distance effects, and Hummels (2001) exploits very detailed US Census Bureau data to compute transport costs.[60] Feyrer (2009) is an interesting comparison to the present paper, as it too is computed from changes in distance (as opposed to the more common static measure).

[60] The US Census Bureau data is not suitable for my purposes as transport costs are calculated "free-alongside-ship". Any changes in overland transport costs in Africa should not affect such a measurement (see Amjadi & Yeats 1995).

Table 2.6: Implied elasticities

	Estimated elasticity w.r.t. distance		Implied elasticity of trade w.r.t. transport costs
	Transport costs	Trade	
This paper (COW)	0.42	-1.42 (lower) -1.98 (upper)	-3.38 (lower) -4.71 (upper)
This paper (PRIO-GRID)	0.27	-0.92 (lower) -1.63 (upper)	-3.41 (lower) -6.04 (upper)
Head & Mayer (2015) + Hummels (2001)	0.28 (road) 0.39 (rail)	-1.1	-3.93 (road) -2.82 (rail)
Feyrer (2009) + Hummels (2001)	0.22 (sea)	-0.46	-2.09

My estimates suggest that trade is slightly more responsive to transport costs than in previous papers, as shown in the final column. This may well be due to my sample selection, based purely on landlocked African trade flows. The exports of such countries are based overwhelmingly on primary commodities, with the limited manufacturing exports being in highly competitive sectors.[61] Radelet and Sachs (1998) argue that most developing countries' manufactured exports face perfectly elastic demand, and a similar case holds for most primary commodities (in which the landlocked countries are price takers). With such export profiles, it is reasonable to expect an elastic response of trade to transport costs for a developing country sample.

[61] UN Comtrade data for 1990 shows that 82% of the exports of Afican landlocked countries were primary commodities. Just 1% was "machinery" (capital goods, SITC code 7) and 14% was in other manufacturing sectors (using the Radelet & Sachs (1998) definition minus machinery).

2.6.2 Lost trade

In this section I calibrate the value of trade that the landlocked countries have lost over the period due to conflicts in transit countries. The methodology is based on that of Glick and Taylor (2010) and makes use of the estimations in Table 2.4. The idea is to identify a "benchmark" level of trade between i and j that would have occurred in the absence of conflict in a transit country; this will be denoted as $trade_{ijo}$. I can then use the estimates in Table 2.4 to compute the implied level of trade in the presence of such conflicts (denoted by $trade_{ij}^{C}$). The implied level of trade between countries i and j in year t is given by:

$$trade_{ij}^{C} = trade_{ijo}\left(\frac{dist_{ij}^{C}}{dist_{ij}}\right)^{\gamma_2} \tag{19}$$

where $dist_{ij}$ is the normal distance between i and j, $dist_{ij}^{C}$ is the distance during a conflict, and γ_2 is the coefficient from equation (18). Glick and Taylor (2010) follow a similar approach, in which they calibrate the value of lost trade as a result of World Wars I and II.[62] For $trade_{ijo}$ the authors choose the level of trade in the year immediately preceding war, i.e. 1913 for World War I and 1938 for World War II. I make an analogous assumption, although I account for the fact that Zimbabwe suffered from an internal conflict preceding the Mozambican war, meaning that an alternative benchmark should be chosen for Zimbabwe. I therefore choose the year immediately preceding Zimbabwe's internal conflict as the benchmark year in that case.

When there is a conflict on a transit route, the volume of lost trade between countries i and j in year t is given by $trade_{ijo}-trade_{ij}^{C}$. To calculate the total volume of lost trade for landlocked country i, I sum across all partner countries j, and then across all years of conflicts in transit countries.

[62] Glick and Taylor do not rely on changes in distance, but rather dummy variables for the presence of war. Hence their expression for $trade_{ij}^{C}$ is somewhat different.

To calculate a total figure for the volume of lost trade, I then sum across all affected landlocked countries.

Two questions are of particular interest:

1. How much higher would landlocked trade have been in the absence of conflicts in transit countries?

2. What percentage of the "landlocked penalty" - the gap between (per capita) landlocked and coastal trade volumes - is accounted for by these conflicts?

Table 2.7 presents answers to these questions, based on the upper and lower bound elasticities of trade w.r.t. distance from Table 2.4. In all cases, trade losses are notably higher using the COW data, primarily due to the higher number of years classified as conflict in this dataset (see Table 2.2). The upper bound estimates using COW suggest that (1) international trade of landlocked African countries would have been almost 12 percent higher in the absence of conflicts in transit countries, and (2) around 10 percent of the "landlocked penalty" is due to such conflicts.

Even accounting for such losses, international trade (per capita) of coastal countries would still have been twice as high as for landlocked countries over the period. It is worth noting however that I am measuring only the contemporaneous loss in trade due to such conflicts. There may be significant longer term implications that I am not capturing. The likelihood of future shocks of this kind may reduce investment in the landlocked countries for example: conflicts in transit countries add an additional degree of risk. Again, this uncertainty is unique to landlocked countries, and quantifying it may help to explain a larger proportion of the "landlocked penalty".

Table 2.7: **The volume of lost trade (1975-2005)**

	Correlates of War	PRIO-GRID
Volume of landlocked trade	\$189.11 bn	\$189.11 bn
Volume of landlocked trade (per capita)	\$1968	\$1968
Volume of coastal trade (per capita)	\$4276	\$4276
Lost trade (lower)	\$15.88 bn	\$5.46 bn
Lost trade (upper)	\$21.88 bn	\$8.78 bn
% higher trade if no transit conflicts	8.4% (lower) 11.6% (upper)	2.9% (lower) 4.6% (upper)
% of landlocked penalty due to transit conflicts	7.2% (lower) 9.9% (upper)	2.5% (lower) 4.0% (upper)

All values are in \$1985 and are calculated using Direction of Trade Statistics. The "lost trade" figures exclude sub-Saharan African and landlocked partner countries, as in Table 4. For consistency, trade volumes are calculated analogously.

2.7 Conclusion

This paper demonstrates that landlocked countries are adversely affected by instability in their transit neighbours. When such neighbours are in conflict, the cost of accessing international markets increases. Based on changes in the distance to coast caused by these conflicts, I estimate an elasticity of transport costs w.r.t. distance in the range 0.27 to 0.42. Using the same strategy, I then estimate an elasticity of trade w.r.t. distance in the range -0.92 to -1.98. Together, these figures imply an elasticity of trade w.r.t. transport costs in the range -3.38 to -6.04. Such a range suggests quite an elastic trade response. I argue that the export profiles of African landlocked countries - concentrated in primary commodities and low value manufactured goods - helps explain this result.

Secondly, I quantify the costs of such conflicts for the African landlocked countries themselves. Over the period 1975-2005, I find that international trade could otherwise have been 12 percent higher. Although substantial, this lost trade would only account for around 10 percent of the "landlocked penalty" - the difference in per capita trade volumes between coastal and landlocked countries. International trade of the landlocked countries would still have been just half that of the coastal countries over the period.

These low trade volumes present difficult policy choices. As there are minimum traffic thresholds for competitive logistics services, it may be optimal for transit traffic to be concentrated on particular routes (Arvis et al. 2011). On the other hand, diversifying routes can promote competition amongst neighbours, reducing the administrative costs of transit. This paper provides an additional motivation for diversifying routes to the coast: conflict in coastal neighbours has limited effect when there are good outside options. It may indeed be optimal for certain "regional routes" to develop, but maintaining viable alternatives remains essential.

3 Regulation, renegotiation and capital structure: Theory and evidence from Latin American transport concessions

Abstract

We examine why private infrastructure providers rely so heavily on debt financing. We concentrate on a particular hypothesis, that debt is used to gain higher regulated prices. If this is true, we expect debt to be lower under price cap regulation, as the price incentive for debt is diminished. We present a model that derives this result. To test this we create a panel dataset of 124 transport concessions in Brazil, Chile, Colombia and Peru over 1992-2011. We have data on financial structure, regulatory design and contract renegotiations. We provide supportive evidence that price cap regulation reduces leverage, all else equal.[63]

Co-authored with Jean-Jacques Dethier (World Bank) and Stephane Straub (Toulouse School of Economics)

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3.1 Introduction

Since the 1990s public private partnerships (PPPs) and concession contracts have been widely used to develop major infrastructure projects. In emerging and developing economies private infrastructure investments, largely promoted by the World Bank, have grown by over 700 percent since 1990.[64] One of the striking features of these investments is that they are largely financed through debt. Leverage, defined here as the ratio of liabilities to assets, is typically over 70 percent for infrastructure firms.[65] There is increasing alarm amongst many analysts over the sustainability of such indebtedness: Helm and Tindall (2009) have warned of "financial corpses" in the UK and The Economist (2011) of "financial zombies" in India.

There are two principal, competing views over the motivation for high leverage in infrastructure projects. The first view, widely held at the World Bank, is that investors prefer as much debt as possible, and will maximise leverage subject only to finding willing creditors. The World Bank Institute's (2012) PPP Reference Guide for example states that "because equity is regarded as more expensive than debt, project sponsors often try to use a high proportion of debt to finance the project" (p.46). Similarly, Farquharson et al. (2011), also published by the World Bank, argue that "equity investment is "first in, last out" ... it follows from this that equity investment has a higher risk than debt, and so equity investors expect a higher return for this risk. Since equity is therefore more expensive than debt, the more debt a project can raise, the lower its overall funding costs will be" (p.53).

As noted by Ehrhardt and Irwin (2004) however, this argument (taken at face value) is at odds with the Modigliani-Miller theorem: higher debt means higher risk, and so rational equity holders will require higher re-

[64] Based on data from the World Bank PPI database, normalised to constant $US.

[65] To put this into context, Esty (2003) shows that the median leverage of similarly-sized firms is 31 percent in the Compustat database, and almost almost 30 percent of listed firms have a leverage ratio below 5 percent.

turns. Therefore higher leverage does not automatically lower the cost of capital. The "World Bank view" is thus unconvincing unless there are some frictions that cause debt to be genuinely cheaper (from an investor's perspective) than equity. Ehrhardt and Irwin (2004) argue that this often occurs as a result of government policy discriminating in favour of debt, such as guaranteeing debt repayments but not equity returns and providing minimum revenue guarantees linked to the repayment of debt. In such cases debt would have a genuine cost advantage over equity, and as noted by Yescombe (2007), the firm would increase the proportion of debt up to the point at which this cost saving is completely offset by the increasing threat of bankruptcy. The "World Bank view" can therefore be seen as analogous to the static trade-off theory of capital structure: less risky projects have a lower risk of bankruptcy and will therefore have higher leverage. Based on this, we would expect more profitable firms with less volatile revenue streams to have higher leverage, and leverage to increase as bond markets develop (as supply side constraints are relaxed).

The second view is that firms use debt to extract higher prices from the regulator. If the regulator is averse to bankruptcy, it may increase prices when leverage is high. The regulator may fear service disruption for example (Ehrhardt and Irwin 2004), or wish to avoid sending negative signals to potential investors. Supportive evidence for this has come from both the United States (Dasgupta and Nanda 1993, Spiegel and Spulber 1994) and Europe (Bortolotti et al. 2011, Cambini and Spiegel 2011). This motivation may be even stronger in an emerging market context, where regulatory commitment is weak. Esty (2003) argues that firms use leverage to enforce contracts with the regulator, noting that "in the presence of high leverage, even small attempts to appropriate value will result in costly default" (pp.15-16).

In this paper we assess these competing arguments in an emerging market context. We focus on the second, "strategic" argument, due to its implications for regulated prices. We first extend the theoretical model of

Spiegel and Spulber (1994), to show that the firm's ability to influence regulated prices is determined by the design of regulation. Under high-powered regulation, such as price cap, prices are unresponsive to the probability of bankruptcy, reducing the firm's incentive to use leverage. Similarly, when the cost of debt increases, we predict that firms operating under price cap will reduce their debt more than those operating under lower-powered regulation (such as rate-of-return). We take these predictions to the data to test the validity of the "strategic" motivation for leverage.

To do so, we create a unique panel dataset of 124 transport concessions in Brazil, Chile, Colombia and Peru over 1992-2011. We collect annual financial data for each firm, much of which is sourced directly from the regulators. To test the role of regulatory design on leverage, we have details on the regulation of every project. This is sourced from project contracts, legislation and renegotiation agreements. Renegotiation is very common in our sample, and potentially undermines the formal regulatory design. For our purposes, if a firm can renegotiate whenever it is in financial difficulty, then the incentive to use leverage will not vary across different types of regulation. That is, even under high-powered regulation the firm can increase prices by using high leverage.[66] We therefore explicitly test whether financial performance is a significant determinant of renegotiation. We find no evidence of this, allowing us to use the project contracts as our main source of regulatory information.

To test the role of regulatory design on leverage, we create a dummy equal to 1 if the firm is regulated by price cap. We begin by running panel regressions with country and sector fixed effects, finding the effect of price cap on leverage to be insignificant. To deal with the likely endogeneity of regulation, we next analyse how leverage responds *within* projects to changes in the cost of debt. As predicted by the model, we find some evidence that price cap firms make larger reductions in leverage when the

[66] This is analogous to the earlier argument of Esty (2003) that imperfect regulatory commitment increases the incentive for leverage.

cost of debt increases. This provides support to the hypothesis that firms use leverage to influence regulatory prices.

Our results are perhaps most striking in how little support they provide to the "World Bank view" that firms simply maximise leverage (subject to finding willing creditors). We find for example that higher profitability, which increases debt availability by lowering bankruptcy risk, actually *reduces* leverage.[67] Additionally, firms significantly reduce leverage as national stock markets develop. Bond market development appears to have no effect. Contrary to the World Bank view, our results therefore suggest that supply-side constraints are stronger with regards to equity than debt.

The paper makes two further contributions. The first is data. Due to the development of project finance, and the creation of special purpose vehicles (SPVs) or "project companies", the firms of interest in infrastructure projects are almost always unlisted and so very little financial data is publicly available. Very little is therefore known regarding the financial structure of such firms, or what motivates these structures.[68] Secondly, we contribute to the literature on PPP renegotiations (e.g. Guasch 2004, Engel et al. 2006) by providing the first evidence on the role of financial performance in triggering renegotiations. Our results are more favourable to the regulators than some previous studies have been (e.g. Sirtaine et al. 2005). We find that contracts are not systematically renegotiated when firms are in financial difficulty, and regulators do a better job in enforcing price caps than sometimes recognised.

To summarise, this paper analyses original and rare data on the finances of private infrastructure providers. We show that the data supports the argument that infrastructure providers use debt to influence regulated prices.

[67] This result is more consistent with the pecking order theory of capital structure (Myers 1984).

[68] Researchers interesting in the financing of PPPS and concessions have typically relied on the snapshot information available at "financial close". In this project we have sourced much of our data directly from regulators, allowing us to generate time-series variation within firms.

In particular, under a price cap regime prices should be less responsive to debt, and so the firm's incentive to use debt is weakened. We indeed find evidence that firms regulated through price cap have less preference for debt. We further show that an alternative argument, in which all infrastructure providers have a strong preference for debt over equity, has little support in the data.

3.2 Theory

The objective of the model is to provide comparative statics regarding the effect of price regulation incentives on the capital structure of the regulated firm. We do so in a simple model that describes the debt-issuing decision of a firm reacting to a pre-announced price setting rule, in a framework inspired by Spiegel and Spulber (1994) and Cambini and Spiegel (2011). After presenting our main results, we discuss how they extend to a situation in which the price setting rule can be renegotiated.

Our principal divergence from Spiegel and Spulber (1994) and Cambini and Spiegel (2011) is in the formulation of the price setting mechanism. Both of the above papers work in the context of US-style regulation, in which the regulator has considerable discretion to change prices at regular intervals. In our Latin American context, details on the mechanisms for adjusting and revising tariffs are typically specified in project contracts, and so regulatory discretion in many cases is very limited. Thus in the absence of formal renegotiations, which we consider explicitly below, the price setting rule is pre-announced.

3.2.1 The model

Consider a setting in which a regulator commits ex ante to set the price p according to a price setting rule of the form $p = a + (1 - b)C$, where C is expected cost and the parameter $b \epsilon [0, 1]$ represents the power of incentives. When b is close to 1, the rule comes close to a fixed price contract, i.e.

a high-powered regulatory rule, while the smaller b, the more responsive prices are to costs, as in a cost-plus contract.

The firm faces a unit demand function and its cost is affected by a random shock c uniformly distributed over $[0, \bar{c}]$, capturing either cost (input prices) or technology contingencies. The firm must invest an amount K, for which it issues a level of debt D and equity E. Hence the firm's investment constraint is given by:

$$K = E + D \tag{20}$$

Ex post, D must be repaid using the net payoff $p - c$. If this falls short of D, the firm suffers a cost of financial distress T, assumed fixed for simplicity. As in Cambini and Spiegel (2011) we assume that external investors (debt holders and new shareholders) are eventually paid in full, and so existing shareholders are responsible for bankruptcy costs T in the case of financial distress. Denote by $\varphi(p, D)$ the probability that the firm finds itself in such a situation, so that its expected cost is $C = \frac{\bar{c}}{2} + \varphi(p, D)T$.

Equation (21) shows the firm's expected total cost C. When the regulated price p is greater than $D + \bar{c}$ (where $\bar{c}$ is the maximum possible cost shock), bankruptcy never occurs. As a result, the expected cost is simply $\frac{\bar{c}}{2}$. Analogously, if $p < D$ then bankruptcy is inevitable regardless of the size of the cost shock c. Only in the intermediate case, in which $D \leq p \leq \bar{c} + D$, is bankruptcy uncertain. In this case, the probability of bankruptcy is given by $\Pr(p - c) < D$, and as p is determined ex ante, this is equivalent to $\Pr(c) > p - D = 1 - \Pr(c) < p - D$. As $c \sim U[0, \bar{c}]$, the probability of bankruptcy is therefore given by $1 - \frac{(p-D)}{\bar{c}}$.

$$C = \left\{ \begin{array}{ccc} \frac{\bar{c}}{2} & if & D + \bar{c} \leq p, \\ \frac{\bar{c}}{2} + \left(1 - \frac{p-D}{\bar{c}}\right) T & if & D \leq p \leq \bar{c} + D, \\ \frac{\bar{c}}{2} + T & if & p < D. \end{array} \right\} \tag{21}$$

The timing is as follows. An exogenous price setting rule of the form $p = a + (1 - b)C$ is announced at stage 0. In stage 1, the regulated firm invests K and chooses its capital structure by issuing an amount of debt D and equity E. At stage 2, given the pre-announced price rule, the firm's cost is revealed, and output and payoffs are realised.

As in Spiegel and Spulber (1994) and Cambini and Spiegel (2011) we assume that the firm's management acts so as to maximize the payoff of existing shareholders. Hence, the management's objective is to choose the mix of debt D and equity E so as to maximise:

$$Y(D) = p(D) - C - R_E E - R_D D \ \text{ s.t. } \ K = E + D \tag{22}$$

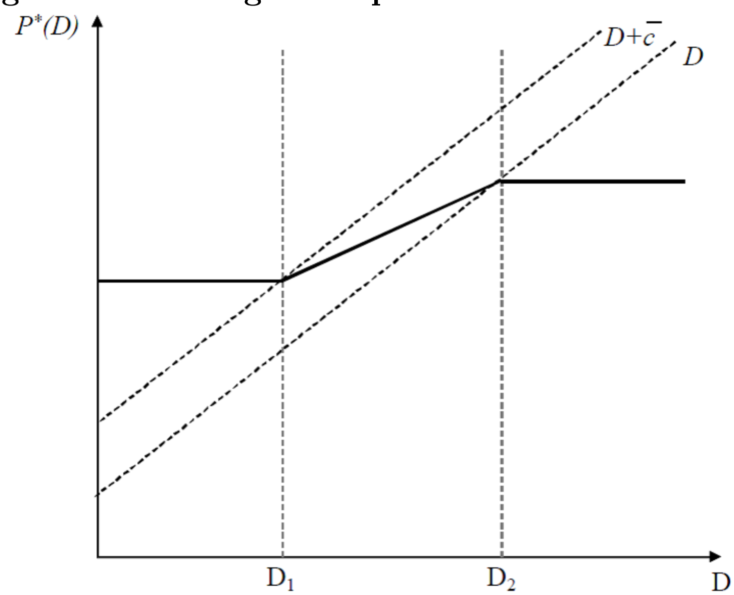
where $R_E \equiv 1 + r_E$ is the cost of equity and $R_D \equiv 1 + r_D$ is the cost of debt. Due to our assumption that existing shareholders remain the residual claimants in the case of financial distress, perfect capital markets and risk neutral investors imply $R_E = R_D$. We relax this below.

From the expected cost C given in equation (21), we can derive the implied regulated prices using the price setting rule $p = a + (1 - b)C$. In the first case, in which bankruptcy never occurs, $C = \frac{\bar{c}}{2}$ and so $p = p_1 = a + (1 - b)\frac{\bar{c}}{2}$. This is the situation whenever $D < p - \frac{\bar{c}}{2}$, and so the price is constant at p_1 until debt reaches the level at which $D = p_1 - \bar{c}$. This level of debt is denoted by D_1. The other extreme, in which bankruptcy is inevitable, is analogous. Bankruptcy is inevitable whenever $D > p$, and so the implied price is constant in this range at $p = p_3 = a + (1 - b)\left[\frac{\bar{c}}{2} + T\right]$. In the intermediate range, the price responds to the threat of bankruptcy, which increases in the chosen level of debt D. The level of debt in this intermediate range is such that bankruptcy is neither impossible ($D < p - \bar{c}$) nor inevitable ($D > p$). This is demonstrated in equation (23).

$$p^*(D) = \left\{ \begin{array}{ccc} p_1 = a + (1-b)\frac{\bar{c}}{2} & if & D < D_1, \\ p_2 = a + (1-b)\left[\frac{\bar{c}}{2} + \left(1 - \frac{p-D}{\bar{c}}\right)T\right] & if & D_1 \leq D \leq D_2, \\ p_3 = a + (1-b)\left[\frac{\bar{c}}{2} + T\right] & if & D_2 < D, \end{array} \right\} \quad (23)$$

where $D_1 = p_1 - \bar{c}$, $D_2 = p_3$, $D_1 < D_2$, and $p_1 < p_2 < p_3$. Figure 3.1 shows how $p^*(D)$ varies with D.

Figure 3.1 The regulated price as a function of debt



Note that the implied price p^*, determined by the ex-ante price setting rule, is a function of the cost shock c, the power of incentives b, and the level of debt D. By choosing D, the firm can influence the regulatory price, but the extent to which it can do so is determined by the power of incentives, b. In this setting, we can prove the following result (for derivations see Appendix C.1):

Proposition 1 *There exists a threshold level of incentives b^* such that $D = D_2$ if $b \leq b^*$ and $D = D_1$ if $b > b^*$.*

That is, if incentives are sufficiently powerful, the firm chooses the lower level of debt D_1. Weaker incentive structures lead the firm to choose the higher level of debt D_2. Intuitively, the firm wants to issue debt to extract higher regulated prices. However, these higher prices only compensate the increased probability of bankruptcy if the share $1 - b$ of cost reimbursed is large enough, leading the firm to choose a level of debt equal to the higher end of the range. The power of incentives here is a simple measure of the responsiveness of the price channel to financial distress. When $1 - b$ is small (as in a high-powered regulation scheme), this responsiveness is low and the equilibrium level of debt chosen is instead equal to the lower end of the range. As such, Proposition 1 tells us that higher powered regulation is likely to translate into a lower level of leverage.

When we allow R_D to deviate from R_E we can show the following (see proof in Appendix C.1):

Proposition 2 *An increase in R_D lowers the threshold level of incentives b^*.*

Intuitively, as the price of debt increases, the share $1 - b$ of the firm's cost reimbursed must be sufficiently high to ensure that higher prices still compensate for the increased probability of bankruptcy. That is, only firms operating under sufficiently low-powered regulation continue to find high levels of debt profitable as debt becomes more expensive.[69] Empirically, we therefore expect that as the cost of debt increases, reductions in debt will be larger amongst firms operating under high-powered regulation.

The model therefore predicts that *leverage will be lower under higher-powered regulation* as the ability to use debt to achieve higher regulated prices is more limited. Additionally, we expect that *firms subject to higher-powered regulation will be more likely to reduce leverage when the cost of debt*

[69] Technically as R_D increases, the threshold b^* falls, implying that among firms with high leverage, the fraction facing the highest-powered incentive will reduce their leverage.

increases. We use this result – Proposition 2 – to motivate our empirical strategy in Section 3.5.

3.2.2 Discussion

Comparison to Spiegel & Spulber (1994)

Our model is in the spirit of Spiegel and Spulber (1994). In particular, the firm maximises profit by choosing levels of debt (D) and equity (E) to satisfy an investment constraint $K = E + D$, with prices ultimately determined by a regulator that is averse to bankruptcy. The model diverges in two principal ways from Spiegel and Spulber. Firstly, in our model the firm takes the required level of investment (K) as given, whereas in Spiegel and Spulber, K is a chosen by the firm. This reflects the different institutional environments being considered: we analyse infrastructure concessions in which the required investment level is stated ex ante by contract, whereas Spiegel and Spulber analyse US utility monopolies in which investment is ongoing and, to some extent at least, is undertaken to stimulate demand.

Secondly, and more fundamentally, the regulator in our model sets a simple pre-announced pricing rule. In Spiegel and Spulber, the regulator sets prices after the firm's capital structure choices, and does so in order to maximise a weighted sum of consumer surplus and firm profits. The firm must therefore act strategically, taking into account the expected actions of the regulator. Again, this divergence reflects the institutional environment. In the US framework of Spiegel and Spulber, there is a legal basis through which the regulator can explicitly balance consumers' and the firm's interests when setting tariffs (see Spiegel and Spulber 1994 p.426). In our Latin American context, the pricing structure is specified ex ante in the project contract, albeit with provisions that allow the regulator to periodically revise tariffs in the event of cost or demand shocks. It is the frequency of these revisions that determine how responsive the regulated price is to changes in costs, such as an increase in the threat of bankruptcy. It is therefore the frequency of these tariff revisions that we use to determine whether regulation is classified as high- or low-powered (see Section 3.4).

The regulatory response to debt

Price is modelled as a function of expected costs, where expected costs include expected bankruptcy costs given by $\varphi(p, D)T$. That is, regulated prices increase as the probability of bankruptcy increases; under high-powered regulation this price response is weaker. Why is it reasonable to think that regulated prices respond to expected bankruptcy costs?

Firstly, there is historical precedent. Ehrhardt and Irwin (2004) provide a number of case studies in which regulators have reacted to the threat of bankruptcy with higher prices or increased subsidies. Such cases include the Melbourne tram and train franchises and the initial toll road concessions in Mexico. They argue that "probably the main reason why governments do not like to see private infrastructure providers go bankrupt is the threat of service disruption" (p.47). Such service disruption could occur either in the transfer of project management to the receivers, or in the more extreme case of liquidation.[70]

As noted by Ehrhardt and Irwin (2004), severe service disruption is in fact generally avoidable. The host government itself often has the power to appoint a receiver to run the company in the event of bankruptcy. Further, liquidation is generally unappealing because infrastructure investments have huge sunk costs; the assets themselves have little value elsewhere. In practice however, governments have generally been reluctant to assume ownership of infrastructure projects; either because they lack the capacity to do so or they fear the legal repercussions of intervention (see Ehrhardt and

[70] Once the company has defaulted on its debt, the debtholder typically has the right to assume management of the company, running the company through a receiver until such debts are repaid. It could instead liquidate the company, selling off the assets and shutting the company down.

Irwin 2004, p.48). They also (incorrectly) tend to associate bankruptcy with liquidation. Such capacity and institutional constraints are likely to be more acute in a developing country context.

A further motivation for avoiding bankruptcy is that it sends negative signals to potential investors regarding the level of risk (Ehrhardt and Irwin 2004). Such signals are amplified by media interest and scrutiny, which is often critical of the government. As argued by Guasch (2004), "accepting concession failures brings political costs" (p.38). We believe it is reasonable therefore to claim that regulators increase prices when the probability of bankruptcy increases, as they have done in the past. It does so to protect its own interests, not because it cares more about the returns of debt holders than of equity holders.

Regulatory commitment

The model in section 3.2.1 assumes that the regulator is committed to the ex ante price setting rule. In practice however, regulatory commitment might be difficult to sustain (see e.g. Moszoro 2013). Importantly, the firm may be able to force a price revision whenever the probability of bankruptcy is high. It is easy to see that the possibility of such a revision pushes the regulation towards a lower-powered scheme. The probability that it then exceeds the threshold b^* increases, making it more likely that leverage is high.

Imperfect commitment presents an empirical challenge. If seemingly high-powered contracts are renegotiated whenever the firm faces financial difficulty, then the importance of the ex ante regulation is undermined. To deal with this problem, we therefore examine the determinants of contract renegotiations in section 3.4. We find no evidence that renegotiations are caused by the likelihood of financial distress. This is reassuring as it suggests that the responsiveness of the price channel to financial distress is indeed weaker under high-powered regulation.

Other channels

Although the model focuses on the channel from regulated prices to leverage, there are other possible mechanisms through which the design of regulation could affect capital structure. Firstly, by transferring greater risk to the firm, high-powered regulation may directly increase the probability of bankruptcy. Under the static trade-off theory of capital structure, this would reduce leverage (all else equal). Our model partially captures this effect, as the probability of bankruptcy increases in b; it does not drive our results as $\frac{\partial \varphi^*}{\partial D}$ is independent of b (see Appendix). Our empirical findings cast doubt on the importance of this mechanism however: revenue volatility is a positive (generally insignificant) determinant of leverage and less profitable firms have higher leverage.

An alternative possibility is that high-powered regulation increases the cost of equity, leading such firms to choose higher leverage. In the Capital Asset Pricing Model (CAPM), the cost of equity is determined by the covariance of the company's returns with the market portfolio. Alexander et al. (1996) find that this covariance is higher in price cap contracts than rate-of-return contracts in regulated infrastructure projects, implying a higher cost of equity. Unlike the previous mechanism, this offsets the predictions of the model. The magnitude of this effect in our sample may not be significant however as almost all contracts include annual tariff adjustments for inflation, and many allow adjustments for exchange rate shocks. Such clauses reduce the extent to which the project's returns are dictated by economy-wide cost shocks. Furthermore, Gaggero (2007) replicates the methodology of Alexander et al. (1996) and does not find that the cost of equity is higher under higher-powered regulation.

3.3 Data

3.3.1 Regulation and financial data

We construct an original dataset of 124 transport concessions in Brazil, Chile, Colombia and Peru over the period 1992-2011. The complete panel – tracking all projects since the year of contract signing – covers 1,360 observations and financial data covers 1,037 observations. Details on the design of price regulation come from project contracts, sector legislation and renegotiation agreements. In addition we have information on the specifics of the projects (investment size, duration, etc.), on the institutional and regulatory environment, the timing and content of renegotiation agreements, as well as the evolution of key economic variables. Table 3.1 provides summary statistics of the main variables. Table C1 in the Appendix provides a full list of variables and sources.

Our principal measure of leverage is the ratio of total liabilities to total assets. The units of observation are project companies (as opposed to project sponsors) which, as argued by Esty (2004), are "strategic research sites" and "provide a new and, potentially, very powerful laboratory to analyse structural decisions and to show why they matter". The fact that project companies are created for a specific and well-defined purpose is greatly beneficial from a research perspective.[71]

Firm-level financial data comes directly from regulatory agencies and from commercial databases. OSITRAN, the Peruvian federal regulator, provided the data for all Peruvian projects and the Agencia Nacional de Infraestructura (ANI) provided data for Colombian road projects. The two commercial databases we use are the ISI Emerging Markets Database of Euromoney Institutional Investor and the Orbis Database of Bureau van

[71] Project companies are created by the "project sponsors" for a specific project. Project sponsors are typically large listed companies with many subsidiaries. The financial accounts of the sponsors therefore tell us little about how leverage responds to regulatory conditions in a specific project.

Dijk.

In Chile, Colombia and Peru all concessions are regulated at the federal level. In Colombia the federal regulator varies across subsectors and across time, whereas in Chile all projects are regulated by the Ministerio de Obras Publicas (MOP) and all Peruvian projects are regulated by OSITRAN. In Brazil concessions are regulated at both the federal and state level. In addition to federal road and rail projects we have data on state-level road projects from Parana and Rio Grande do Sul and rail projects from Rio de Janeiro.

Table 3.1: Summary statistics

	All	Brazil	Chile	Colombia	Peru	Price cap=1	Price cap=0
Observations (Full)	1360	452	441	311	156	1174	186
Observations (Financial)	1037	351	398	147	141	917	120
Projects	124	37	40	23	24	107	17
Leverage	0.69	0.81	0.66	0.52	0.62	0.69	0.62
LT Leverage	0.44	0.43	0.54	0.26	0.31	0.45	0.34
Net Leverage	0.64	0.76	0.63	0.49	0.51	0.65	0.57
Price cap (% obs)	0.86	0.71	1.00	0.82	1.00	1.00	0.00
MIG (% obs)	0.48	0.00	0.80	0.64	0.67	0.56	0.00
Flexible contract (% obs)	0.11	0.00	0.24	0.16	0.00	0.13	0.00
Investment Size ($m, 2000)	268.84	459.56	211.81	140.27	133.79	244.97	419.51
Contract Duration (yrs)	22.57	23.23	22.19	20.38	26.10	22.59	22.44
Return on Assets	0.10	0.10	0.10	0.08	0.10	0.09	0.17
Volatility	0.11	0.13	0.08	0.11	0.11	0.11	0.11
GDP Growth	0.04	0.03	0.04	0.04	0.06	0.04	0.03
Inflation	0.11	0.19	0.06	0.10	0.04	0.07	0.36
Stock Market Value	12.84	22.23	13.45	2.80	3.39	12.17	17.10
Pr. Bond Market Capitalization	11.10	13.67	18.46	0.43	3.78	11.28	9.96
Renegotiations per Project	3.22	1.46	2.73	7.57	2.58	3.57	1.00
Renegotiations per Project-Year	0.29	0.12	0.25	0.56	0.40	0.33	0.09

Mean values reported. MIG stands for Minimum Income Guarantee, Return on Assets is calculated as EBIT/total assets, and Volatility is the standard deviation of ROA by project.

3.3.2 Renegotiations

A renegotiation is considered to have occurred "if a concession contract underwent a significant change or amendment not envisioned or driven by stated contingencies" (Guasch 2004, p.80). There are a total of 399 renegotiations across the sample, with an average of 3.22 per project. The most significant renegotiations occurred in the Brazilian states of Parana and

Rio Grande do Sul. In Parana the state government significantly reduced tariffs in 1998, less than a year after the projects had become operational. This was followed by further renegotiations in 2000 and 2002, which revised tariffs and investment obligations in an attempt to restore the economic-financial equilibrium of the contracts. A similar situation occurred in Rio Grande do Sul, where the state government blocked contractual tariff adjustments and attempted to cut tariffs within a year of the contracts being signed. Again this was followed by multiple renegotiations compensating the firm and attempting to restore economic-financial equilibrium.

Another major set of renegotiations occurred in Chile in 2003/04 with the introduction of the Income Distribution Mechanism (IDM). The IDM guaranteed that firms would receive toll revenues equivalent to annual traffic growth of x% throughout the project (where x = 4, 4.5 or 5% and was chosen by the firm). If the guaranteed revenue was not met, the concession could be extended by up to 10 years, and ultimately the government would be liable for any remaining difference. In exchange for the guarantee, firms were required to carry out additional investments (see Engel et al. 2006 and Vassallo 2006 for further details).

The reasons for renegotiation are shown in Figure 3.2. Almost half are to alter the project's investment plan or schedule, such as the IDM renegotiations in Chile. These renegotiations are typically instigated by the regulator. The firm may seek a renegotiation to compensate for exogenous changes in demand or costs, or due to previous government action ("in the public interest"). Such "public interest" renegotiations include the reduction of tariffs in Parana and Rio Grande do Sul, plus a number of renegotiations in Colombia which lowered road tolls for local residents. The "Other" category consists largely of changes to deadlines of various kinds. The category also includes changes to environmental legislation, changes in the assets of the firm (in lease agreements) and disagreements over taxes and other costs.

Figure 3.2: Reasons for renegotiation

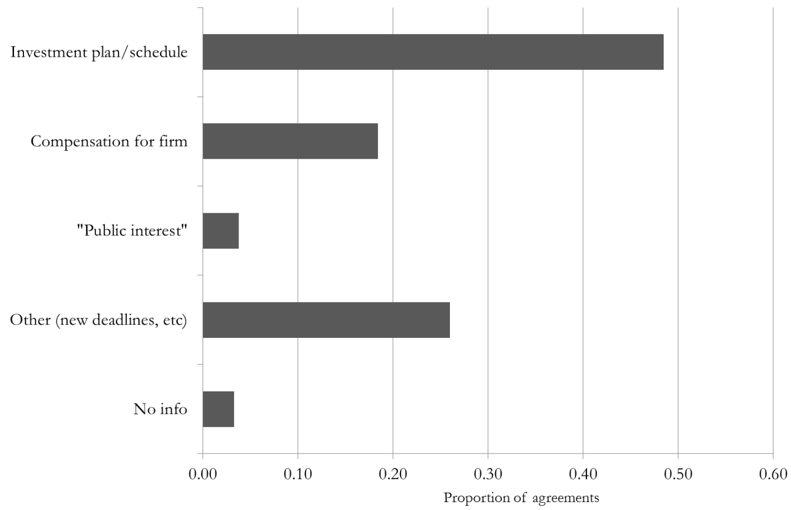
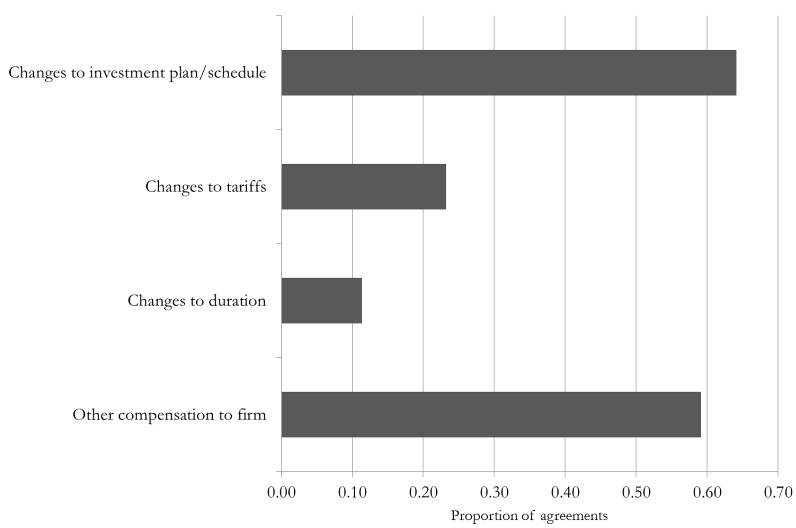


Figure 3.3 shows the outcomes of renegotiations. Again, the most common outcome is a change to the investment plan or schedule. Typically, the firm will agree to increase the volume of investment in exchange for a direct payment from the regulator, an increase in tariffs or an extension of the contract. Indeed, this particular scenario accounts for 38 percent of all renegotiations in the sample. Tariffs themselves are affected by just over 20 percent of renegotiations.

Figure 3.3: Outcomes of renegotiation



3.4 Regulation and renegotiations

As discussed in Section 3.2.2, the de facto regulatory regime is a function of both (i) the project contract, and (ii) the commitment of the regulator to that contract. If the firm can force a renegotiation when the probability of financial distress is high, the regulatory regime becomes less high-powered. Ultimately, the distinction between very high-powered contracts (e.g. price cap) and much lower-powered contracts (e.g. rate of return) could become meaningless. Given the high rate of renegotiation in Latin American infrastructure projects, this is potentially a serious issue. Sirtaine et al. (2005, p.37) argue that in Latin America:

> "The short interval between the granting of a concession and its renegotiation, about two years, and the outcome of the renegotiation process, makes the resulting regime a hybrid of price caps and rate of return... Thus in practice both types of regulatory regime tend to converge to a hybrid."

For our purposes, the key distinction between high- and low-powered regulation is the regulator's responsiveness to the risk of financial distress. In this Section we therefore first outline our classification of regulatory regimes, and then investigate whether renegotiations fundamentally change the incentive structure of the original contracts. In particular, we ask whether high levels of debt or poor financial performance are strong predictors of renegotiation. We show that this is not the case. This means that in our core empirical specification (Section 3.5), we can rely primarily on the project contract for our measurement of regulatory design.

3.4.1 Ex ante regulation

To capture the (ex ante) incentive structure of the contract, we include a dummy variable equal to 1 if the project is subject to price cap regulation. We define a contract as price cap if there is an automatic tariff revision at most every 5 years. Table C2 in the Appendix provides summary details on the rules for revising and adjusting tariffs across projects.

In the context of the sample, this simple classification appears reasonable. In a large number of projects, there are no automatic tariff revisions in the contract. Although some of these projects allow for discretionary reviews, they are essentially pure fixed price contracts. In Peru, a number of projects are RPI-X with revisions every 5 years.[72] As standard therefore, we also classify RPI-X projects as price cap.

A drawback of the sample is that variation in the type of regulation is relatively limited: 14 percent of observations are non-price cap, and this consists of 14 federal road projects in Brazil and 3 port projects in Colombia. The Brazilian projects have tariff reviews every year. The aim of the regulation is to re-establish the ex ante (contracted) internal rate of return (IRR) of the project whenever an event occurs for which the regulator bears the risk (see Veron and Cellier 2010 for details). In the Colombian port projects, tariffs are revised every 2 years. The firm submits a tariff proposal to the regulator, which the regulator can approve or reject. If the proposal is rejected the regulator imposes a "competitive tariff" which ensures an "acceptable" rate of return for the firm.

Although some contract clauses are tailored to individual projects, the design of regulation itself appears to have broader determinants. Guasch et al. (2007) for example consider the determinants of regulatory design in Latin American water and transport concessions. They find that "the choice of regulation appears to hinge mostly on the quality of institutions. Price cap regulation is less likely when the bureaucracy is more efficient, capturing perhaps the enhanced ability of bureaucrats to manage informationally demanding schemes like rate of return regulation" (p.26). This explanation is broadly consistent with the variation in our sample, as the non-price cap

[72] RPI-X regulation consists of periodic price reviews (typically every 5 years) in which a tariff is set that increases at the rate of inflation (RPI) minus a factor X to account for productivity gains.

projects are all regulated at the national level. In Brazil for example the national road concessions are non-price cap, whereas the federally regulated projects are all price cap. Guasch (2004) and Holt (2007) also argue that there are "trends" in the design of regulation, particularly the increased use of price cap following its development in the UK. We therefore do not believe that the non-price cap projects have been allocated such regulation for very specific project-related reasons. Our results are not dependent on regulation being randomly assigned however; indeed we analyse how leverage changes over time *within projects* to deal with the possible endogeneity of regulation.

3.4.2 Determinants of renegotiation

Having established an ex ante classification of regulatory regimes, we now ask whether renegotiations fundamentally alter this classification. In particular, we are interested in whether renegotiations are a response to poor financial performance. If the firm can renegotiate when there is a risk of financial distress, then the incentive to use leverage to gain higher prices may be just as strong under high-powered regimes as low-powered regimes.

To test this, we create a renegotiation dummy R_{ijnt} equal to 1 if concession contract i in sector j in country n at time t is renegotiated. We regress this on three alternative measures of poor financial performance or distress. The first is the leverage ratio, the second is a "distress" dummy equal to one if the firm has a working capital ratio less than 0.5, and the third is a "poor performance" dummy equal to 1 if the firm has return on assets (ROA) more than 1 standard deviation below the mean for its country.[73]

[73] The working capital ratio is defined as current assets divided by current liabilities. A ratio below 1 is typically used as an indicator of liquidity problems. Given the highly leveraged nature of project finance transactions however, a ratio below 1 is extremely common. We therefore choose a more extreme ratio of 0.5. Even at this level, over a third of observations classify as being in "distress".

We run the following linear probability model:

$$R_{ijnt} = \gamma_1 fin_{it} + X'_{ijnt}\gamma_2 + \delta_i + \delta_t + e_{ijnt} \tag{24}$$

where R_{ijnt} is the renegotiation dummy, fin_{it} is the measure of financial performance for firm i in year t and X_{ijnt} is the vector of controls used by Guasch et al. (2007) in their study of renegotiations in Latin America. Specifically, X_{ijnt} consists of project age, a price cap dummy, a measure of bureaucratic quality, a lagged election dummy, and lagged GDP growth. To estimate the effect of these variables on renegotiation, for comparison with the Guasch et al. study, we first run the model with country and sector fixed effects. We then re-estimate the model using project fixed effects δ_i.[74]

The results are presented in Table 3.2. Whether we use country and sector fixed effects, columns (1) to (3), or project fixed effects, columns (4) to (6), none of the financial performance variables are significant. Firms with higher leverage and weaker profitability are no more likely to experience renegotiations than others. Of the Guasch et al. control variables, there is some evidence that price cap contracts are more likely to be renegotiated. This is largely driven however by the Brazilian federal road projects, which are non-price cap and include provisions in the contract for regular investment adjustments (see also Veron and Cellier 2010). In such projects the investment programme changes frequently, but it is not considered a renegotiation (bringing down the rate of renegotiation amongst non-price cap projects). As in Guasch et al. (2007), bureaucratic quality reduces renegotiation, and older projects appear less likely to be renegotiated (the project age variable being highly significant when year fixed effects are excluded).

In Appendix C.3 we replicate the Guasch et al. methodology by estimating equation (24) by random effect probit (Table C3).

[74]Most of the Guasch et al controls are removed by the project fixed effects. Those that remain are insignificant and do not affect the results of interest.

Table 3.2: Determinants of renegotiation

	(1)	(2)	(3)	(4)	(5)	(6)
Leverage	0.056			0.063		
	(0.075)			(0.046)		
Distress		-0.003			0.033	
		(0.010)			(0.036)	
Performance			0.041			0.111
			(0.049)			(0.081)
Guasch et al (2007) controls						
Project age	-0.007	-0.008	-0.010			
	(0.005)	(0.006)	(0.005)			
Price cap	0.114	0.143**	0.124*			
	(0.057)	(0.030)	(0.051)			
Bureaucratic quality	-0.224**	-0.244***	-0.233**			
	(0.041)	(0.027)	(0.042)			
Election (-1)	-0.041	-0.048	-0.019			
	(0.020)	(0.025)	(0.023)			
GDP growth (-1)	0.021	0.016*	0.024			
	(0.010)	(0.007)	(0.012)			
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Sector & country	Sector & country	Sector & country	Project	Project	Project
Observations	981	946	878	983	948	879
R-squared (within)	0.09	0.09	0.1	0.06	0.07	0.08

Robust standard errors (clustered by country in columns 1-3 and by project in columns 4-6) in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Such results are only indicative. They do not imply that firms cannot renegotiate when in financial difficulty; only that being in difficulty does not increase the likelihood of renegotiation. To address this, we can look in more detail at those firms that have particularly high leverage, or particularly poor profitability, and analyse the renegotiations that occur. That is, we can explicitly check the renegotiation agreements for evidence that firms in difficulty achieve favourable renegotiations.

We found little evidence that this is the case. Take the Distress variable used in Table 3.2 for example. This is a dummy equal to 1 if the firm has a working capital ratio less than 0.5. There are 342 project-year observations in which this variable equals 1, and 70 of these observations involve a contract renegotiation. Based on the renegotiation agreements however, we classify only 14 of these as being to financially compensate the firm (as in Figure 3.1). In each of these cases, compensation mechanisms were agreed only because of previous breach of contract by the regulator, which disadvantaged the firm. The vast majority of the renegotiations occurred to change the investment works and schedule. Whilst this could in principal be a way to financially assist the firms, analysing the text of the renegotiation agreements suggest that this is not the case.[75]

Across our sample therefore, it does not seem that contracts are systematically renegotiated when firms face financial difficulty. This reduces the concern that the different regulatory regimes "converge to a hybrid", and suggests that regulators perhaps do a better job than often recognised in enforcing price caps. For our purposes, it suggests that the transmission from debt to prices is indeed weaker under high-powered contracts. For our empirical methodology we can therefore concentrate on the regulatory design as specified in the project contracts.

3.5 Methodology

We return now to our primary question: what is the effect of regulatory design on the leverage of the project companies? Building on the previous Section, we use our price cap dummy to capture the power of the regulation. Our initial specification is given by:

$$l_{ijnt} = \beta_1 pc_i + F_{it}'\beta_2 + M_{nt}'\beta_3 + \delta_j + \delta_n + \delta_t + \epsilon_{int} \tag{25}$$

where l_{ijnt} is the leverage of firm i in sector j in country n at time t; pc_i is the price cap dummy; F_{it} is a vector of financial controls for firm i at time t; M_{nt} is a vector of macroeconomic controls for country n at time t; and δ_j, δ_n and δ_t are sector, country and year fixed effects respectively.

[75] Many of the changes to investment and works appear quite "benign", such as ammending works to improve traffic safety and modifying investment plans under community pressure.

We also show that the results are not affected by replacing the sector and country fixed effects with sector-country fixed effects δ_{jn}.

The control variables F_{it} and M_{nt} are standard in the capital structure literature. The firm-level financial variables F_{it} consist of ROA, $volatility$, log of $assets$ and the ratio of fixed to total assets (as a measure of "$tangible$" assets).[76] When ROA is higher, the probability of financial distress is lower, which should increase the availability of debt (Rajan and Zingales 1995, Frank and Goyal 2009). If the "World Bank view" is correct, that firms prefer as much debt as creditors will allow, we expect this variable to be positively correlated with leverage.[77] For much the same reasons $volatility$, defined as the standard deviation of ROA, is expected to be negatively correlated with leverage. Larger firms, captured by $assets$, may be less susceptible to revenue swings and so have a greater appetite for debt, as the probability of distress is lower. Finally *tangible* assets retain value in the event of bankruptcy, increasing the firm's ability to borrow (Rajan and Zingales 1995).

The macro variables M_{nt} are particularly relevant to an emerging market context, in which firms face supply-side constraints. We expect GDP $growth$ to boost leverage if firms are able to borrow against future growth prospects (Booth et al. 2001). Similarly the *bond market* capitalization to GDP ratio increases the supply of debt, whilst the *stock market* value to GDP ratio increases the supply of equity. As in Booth et al. (2001) and De Jong et al. (2008) we expect larger bond markets to increase leverage, and larger stock markets to reduce leverage.

The principal concern with equation (25) is that regulation is not randomly assigned. As an example, it is reasonable to suppose that firms bidding for price cap contracts are less risk-averse than those bidding for rate-of-return contracts. Being less risk-averse, these firms may also prefer

[76] Volatility is the standard deviation of ROA by project.

[77] The "World Bank view" is a variant of the static trade-off theory. The traditional rival view is the pecking order hypothesis, which predicts that ROA will be negatively correlated with leverage.

debt financing. This selection problem will bias β_1 upwards in equation (25), offsetting the true effect of price cap regulation (if that is negative as argued in Section 3.2). Similarly, price cap contracts may be systematically assigned to less risky projects. Again, this could generate a spurious (positive) relationship between price cap regulation and leverage.

To deal with this selection issue, we introduce project fixed effects and analyse the response of firms to changes in the cost of debt. The fixed effects control for selection issues by analysing changes *within* projects once contracts have already been assigned. We use the country's lending interest rate as our cost of debt measure as this is plausibly exogenous to the firm's actions. The lending rate is collected by the IMF as a representative interest rate offered by banks to resident customers. It is considered to be the rate that usually meets the short- and medium-term financing needs of the private sector. Although in practice the interest rate charged to each firm will include a firm-specific default risk, this risk will be partly determined by the firm's leverage ratio. By using country-level interest rates, we are able to focus only on those shocks that are exogenous to the firm.

The model presented in Section 3.2 predicts a greater reduction in leverage amongst firms subject to price cap regulation when there is an increase in the cost of debt. We therefore expect the interaction between price cap and the interest rate to be negative in the following regression:

$$l_{ijnt} = \vartheta_1 r_{nt} + \vartheta_2 pc_i * r_{nt} + F'_{it}\vartheta_3 + M'_{it}\vartheta_4 + \delta_i + \delta_t + \sigma_{ijnt} \qquad (26)$$

where r_{nt} is the lending interest rate in country n in year t; F_{it} and M_{nt} are the financial and macro controls as above; δ_i and δ_t are project and year fixed effects respectively; and σ_{ijnt} is the error term. We being by running equation (26) using the leverage ratio as the dependent variable l_{ijnt}. When the interest rate r_{nt} changes however, this will change the firm's future earnings expectations, which in turn will affect their leverage decision. It is likely that firms expect lower growth in subsequent periods when the interest rate increases. If this is the case, then the firm's demand for equity will also change (Frank & Goyal 2009). As well as using the leverage ratio as our dependent variable in equation (26), we therefore also estimate this model using the log of liabilities as the dependent variable. This provides a potentially cleaner way to test the relative effect of the cost of debt on price cap and non-price cap firms.[78]

3.6 Results

Table 3.3 presents the baseline results from equation (25). Columns (1) and (2) include sector and country fixed effects, and columns (3) to (4) include sector-country fixed effects. Although the latter approach better controls for omitted variables, it substantially reduces the available variation in regulation. Columns (2) and (4) exclude extreme outliers, defined as an observation where the leverage ratio is 3 standard deviations above the relevant country mean. It is common to exclude such observations in all specifications (e.g. Booth et al. 2001), but here we prefer to present results for both the full and smaller sample.

The first row shows that the price cap dummy is insignificant in all specifications, which may reflect some of the selection concerns discussed above. Of the remaining variables, the negative coefficients on ROA and the country's stock market value are particularly notable. These results are at odds with the view of many infrastructure practitioners that firms have a strong preference for debt over equity (World Bank Institute 2012). Instead we find that when profitability is higher, and so debt availability should be greater, firms reduce their leverage.[79] The negative impact of profitability on leverage is now well established in the empirical literature

[78] In this case, we drop the natural logarithm of real assets as this consists of liabilities plus equity. We would still expect the size of the firm to have a significant impact on total liabilities however, and so we replace the variable with the natural logarithm of real revenues.

[79] We note however that the positive coefficients on *size* and *GDP growth* lend some support to the "World Bank view".

(Frank & Goyal 2009) and lends support to the pecking order theory of capital structure (Myers 1984). Likewise, as stock markets develop, and so equity availability is greater, firms reduce leverage. If the trade-off theory were correct, we would not expect such a significant (negative) role for stock market development. Our results suggest that supply-side constraints are actually stronger with regards to equity than debt.[80]

Table 3.3: Baseline estimations - Regulation and leverage

	(1)	(2)	(3)	(4)
Price cap	0.033	0.019	0.040	0.068
	(0.059)	(0.054)	(0.077)	(0.060)
Firm-financial controls (F)				
ROA	-0.351*	-0.197**	-0.370*	-0.203**
	(0.202)	(0.079)	(0.206)	(0.081)
Volatility	0.296	0.091	0.438*	0.124
	(0.223)	(0.166)	(0.256)	(0.157)
Size	0.019	0.054***	0.016	0.057***
	(0.024)	(0.017)	(0.027)	(0.017)
Tangible	-0.089	0.009	-0.104	-0.004
	(0.085)	(0.077)	(0.085)	(0.078)
Macro controls (M)				
GDP growth	0.015*	0.014***	0.015**	0.014***
	(0.008)	(0.005)	(0.008)	(0.005)
Bond market	-0.007	-0.003	-0.007	-0.003
	(0.008)	(0.004)	(0.008)	(0.004)
Stock market	-0.005*	-0.006**	-0.006*	-0.006**
	(0.003)	(0.003)	(0.003)	(0.003)
Year effects	Yes	Yes	Yes	Yes
Fixed effects	Sector & country	Sector & country	Sector-country	Sector-country
Observations	815	803	815	803
Projects	111	111	111	111
R-squared (within)	0.09	0.23	0.09	0.23
R-squared (between)	0.38	0.27	0.40	0.34

The dependent variable is the ratio of total liabilities to total assets (book values). Robust standard errors (clustered by firm) in parentheses. Columns (2) and (4) exclude extreme outliers.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

[80] If the price cap variable is endogenous as argued, then in general all the coefficients will be inconsistent. The coefficients on the control variables are almost unchanged when we re-estimate the regression without the price cap variable however.

Table 3.4 presents the results from the fixed-effects regression (26). Column (1) uses leverage as the dependent variable, and columns (2) to (4) use log liabilities as the dependent variable. Column (3) lags the interest rate one period, and column (4) additionally drops outliers as above.[81]

In all columns the interaction between the interest rate and price cap dummy is negative and significant. When the cost of borrowing increases, price cap firms reduce leverage more than others. This interpretation is strengthened when we use log liabilities as the dependent variable, as the interest rate itself also enters negatively. (As argued above, the inclusion of equity in the calculation of leverage makes it difficult to predict the effect of interest rate changes on leverage.) These results support the predictions of the model, and suggest that firms operating under price cap have a lower demand for debt than those operating under less high-powered regulation.

The control variables enter similarly to Table 3.3. Again, it is notable that the ROA is negative in all specifications, and highly significant when log liabilities are the dependent variable. The country stock market value is again negative and highly significant, whereas bond capitalization is insignificant throughout. As we might expect in an emerging market sample, these results suggest that firms face supply-side barriers to achieving their desired capital structure. Again it is notable that such barriers appear particularly strong for accessing equity.

[81] The results are generally stronger when using log(liabilities) as the dependent variable. If we replicate columns (3) and (4) using leverage as the dependent variable the interaction term is not significant. The results are omitted in the Table for brevity.

Table 3.4: Fixed effects estimations – Cost of debt and leverage

	(1)	(2)	(3)	(4)
	leverage	ln (liab.)	ln (liab.)	ln (liab.)
Interest	0.002	-0.004	-0.016**	-0.018**
	(0.003)	(0.009)	(0.008)	(0.008)
Interest * Price cap	-0.005*	-0.015**	-0.016**	-0.015*
	(0.003)	(0.007)	(0.008)	(0.008)
Firm-financial controls (F)				
ROA	-0.267	-1.472***	-1.527***	-1.750***
	(0.218)	(0.442)	(0.441)	(0.511)
Size	0.001	0.307***	0.306***	0.312***
	(0.047)	(0.105)	(0.104)	(0.104)
Tangible	0.022	1.372***	1.312***	1.312***
	(0.109)	(0.401)	(0.384)	(0.386)
Macro controls (M)				
GDP growth	0.017**	0.041*	0.037	0.036
	(0.008)	(0.024)	(0.023)	(0.023)
Bond market	-0.007	0.018	0.019	0.016
	(0.009)	(0.014)	(0.014)	(0.014)
Stock market	-0.007**	-0.022**	-0.034***	-0.033***
	(0.003)	(0.010)	(0.012)	(0.012)
Year effects	Yes	Yes	Yes	Yes
Fixed effects	Firm	Firm	Firm	Firm
Observations	815	772	772	760
Projects	111	108	108	108
R-squared (within)	0.09	0.35	0.36	0.38

Robust standard errors (clustered by firm) in parentheses. The dependent variable in column (1) is the ratio of total liabilities to total assets (book values). In columns (2) to (4) the dependent variable is ln(liabilities). Column (3) replaces the interest rate with its lag, and column (4) replicates column (3) but excluding extreme outliers. In column (1) "size" is the log of total assets, which is replaced by the log of revenues in columns (2) to (4)
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

3.7 Conclusion

PPPs and concession contracts have become a popular mechanism for delivering major infrastructure projects. The understanding of how such projects are financed, and why, is still relatively limited however. It has been argued that private investors use leverage to secure higher prices, which is feasible when prices increase with expected costs, including possible bankruptcy costs. In practice, prices may respond to such costs if the regulator wants to avoid bankruptcy. Ehrhardt and Irwin (2004, p.47) argue that "probably the main reason why governments do not like to see private infrastructure providers go bankrupt is the fear of service disruption". We present a simple model that captures this idea. The model shows that when regulation is high-powered, such as under a fixed price or "price cap" regime, this price incentive for leverage is weakened. We therefore expect firms operating under price cap contracts to have less demand for debt, all else equal.

To test this we construct a unique database of 124 transport concessions in Brazil, Chile, Colombia and Peru. We source data on financial structure, the design of regulation (from contracts and sector legislation) and contract renegotiations. Following the model, we find that price cap firms reduce debt faster than others when the cost of debt increases. We conclude that, all else equal, high-powered regulation reduces leverage.

Our paper makes two further contributions. Firstly, we contribute to the scarce evidence base on the financing of infrastructure projects in developing and emerging markets. By sourcing financial statements directly from regulatory agencies we are able to create a panel of over 1,000 observations and analyse within-project variation. In doing so, we question some of the prevailing logic including the view that infrastructure investors have a strong preference for debt over equity (World Bank Institute 2012). If this were true, we would expect leverage to increase in profitability as it is easier for firms to meet lenders' requirements (Yescombe 2007). Instead, we find that leverage falls in profitability. This in fact suggests that the pecking order hypothesis may be more relevant to infrastructure firms than the commonly held trade-off theory. We also find that leverage falls as stock markets become more developed.

Secondly, we contribute to the literature on incomplete contracting and renegotiation. The high frequency of renegotiation in Latin American concessions has been identified elsewhere (e.g. Guasch 2004, Guasch et al. 2007) although the role of financial performance in triggering renegotiations has not been explored. We provide what is perhaps encouraging evidence: financial performance does not appear to be a significant predictor of renegotiation. This reduces the concern that regulation varies on paper but not in practice. That is, price cap contracts appear to still be high-powered despite pervasive renegotiations.

Our results provide useful insights for regulators concerned about capital structure and prudent financial management. Given that PPPs represent sizeable investments, particularly for developing countries, even small improvements in financial management can lead to substantial cost savings. It is therefore important to understand the motivations underlying firm's financial decisions and how they respond to changes in the policy environment. This paper provides new evidence in that direction.

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5 Appendices

A Chapter 1

A.1 Maps

Figure A1 shows the Admin Level 1 regions used in the empirical work. Boundaries are taken from Natural Earth, available as a .shp file at http://www.naturalearthdata.com/downloads/

Figure A1: Admin 1 regional boundaries

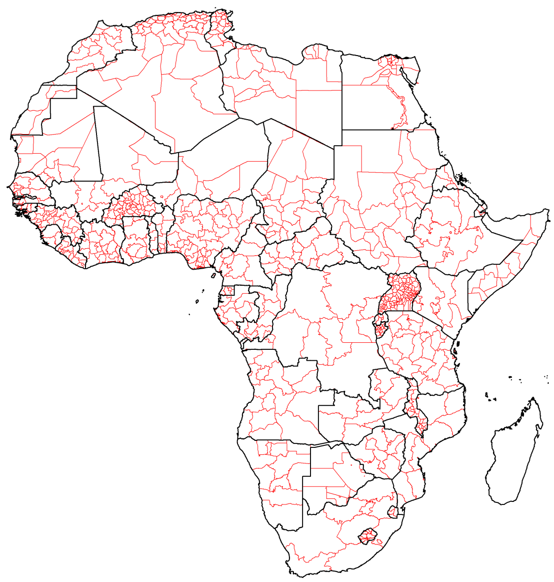
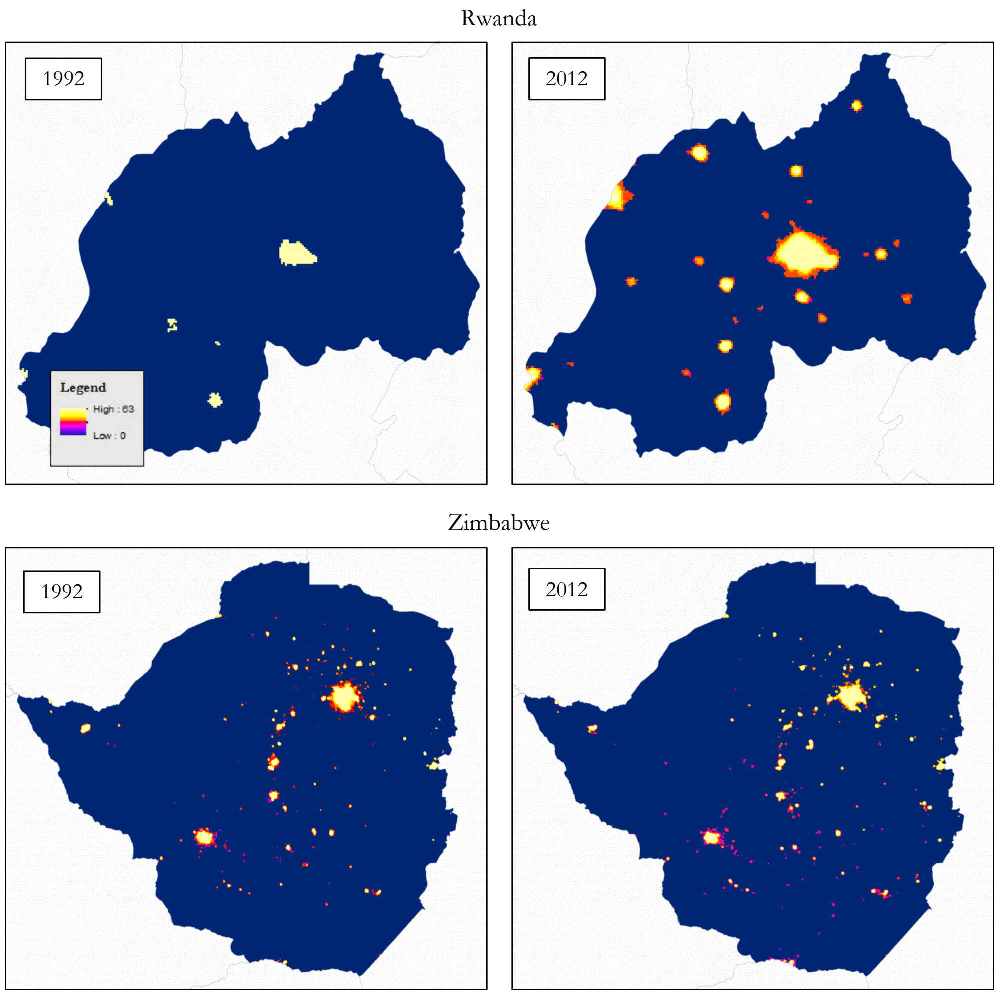


Figure A2 presents light output for Rwanda and Zimbabwe for 1992 and 2012. As evident in the figures, Rwanda witnessed rapid growth over the period, with real GDP growing by an average of 4.7% per year.[82] Zimbabwe suffered an overall decline in output over the period, with an average growth rate of -0.5% per year. The contrast in lights growth compared to Rwanda

[82] Calculated using a compound growth rate on World Bank *World Development Indicators* figures in constant $2005. Growth of GDP per capita was somewhat slower over the period at 1.8% per year. In Zimbabwe, GDP per capita declined by an average of 1.6% per year.

is clear from the Figure (it is also notable from the lights output that Zimbabwe started from a much higher base, with GDP per capita more than twice as high as Rwanda's in 1992).

Figure A2: Lights growth, Rwanda and Zimbabwe



A.2 Robustness checks

The robustness checks re-estimate the main regression of interest - equation (14), Table 1.4 - but modify the sample in the following ways: column (1) removes the 10 km buffers around country borders; column (2) includes domestic conflict years; column (3) includes domestic regions in the calculation of $\widehat{IMA}$; column (4) includes North African regions in the calculation of $\widehat{IMA}$; column (5) recalculates $\widehat{IMA}$ using the gravity estimates of Head and Mayer (2015); column (6) restricts the sample to regions that have a positive light reading in every year; column (7) drops all observations from 1992; and column (8) drops countries with a population below 5 million in 2000. All columns include a region-specific time trend.

Table A3: Robustness checks
Regional output and market access (1992-2012)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: OLS (CYFE)								
$\ln(\widehat{IMA}_2)$	0.658**	0.746***	0.656**	0.662**	0.965**	0.641***	0.696***	0.462*
	(0.272)	(0.206)	(0.272)	(0.273)	(0.419)	(0.225)	(0.255)	(0.251)
Obs.	8,956	9,565	8,956	8,956	8,956	7,046	8,623	7,081
Regions	508	508	508	508	508	360	508	401
R-Squared	0.75	0.75	0.75	0.75	0.74	0.82	0.74	0.76
Panel B: PPML (CYFE)								
$\ln(\widehat{IMA}_3)$	0.903**	0.946***	0.897**	0.891**		0.833***	0.923**	0.624*
	(0.392)	(0.278)	(0.392)	(0.391)		(0.312)	(0.365)	(0.366)
Obs.	8,956	9,565	8,956	8,956		7,046	8,623	7,080
Regions	508	508	508	508		360	508	401
R-squared	0.75	0.75	0.75	0.75		0.82	0.74	0.76

Robust standard errors (clustered by region) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

B Chapter 2

B.1 Transit Routes & Disruptions

This Appendix provides details on the transit routes used by each landlocked country, together with evidence of disruptions caused by conflicts. As in other studies, e.g. Arvis et al. (2011), it is helpful to classify the continent into Eastern, Southern, Central and Western regional blocks. The Eastern landlocked countries are Burundi, Rwanda, and Uganda. The Southern landlocked countries are: Botswana, Lesotho, Malawi, Swaziland, Zambia and Zimbabwe. The Central landlocked countries are: Chad and Central African Republic. The Western landlocked countries are: Burkina Faso, Mali, and Niger.

Eastern

The Eastern countries of **Burundi**, **Rwanda** and **Uganda** are connected to Dar es Salaam on the Central Corridor and Mombasa on the Northern Corridor (UNCTAD 1994, Hoyle and Charlier 1995, Faye et al. 2004, Arvis et al. 2011). The Northern Corridor passes through both Uganda and Rwanda through to Burundi; Faye et al. (2004) describe the route as the region's "umbilical cord".[83] Reflecting relative distances, Burundi's traffic is concentrated on Dar es Salaam, Uganda's on Mombasa, and Rwanda makes heavy use of both corridors. Data collected from port authorities for example shows that over 1998-2010, the average proportions of traffic on the Central Corridor for Burundi, Rwanda and Uganda were 84 percent, 32 percent and 3 percent respectively.[84]

[83]Within the Northern Corridor there are both road and rail options, although the all-road route handles the vast majority of transit traffic (UNCTAD 1994).

[84]That is, 84% of Burundi's transit traffic used the Central Corridor and 16% used the Northern Corridor (analogously for the other countries). I am grateful to Olivier Hartmann for providing this data.

As the Northern Corridor passes through all three of the region's landlocked countries, civil wars in Uganda and Rwanda are considered to be instances of conflict on a major transit route. As noted by Faye et al. (2004), "Rwanda's recent brutal civil war [...] rendered the country's infrastructure virtually impassable not only for Rwandan transit, but for Burundian transit as well" (p.57). UNCTAD (1994) similarly argue that "it is now a major policy of all the [Eastern] landlocked countries to diversify their transport routes and modes, both for economic reasons and to enhance transit security in the light of the recurrent incidence of civil strife which renders some of the traditional routes impassable" (p.7).

Southern

Botswana's transit is predominantly via South Africa (UNCTAD 1995). It is connected via the North-South Road Corridor, benefiting from high-quality paved surfaces (UNCTAD 1995, Briceño-Garmendia and Pushak 2011). Following the North-South Corridor is Botswana's single railway line, connecting to both the South African railway system (Spoornet) and the National Railways of Zimbabwe (NRZ). With exports heavily concentrated in diamonds, air transport also plays a significant role (UNCTAD 1995, Faye et al. 2004). Botswana now benefits from an additional transit route along the Trans-Kalahari Corridor to Walvis Bay, Namibia (Arvis et al. 2011), although this corridor was not completed until 1998.

Malawi's traditional transit routes were to the ports of Nacala and Beira (Mozambique) by rail. Indeed, prior to the Mozambican civil war, Malawi relied almost exclusively on such routes (Kennedy 1988, World Bank 1988). As a result of the conflict, the line to Nacala closed in July 1985 and the line to Beira closed in December 1983 (World Bank 1988). Commercial operations began on the Nacala route in 1993, and a road route to Beira was opened in 1995 (World Bank 1995). The rail line to Beira is still out of service.

Kennedy (1988) shows that 95 percent of Malawian overseas transit was diverted to South African routes. Avoiding Mozambique completely meant a road journey to Lusaka, and use of Zambian routes to South Africa (i.e. through Zimbabwe). This involved a total journey of around 3,500 km (World Bank 1988). Alternatively, passage through the Mozambican region of Tete to Zimbabwe was possible in armed convoys, although terrorist attacks were frequent. This limited the total distance to 2,667 km. Until 1984, access to Dar es Salaam was via road to Lusaka, meaning the total distance was in excess of 3,000 km (World Bank 1988). A gravel road connected Malawi with Mbeya (Tanzania) in 1984, with a connection to the TAZARA railway reducing the distance to Dar es Salaam to 1,770 km. Numerous problems with this route however, including poor road infrastructure and limited freight competition, meant that it played a minor role during the Mozambican conflict (see Kennedy 1988 for details).

Kennedy (1988) estimates Malawi's additional transport costs during the Mozambican conflict in the region of $100 million per year. Table B1 demonstrates the cost difference between the traditional routes through Mozambique and those through South Africa.

Table B1: Transport costs from Blantyre, MK per ton (1988)

	via Durban	via Beira or Nacala
Tobacco in container	310	90
Tea in container	270	85
Sugar in bags	225	60
Diesel	440	45
Petrol	520	75

Source: World Bank (1988)

Swaziland has direct road and rail connections to the port of Maputo in Mozambique and Durban in South Africa. Prior to the Mozambican conflict, almost all of Swaziland's exports went by rail to Maputo (World Bank 1978). This connection remained open during the conflict, although only during daylight hours. The World Bank (1989) noted that "the line [to Maputo] is in poor condition and is frequently closed because of security problems". An additional rail connection to Maputo via Komatipoort (South Africa) was completed in 1986, avoiding some of the most dangerous areas (Kennedy 1988). This too was only operational during daylight hours however, and subject to service disruptions. Hence, during the conflict substantial traffic was diverted to South African ports (World Bank 1989).

At independence in 1964, **Zambia's** coastal access was almost exclusively via Rhodesia (Zimbabwe) to the ports of Beira and Maputo in Mozambique (Mwase 1987, Gleave 1992). Coastal access was also available through Congo and Angola (the latter on the Benguela Railway), although such routes were little used due to agreements made with Rhodesia Railways during the colonial period. The link to Dar es Salaam was unpaved and carried little traffic (Gleave 1992). The Rhodesian unilateral declaration of independence in 1965 however, and subsequent oil embargo, dramatically increased the significance of the northern routes. In 1968 the TAZAMA oil pipeline was completed, and in 1972 the TANZAM Highway was completed; both connecting Ndola with Dar es Salaam. By the early 1970s, only 50 percent of Zambia's exports and imports were via Zimbabwe (Mwase 1987).

In 1973, the border with Rhodesia was closed and Zambia's traditional transit routes were blocked. The closure was imposed by the Rhodesian government in response to Zambian support for rebel groups during the civil war (Mwase 1987). Loss of rail access to the south meant that Zambia's external transit was split between Angola, on the Benguela Railway, and Tanzania on the TANZAM Highway. Guerrilla activity forced the closure of the Benguela rail link in August 1975.[85] In the same year, the TAZARA rail link to Dar es Salaam was completed. Between 1975 and 1978 therefore, the Dar es Salaam corridor was Zambia's only major transit route to the

[85] 1975 marked the beginning of the Angolan civil war, defined as 1,000 or more deaths per year.

coast (Hoyle and Charlier 1995).

In October 1978 Zambia partially reopened the southern routes through Zimbabwe, and such routes were opened completely following Zimbabwean independence in 1980 (Mwase 1987). Zambia's transit routes via Mozambique were therefore completely blocked during the Zimbabwean civil war (1973-1979).

Zimbabwe's shortest transit routes are by rail to Beira and Maputo in Mozambique. The line to Maputo closed in 1984 due to the Mozambican conflict (World Bank 1989), although the line to Beira remained open throughout. The Beira line was guarded by Zimbabwean and Mozambican troops, although incidents of terrorism and sabotage were common (Kennedy 1988, World Bank 1989).[86] The World Bank (1990) noted that "full use of these lines [through Mozambique] has been severely handicapped by armed bandit attacks and deterioration of facilities. As a consequence, Zimbabwe's trade has become heavily dependent upon the relatively long and costly rail routes through RSA". The report estimated potential savings of $65 million for Zimbabwe in 1988, based on rerouting flows through Mozambique from South Africa. A later World Bank study (1999) estimated the combined transport costs for Mozambique's neighbours, as a result of the civil war, to be in the region of $200 million per year.

Central

The two Central African countries – **Chad** and **Central African Republic** – rely overwhelmingly on transit routes through Cameroon, with over eighty percent of overseas trade now using the port of Douala (Teravaninthorn and Raballand 2006, UNCTAD 2007). Historically, the road/river/rail route to Pointe Noire (Congo) provided an alternative route for both landlocked countries. Specifically, the route involves: road from Ndjamena

[86] Gleave (1992) argues that "a systematic campaign was waged by MNR [Mozambican National Resistance] to cut all motor roads and railways as well as vital bridges linking Zimbabwe to the ports of Beira and Maputo...So successful was MNR that Zimbabwe deployed about 12,000 soldiers in Mozambique to defend the route to Beira" (p.252).

(Chad) to Bangui (Central African Republic), Oubangui-Congo rivers to Brazzaville along the Congo-Democratic Republic of Congo border, then rail to Pointe Noire. The river route is slower but cheaper than that through Cameroon, and was traditionally preferred for the transit of bulk, low-value commodities (UNCTAD 1995, Bakhache et al. 2006).

The river route has dramatically declined in importance, with freight volumes falling by 92 percent between 1985 and 2000 (UNCTAD 2007). There is some disagreement in the literature as to the reasons for this decline, with Bakhache et al. (2006) and Faye et al. (2004) both noting the effects of security problems and pirating along the route owing to instability in the Democratic Republic of Congo. Likewise, Collier (2008) argues that "[Central African Republic's] lifeline should be the Oubangui River...but, unfortunately, downstream from the Central African Republic was an area nominally part of the Democratic Republic of the Congo - civil war territory, and hence lawless. So the river could not be used and the logs were sent by road" (p.55). Other authors however have noted a decline in water levels along the river, which is only navigable for 8 months of the year (UNCTAD 1995, Faye et al. 2004, UNCTAD 2007). The route is considerably longer for Chad, including a 500 km road journey to Bangui, and had lost all market share by the early 1990s (Teravaninthorn and Raballand 2009).[87] In the Central African Republic however, the route still accounted for a considerable proportion of transit traffic until the late 1990s (Bakhache et al. 2006).

Western

Finally, the Western landlocked countries – **Burkina Faso**, **Mali** and **Niger** – are afforded the most transit options, with 5 coastal countries to the south, and Senegal serving Mali to the west. Two international rail networks serve the landlocked countries; Sitarail, connecting Ouagadougou

[87] Chad also benefits from an alternative road route to Lagos (UNCTAD 1995, Arvis et al 2011).

to Abidjan, and Transrail, connecting Bamako to Dakar. Both lines were constructed during the French colonial period, and have recently been privatized (Sitarail in 1995 and Transrail in 2003) (see Bullock 2009 for details). As noted by Chowdhury and Erdenebileg (2006), the Western landlocked countries have largely maintained their traditional routes through Francophone neighbours. Despite the port of Tema being closer to Ouagadougou than Abidjan for example, Ghana has until recently captured only limited transit flows from Burkina Faso (see UNCTAD 1995 for a discussion).

Prior to the recent conflict in Cote d'Ivoire, the vast majority of overseas exports from Burkina Faso and Mali went through Abidjan.[88] In 2001, 78 percent of Burkina Faso's exports, and 87 percent of Mali's, went through Abidjan (AFD 2005, Port Authorities data). These flows collapsed in 2003 during the Ivorian crisis: just 1 percent of Burkina's exports, and 7 percent of Mali's, passed through Abidjan in that year. The Sitarail connection also suffered from lengthy service suspensions, with traffic collapsing by over 80 percent between 2001 and 2003. The World Bank (2006) state that rail transit to Ouagadougou from the coast is both faster, and around 30-40 percent cheaper, than road transport. Even with the commencement of the service however, UNCTAD (2007) found that it was still difficult to insure goods on the line many years after the initial outbreak of violence.

Niger's transit traffic is concentrated on the rail/road corridor through Benin and road corridors through Togo and Nigeria (UNCTAD 1995, Arvis et al. 2011). The majority of Niger's transit is via Benin (AFD 2005), largely due to proximity, bilateral political agreements and joint ownership of the Organisation Commune Benin-Niger (OCBN) railway (UNCTAD 1995). Little use is made of Abidjan; both prior to, and after, the Ivoirian crisis less than 1 percent of overseas transit passed through the

[88] UNCTAD (1995) notes that Malian cotton is produced in the sourthern region, making Abidjan somewhat closer than Dakar. The latter port plays a more prominent role for imports. Similarly, Burkina Faso's transit routes are more diversified for imports. In 2001, 49% of imports came through Abidjan, compared to 78% of exports (Port Authorities data).

port (Port Authorities data).

B.2 Transport Costs: Alternative Forms

Table B2 presents results from a linear form of equation (17), i.e.

$$t_{it} = \alpha + \beta_1 T_{it} + \beta_2 dist_{it} + \delta_i + \delta_t + \varepsilon_{it}$$

with variables defined as before (distance is rescaled to thousands of km).

Table B2: Transport costs, linear form (1975-2005)

Panel A: No time trend

	Correlates of War			PRIO-GRID		
	(1)	(2)	(3)	(4)	(5)	(6)
	t	fr.	ins.	t	fr.	ins.
T	-0.017	-0.018	-0.000	-0.002	-0.005	-0.000
	(0.020)	(0.017)	(0.003)	(0.016)	(0.012)	(0.002)
dist	0.064***	0.058***	0.007***	0.048***	0.045***	0.005***
	(0.006)	(0.005)	(0.001)	(0.005)	(0.004)	(0.001)
Obs.	342	359	342	342	359	342
Countries	14	14	14	14	14	14
R-Sq.	0.38	0.35	0.29	0.30	0.28	0.25

Panel B: Linear time trend

	Correlates of War			PRIO-GRID		
	(1)	(2)	(3)	(4)	(5)	(6)
	t	fr.	ins.	t	fr.	ins.
T	-0.009	-0.010	0.000	-0.009	-0.011	-0.001
	(0.017)	(0.014)	(0.002)	(0.014)	(0.011)	(0.002)
dist	0.046***	0.041***	0.006***	0.035***	0.032***	0.005***
	(0.006)	(0.005)	(0.001)	(0.007)	(0.006)	(0.001)
Obs.	342	359	342	342	359	342
Countries	14	14	14	14	14	14
R-Sq.	0.52	0.50	0.56	0.50	0.48	0.54

Robust standard errors in parentheses. All regressions include country and year fixed effects.
The dependent variables are ad valorem transport costs (columns 1 and 4), ad valorem freight costs (columns 2 and 5) and ad valorem insurance costs (columns 3 and 6). Constants are included but not reported.
*** p<0.01, ** p<0.05, * p<0.1

Table B3 presents results from a log-level form of equation (17), i.e.

$$\ln(t_{it}) = \alpha + \beta_1 T_{it} + \beta_2 dist_{it} + \delta_i + \delta_t + \varepsilon_{it}$$

with variables defined as before (again distance is rescaled to thousands of km).

Table B3: Transport costs, log-level form (1975-2005)

Panel A: No time trend

	Correlates of War			PRIO-GRID		
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(t)	ln(fr.)	ln(ins.)	ln(t)	ln(fr.)	ln(ins.)
T	-0.066	-0.171	0.134	0.191	0.072	0.410
	(0.191)	(0.175)	(0.292)	(0.156)	(0.137)	(0.373)
dist	0.537***	0.599***	1.003***	0.325***	0.396***	0.695***
	(0.090)	(0.079)	(0.112)	(0.054)	(0.033)	(0.109)
Obs.	342	359	342	342	359	342
Countries	14	14	14	14	14	14
R-Sq.	0.27	0.21	0.40	0.22	0.16	0.35

Panel B: Linear time trend

	Correlates of War			PRIO-GRID		
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(t)	ln(fr.)	ln(ins.)	ln(t)	ln(fr.)	ln(ins.)
T	-0.098	-0.222	0.140	0.015	-0.121	0.239
	(0.155)	(0.157)	(0.245)	(0.150)	(0.136)	(0.295)
dist	0.271***	0.287***	0.718***	0.162**	0.198***	0.457***
	(0.076)	(0.074)	(0.109)	(0.064)	(0.050)	(0.105)
Obs.	342	359	342	342	359	342
Countries	14	14	14	14	14	14
R-Sq.	0.47	0.39	0.49	0.47	0.38	0.48

Robust standard errors in parentheses. All regressions include country and year fixed effects.
The dependent variables are ad valorem transport costs (columns 1 and 4), ad valorem freight costs (columns 2 and 5) and ad valorem insurance costs (columns 3 and 6). Constants are included but not reported.
*** p<0.01, ** p<0.05, * p<0.1

B.3 Trade: Robustness Checks

Table B4 presents the following robustness checks, all using the COW definition of conflicts: (i) the definition of transit routes is changed to include the route from Chad to Pointe-Noire (Congo), via Central African Republic and Democratic Republic of Congo, (ii) the distance from Malawi to Durban is changed by allowing a route through the Tete region of Mozambique (see World Bank 1988 for details), (iii) straight lines distances, taken from the World Bank *Trade, Production and Protection Database*, are used in place of sea distances, (iv) small partner economies (with populations less than one million in 1990) are no longer excluded, (v) a dummy = 1 is included if country i is a member of the GATT/WTO, (vi) the Sachs-Warner "openness" dummy is included for country i, with data taken from Wacziarg and Welch (2008).

Table B4: Trade and conflict, robustness checks (1975-2005)

	(1) ln(trade)	(2) ln(trade)	(3) ln(trade)	(4) ln(trade)	(5) ln(trade)	(6) ln(trade)
T	0.029	0.036	0.017	0.018	0.034	0.040
	(0.074)	(0.081)	(0.076)	(0.078)	(0.081)	(0.088)
ln(dist)	-2.056***	-2.423***	-1.642***	-2.574***	-2.036**	-1.402**
	(0.788)	(0.916)	(0.567)	(0.769)	(0.797)	(0.690)
$\ln(Y_{it})$	-0.024	-0.028	0.025	0.045	-0.038	-0.075
	(0.115)	(0.115)	(0.106)	(0.107)	(0.117)	(0.118)
$\ln(Y_{jt})$	0.391***	0.388***	0.275**	0.277**	0.394***	0.315**
	(0.132)	(0.132)	(0.121)	(0.124)	(0.131)	(0.144)
Conflict	-0.268***	-0.279***	-0.297***	-0.269***	-0.276***	-0.302***
	(0.086)	(0.085)	(0.084)	(0.085)	(0.086)	(0.092)
Conflict+1	-0.449***	-0.448***	-0.376***	-0.388***	-0.457***	-0.443***
	(0.090)	(0.089)	(0.085)	(0.087)	(0.089)	(0.099)
WTO_{it}					0.074	
					(0.146)	
$Open_{it}$						-0.001
						(0.117)
Obs.	21,404	21,413	26,109	24,977	21,419	16,878
Pairs	1,046	1,047	1,413	1,275	1,045	979
R-sq.	0.03	0.03	0.03	0.03	0.03	0.02

Columns 1 and 2 use alternative definitions of transit routes, column 3 uses straight line distances instead of sea and land distances, column 4 includes partner countries with populations <1 million in 1990, column 5 includes a dummy for WTO membership of African country *i*, and column 6 includes the Sachs-Warner openness dummy for African country *i* (excludes 2001+ due to data limitations).

C Chapter 3

C.1 Mathematical appendix

Proposition 1

The derivation follows closely Cambini and Spiegel (2012). Consider first the case $D < D_1$. Then $\varphi^*(p, D) = 0$, $\frac{\partial p^*}{\partial D} = 0$, so that $\frac{\partial Y(D)}{\partial D} = 0$.

Consider now the case $D_1 < D < D_2$. Then $\varphi^*(p, D) = \left(1 - \frac{p^* - D}{\bar{c}}\right)$ and $p^*(D) = a + (1-b)\left[\frac{\bar{c}}{2} + \left(1 - \frac{p^* - D}{\bar{c}}\right) T\right]$. This imply that $\frac{\partial \varphi^*}{\partial D} = \frac{1}{\bar{c}}$, $\frac{\partial \varphi^*}{\partial p} = -\frac{1}{\bar{c}}$, and $\frac{\partial p^*}{\partial D} = (1-b)T\frac{1}{\bar{c}}$. Using the fact that

$$\frac{\partial Y(D)}{\partial D} = \frac{\partial p^*}{\partial D} - \left(\frac{\partial \varphi^*(p(D), D)}{\partial p^*}\frac{\partial p^*(D)}{\partial D} + \frac{\partial \varphi^*(p(D), D)}{\partial D}\right) \tag{27}$$

straightforward computations lead to

$$\frac{\partial Y(D)}{\partial D} = \frac{1}{\bar{c}}\left[(1-b)\frac{T}{\bar{c}} - b\right] \tag{28}$$

Thus $\frac{\partial Y(D)}{\partial D} > 0$ if $\frac{T}{\bar{c}} > \frac{b}{(1-b)}$. In this case, which occurs if b is small enough, the firm chooses $D = D_2$ for which its profit is maximum, while for $\frac{\partial Y(D)}{\partial D} < 0$, the firm's profit is maximized at $D = D_1$.

Finally, when $D > D_2$, $\varphi^*(p, D) = 1$, $p^*(D) = a + (1-b)\left[\frac{\bar{c}}{2} + T\right]$, so that $\frac{\partial p^*}{\partial D} = \frac{\partial \Phi^*}{\partial D} = \frac{\partial \Phi^*}{\partial p} = \frac{\partial \Pi(D)}{\partial D} = 0.$

Proposition 2

If $R_E \neq R_D$ equation (28) becomes:

$$\frac{\partial Y(D)}{\partial D} = \frac{1}{\bar{c}}\left[(1-b)\frac{T}{\bar{c}} - b\right] + R_E - R_D \tag{29}$$

and denoting $\frac{T}{\bar{c}} \equiv z$ we have that $\frac{\partial Y(D)}{\partial D} > 0$ if $b < \frac{z-(R_D-R_E)/z}{1+z}$.

C.2 Data and regulation details

Table C1: Variable definitions and sources

Variable	Sources
Leverage: Total liabilities/ total assets.	"Financial sources": OSITRAN; Agencia Nacional de Infraestructura (ANI); ISI Emerging Markets Database; Orbis Database.
Return on Assets (ROA): EBIT/ total assets.	Financial sources.
Volatility: Standard deviation of ROA.	Financial sources.
Price cap: Dummy variable indicating whether the contract is price cap.	Project contracts; bidding documentation; renegotiation agreements available from the regulatory agencies.
Renegotiation: Dummy variable indicating whether there was a renegotiation of the concession contract.	Regulatory agencies; Guasch (2004); Engel et al. (2009).
Independent Regulatory Agency (IRA): Dummy variable indicating whether the regulator is independent of the sector Ministry.	Country legislation; Guasch (2004); Correa et al. (2006); Serebrisky (2012)
Investment: Natural logarithm of investment commitments, in constant $2000 (millions).	World Bank/PPIAF Private Participation in Infrastructure (PPI) database; World Bank *World Development Indicators.*
Contract duration: Duration of concession contract in years.	Project contracts.
Minimum income guarantee: Dummy variable indicating whether there is a minimum income guarantee from the government.	Project contracts; renegotiation agreements.
Flexible contract: Dummy variable indicating whether the contract length is flexible.	Project contracts; renegotiation agreements.
Multilateral support: Dummy variable indicating whether the project received financial assistance from the World Bank, Inter-American Development Bank, International Financial Corporation or Corporacion Andina de Fomento.	PPI database.
GDP growth: Annual GDP growth in $2000.	World Bank *World Development Indicators.*
Inflation: Annual inflation (GDP deflator).	World Bank *World Development Indicators.*
Interest: Lending interest rate	IMF *International Financial Statistics.*
Spread: Interest rate spread. Lending interest rate minus deposit interest rate.	IMF *International Financial Statistics.*
Stock market value: Total shares traded on the stock market exchange/ GDP.	Beck, Demirgüç-Kunt and Levine (2000) *Financial Development and Structure Dataset* (September 2012 update).
Bond capitalization: Private domestic debt securities issued by financial institutions and corporations/ GDP.	*Financial Development and Structure Dataset.*
Corruption: Government corruption. Range from 1 to 6. Higher value means less corruption.	Political Risk Service, International Country Risk Guide.

Table C2: Regulation summary

Country	Sector	Regulator	Projects	Revision < 5 years (Y/N)	Inflation/ER adjustment (Y/N)	Adjustment frequency (Years)
Brazil	Road	DNER/ ANTT	"First phase" federal projects	Y	Y	1
Brazil	Road	ANTT	"Second phase" federal projects	Y	Y	1
Brazil	Road	DER Parana	All	N	Y	1
Brazil	Road	DAER (Rio Grande do Sul)	All	N	Y	1
Brazil	Rail	RFFSA/ ANTT	Federal freight concessions	N	Y	1
Brazil	Rail	ASEP RJ/ AGE TRANSP	Rio metro	N	Y	1
Brazil	Rail	ASEP RJ/ AGE TRANSP	SuperVia	N	N	.
Chile	Road	MOP	All	N	Y	=1
Chile	Air	MOP	All	N	Y	0.5
Col	Road	Invias/ INCO	All	N	Y	=1
Col	Rail	Invias/ INCO	Federal freight concessions	N	Y	1
Col	Air	Aerocivil	All	N	Y	=1
Col	Port	MOT/INCO	All	Y	N	.
Peru	Road	OSITRAN	All	N	Y	0.5
Peru	Rail	OSITRAN	All	N	Y	1
Peru	Air	OSITRAN	Co-pay contracts	N	Y	1
Peru	Air	OSITRAN	RPI-X contracts	N	Y	1
Peru	Port	OSITRAN	All	N	Y	1

C.3 Renegotiation: probit results

Table C3 presents the results of running random effects probit regressions for the probability of contract renegotiation following Guasch et al. (2007).

Table C3: Determinants of renegotiation - probit estimations

	(1)	(2)	(3)	(4)	(5)	(6)
Leverage	0.228			0.245		
	(0.231)			(0.237)		
Distress		-0.040			0.005	
		(0.065)			(0.054)	
Performance			0.165			0.181
			(0.124)			(0.131)
Guasch et al (2007) controls						
Project age	-0.048***	-0.050***	-0.053***	-0.050***	-0.050***	-0.056***
	(0.014)	(0.015)	(0.016)	(0.015)	(0.017)	(0.018)
Price cap	0.823	1.100*	0.878	0.774	1.035*	0.824
	(0.641)	(0.606)	(0.637)	(0.656)	(0.619)	(0.659)
Bureaucratic	-0.185	-0.100	-0.021	-0.413***	-0.323***	-0.286
quality	(0.279)	(0.234)	(0.249)	(0.121)	(0.119)	(0.196)
Election (-1)	-0.158	-0.155	-0.122	-0.154	-0.150	-0.117
	(0.113)	(0.120)	(0.112)	(0.115)	(0.120)	(0.113)
GDP growth (-1)	-0.031**	-0.038**	-0.033*	-0.032*	-0.039**	-0.034*
	(0.016)	(0.016)	(0.017)	(0.018)	(0.018)	(0.019)
Sector dummies						
Road	-0.168	0.122	-0.084	-0.144	0.147	-0.055
	(0.739)	(0.616)	(0.722)	(0.747)	(0.631)	(0.740)
Rail	-0.454	-0.168	-0.333	-0.401	-0.099	-0.272
	(0.605)	(0.494)	(0.640)	(0.601)	(0.493)	(0.647)
Air	-0.660	-0.400	-0.614	-0.651	-0.389	-0.608
	(0.862)	(0.739)	(0.873)	(0.872)	(0.756)	(0.900)
Country dummies						
Brazil				-0.935***	-0.840***	-0.880***
				(0.083)	(0.033)	(0.027)
Chile				0.110	0.051	0.063
				(0.180)	(0.167)	(0.285)
Peru				-0.253*	-0.165	-0.242
				(0.147)	(0.141)	(0.170)
Observations	981	946	878	981	946	878
Log-likelihood	-483.29	-458.97	-421.55	-475.85	-452.26	-414.77

The dependent variable is a dummy equal to one if project *i* was renegotiated in year *t*. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1