CONCRETE THINKING ABOUT DEVELOPMENT*

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Abstract

Misallocation is increasingly recognized as an important factor in explaining productivity differences across countries. This paper uses new micro-data on key input prices in the construction sector and market structure at a global level to study distortions in construction sector inputs and their consequences. We document that (i) there is large dispersion in construction sector input prices and that cement prices are particularly high in the poorest countries; (ii) cement prices are highest in countries with few firms; (iii) cement plays a significant role in construction sector expenditures, particularly in the poorest countries. To understand the reasons for price differences in cement we estimate a model of oligopoly using both a demand-based instrument and exploiting geological variation in the dispersion of limestone deposits within countries. Our results suggest that lower levels of competition lead to significantly higher prices. Firm-level financial accounts data point toward substantial economic rents. We then embed the oligopoly structure into a dynamic general equilibrium network model to analyse the consequences of distortions on the wider economy. We find that due to cement's network position, distortions have large effects on steady-state output: for every dollar increase in cement profits, steady-state output falls by two. Finally, we find that common ownership in cement is an important source of distortions accounting for between 75% and 85% of the wedge due to markups in cement.
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1. Introduction

An increasing body of evidence suggests that misallocation is crucial for understanding differences in total factor productivity across countries (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008).[1] Misallocation might be particularly important if it distorts key firms or sectors (Schmitz, 2001; Liu, 2019). The focus of this paper is on misallocation in the construction sector. Complementarities between investment in structures and other parts of the economy have long been recognized (Hirschman, 1958).[2] Aggregate data suggest that the cost of physical investment is high in low-income countries (Caselli and Feyrer, 2007; Restuccia and Urrutia, 2001) and investment productivity is low (Hsieh and Klenow, 2007). We use new micro-level evidence to document the existence of a large distortion in cement, a key input of the construction sector.[3] Our paper thereby adds to a recent evidence on other key sectors such as electricity (Fried and Lagakos, forthcoming) or intermediate inputs (Boehm and Oberfield, 2020).

We start by documenting three novel motivating facts at a global level on price dispersion of precisely defined key construction sector inputs across space and time, market structure in the global cement industry across time and space, and the role of construction in capital formation as well as the role of cement in construction sector expenditures.[4] To do this, we use confidential micro-data collected as part of the 2011 and the 2017 rounds of the International Comparison Program (World Bank, 2015b, 2020). We also collect and hand-code current and historical data from industry reports on market structure in the cement industry, such as the name and number of firms operating in each country in a given year and each firm's capacity, and match these with markups from Worldscope for publicly listed cement manufacturing firms. To our knowledge this represents the most comprehensive

[1]See Hopenhayn (2014) and Restuccia and Rogerson (2017) for recent surveys.

[2]Çakmaklı et al. (2021) highlight that the construction sector in the U.S. is the top sector in terms of intermediate input usage.

[3]Throughout the paper we use the term "distortion" to refer to a range of situations that result in off-marginal-cost pricing, for example, markups to pay for fixed costs, excess returns due to market power, or market imperfections in the form of credit market frictions. When using firm financial accounts data we pay particular attention to identifying the various components of markups.

[4]To avoid confusion from the onset: *cement* is a powder, typically grey, while *concrete* consists of cement, sand, water, aggregates and admixtures.

dataset on market structure, prices and profits of the cement industry at a global level.

We find a striking degree of spatial price dispersion in key construction sector inputs which has previously been masked in aggregate price indices even at a sector level: for example, in 2011 a ton of Portland cement cost $487 in the Central African Republic compared to $139 in the United States. Nine of the ten most expensive countries to purchase cement are located in Sub-Saharan Africa during this time. When expressed in PPP terms, price differences are even larger, with a price difference of a factor of 3.5 or higher for 21 Sub-Saharan African countries. In other words, the region with the lowest level of infrastructure also faces the highest prices of an essential input.

Our second motivating fact is that cement prices are decreasing in the number of firms and increasing in market concentration as measured by the Herfindahl-Hirschman index in both time periods. Our third set of motivating facts shows that the construction sector accounts for roughly half of gross fixed capital accumulation in both rounds of the ICP. We find that cement, while accounting for a small proportion of overall expenditures, accounts for a significant share of construction expenditures. The median country spends about 8% of construction sector expenditures on cement, and the 75th percentile of countries spend more than 17% of their overall construction expenditures on cement. We show that predominantly the poorest countries have high expenditure shares on cement.

Several of the observed price differences of construction sector inputs call for an investigation into the underlying reasons. In the remainder of the paper we focus on cement, which we argue presents an important case study for a number of reasons. First, there are few alternatives to cement. It is a core constituent of concrete, the second most used resource in the world.[5] Distortions in the price of cement have therefore potentially economy-wide ramifications (Jones, 2011; Kremer, 1993). Second, it is largely a homogeneous good. Price differences are suggestive of distortions as they are unlikely to reflect differences in quality, which has been proven to be important, for example, in the market for agricultural equipment (Caunedo and Keller, 2021). Third, less than 5% of cement consumed is traded so that

[5]Concrete's main attractive properties are that it is resistant to water, the ability to form it into a variety of shapes and the fact that it tends to be readily available and cheap (Mehta and Monteiro, 2012).

it is the classic example of a non-tradable good due to its low value to weight ratio (International Cement Review, 2019a). The functioning of markets at a local level is likely to play an important role in explaining price differences rather than frictions in trade (Eaton and Kortum, 2001). Finally, the cement industry is known to be one with significant market power (Röller and Steen, 2006; McBride, 1983; Miller and Osborne, 2014; World Bank, 2016; Global Competition Review, 2020). For instance, some of Africa's greatest fortunes were made based on cement. One interesting example is Nigeria. Dangote Cement accounts for about 60% of cement capacity in Nigeria (International Cement Review, 2019a). Dangote's profit margin in 2015 was 42.3% compared to the average global cement profit margin of 17.2% (Quartz Africa, 2017). Its owner is the richest man in Africa (Forbes, 2020); also among the ten richest billionaires in Africa is the owner of BUA Cement, accounting for almost 20% of the Nigeria's capacity. The remaining 20% of capacity are produced by plants owned by LafargeHolcim, the second largest cement producer world-wide.

The second part of the paper focuses on market power as an example of a particular type of distortion in cement by modelling the cement sector as an oligopoly. We write down a simple, illustrative model with the objective of guiding our empirical analysis and informing our choice of instruments. From the model we obtain a market-level price equation which we estimate using cross-country data and two instruments implied by the theory: a demand-based instrument and a novel instrument for entry exploiting exogenous geological variation in the natural availability of limestone across space, the key ingredient in cement production. We also use the structure of the model to estimate the demand elasticity of cement which we use as a parameter in the macro model. We then use firm-level accounting data for all cement firms globally to identify the causes of high markups.

We show that our estimates of the effect of competition on prices are remarkably consistent across all specifications including the two different instrumental variables strategies and across a battery of robustness checks that take into account alternative market definitions, the location of cement plants, controls for further input costs in cement production, plant sizes, the quality and quantity of transport infrastructure, imports and tariffs. Our IV estimates suggest an elasticity of prices to competition of around .3 to .7. Given the wide range of competition levels seen in the data, these are large effects; but as we discuss, given the observed entry in the market during our sample period and fall in prices, these estimates are not out of line with what we observe in the data. One strength of our paper is that we conduct our analysis at a global level. A drawback is our lack of data on prices within countries and across firms within these countries so that we are not able to quantify the local effects of competition on price dispersion within countries nor examine firm heterogeneity within countries. Still, our analysis provides compelling evidence for significant effects of domestic market power in raising the price of cement.

High prices need not imply the presence of economic rents, as profits may simply pay for the fixed costs of firms. To investigate this possibility we use accounting data on publicly listed cement firms from Worldscope. We measure rents as the excess returns on firm capital, i.e., the discrepancy between a firm's returns and its risk-adjusted user cost. This measure accounts for all expenses of a firm in financial accounts, and is averaged over ten years to account for volatility in earnings. Our baseline estimate of global excess returns is 2.5% annually, implying substantial rents in the cement industry. The existence of such rents in equilibrium suggest the presence of significant barriers to entry.

Third, we turn to examining the macroeconomic impacts of distortions in construction input markets. Distortions and linkages in the entire production network cause some sectors to be over-supplied and others to be under-supplied (Baqaee and Farhi, 2020; Liu, 2019; Bigio and La'O, 2020). It is therefore a priori impossible to say whether reducing distortions in a given market increases or decreases aggregate output. We formulate a simple neoclassical model of capital accumulation which distinguishes between investment and consumption goods and allows for a production network.[6] We use the model and input-output data to (i) study cement's position in the production network, (ii) understand the impacts of distortions on steady-state output, and (iii) quantify the costs of low entry and common ownership.[7]

[6]Our static network block features two final goods, which is the sole departure from the static models studied by, for example, Liu (2019), Baqaee and Farhi (2020) and Bigio and La'O (2020). In recent work, vom Lehn and Winberry (2021) analyse the role of the network of investment on real business cycles and labour supply in a perfectly competitive environment.

[7]A key mechanism in our model is that cement prices pass through to the price of construction goods.

Our dynamic general equilibrium network model highlights the importance of distinguishing between consumption and investment. Once we account for the production of investment, construction and cement have the highest long-run distortion centrality, and therefore profits in these sectors are amongst the most costly for steady-state output on a per dollar basis. At the margin, an extra dollar of profits causes the loss of two dollars in aggregate income. In other words, a one percent rise in cement profits has roughly the same effect as a two percent fall in cement productivity in a competitive model. Our quantification exercise suggests that common ownership, i.e., many plants being owned by the same firm, is particularly costly accounting for between 75% and 85% of the wedge due to markups in cement. Lack of entry leads to lower costs – up to 20% of the markup wedge – due to decreasing returns to scale at the plant level. The costs of common ownership are convex in the level of competition, with particularly high costs in the most concentrated markets. These results suggest that common ownership in cement is an important source of distortions in the market with consequences for aggregate output.

Our paper is at the intersection of several literatures: macro, development and industrial organization. In addition to the work cited so far, we relate to the literature on the cost of capital (Caunedo and Keller, 2021; Collier et al., 2016; Jones, 1994), input-output linkages in production networks (Baqaee and Farhi, 2019; Kremer, 1993; Jones, 2011; Demir et al., 2021; Grassi, 2018; Carvalho, 2014; Carvalho et al., 2020), and the role of firm-level markups in general equilibrium (Gutiérrez and Philippon, 2016; De Loecker et al., 2020; Edmond et al., forthcoming; Mongey, 2019). Our key contribution is to bring new micro-data to investigate distortions in a specific sector that is crucial in the production of investment. Our results are consistent with the presence of entry barriers which inhibit competition. Gutiérrez and Philippon (2019) find similar results across industries in the US, while Gutiérrez et al. (2021) analyse the aggregate implications of such costs for the US economy. We complement their findings by providing new evidence of entry barriers in developing countries, and quantifying the implications for misallocation and development.

Using micro-data from the 2005 ICP on construction components and digitizing data on costs per square meter across cities and countries in Appendix H we present evidence suggesting that there is significant pass-through of cement prices to building costs with an elasticity between 0.4 and one.

Second, we contribute to a growing literature in development on the role of competition (Atkin and Donaldson, 2015; Atkin et al., 2015; De Loecker et al., 2016; Bergquist and Dinerstein, 2020; Besley et al., 2021) and misallocation (Restuccia and Rogerson, 2008; Schmitz, 2001; Bartelsman et al., 2013; Peters, 2020; Buera et al., 2011). We add to this literature by examining the role of market power in an essential input for investment goods and its impact on the steady-state output across countries. By presenting a case study on cement, we contribute to a literature that zooms in on specific industries (Bridgman et al., 2015; Schmitz, 2005) or policy changes (Bau and Matray, 2023) to document distortions. The focus of our paper is on the impact of market power on prices. In reality, market power might have even more wide-reaching impacts than simply affecting prices, e.g., by sabotaging potential entrants or competing technologies, as documented powerfully by Schmitz (2020).

Finally, cement and ready-mix concrete have been the subject of a large body of literature in the empirical IO literature, including Backus (2020), Ryan (2012) and Syverson (2004).[8] We contribute to this literature by studying the industry at a global level and focusing on the macroeconomic consequences of markups, highlighting heterogeneity in effects of markups for countries at different income levels. In a paper that follows ours, Leone et al. (2021) estimate a similar model to the one we outline in Section 3, also using data from the International Comparison Program and cement firms but focusing on the decline of cement prices in Africa. We take a different approach by first presenting new evidence on price differences in a broad set of key construction sector inputs. We use our oligopoly model to establish the effect of competition, and then examine firms' financial accounts data to investigate the sources of markups. Further, our general equilibrium model allows us to quantify the equilibrium effects of distortions in the investment sector on capital accumulation and output and conduct quantification exercises.

The paper is structured as follows. Section 2 shows spatial price dispersion of key input prices, and key facts about the production and consumption of cement. Section 3 introduces

[8] Further studies on cement or ready-mix concrete include Collard-Wexler (2013), Hortaçsu and Syverson (2007), Miller and Osborne (2014), and Salvo (2010). For a review of the literature on ready-mix concrete, see Syverson (2008).

the oligopoly model of the cement industry, outlines our main empirical specification, and presents the key results on the effect of market structure on prices. Section 4 formulates our network model of capital accumulation. Section 5 presents the quantitative results from our network model and quantification exercises. Section 6 concludes.

2. Motivating facts

This section presents key motivating facts on the dispersion of input prices, the global cement industry, the construction sector's role in gross fixed capital formation and cement's role in construction. We discuss the main features of the data in this section; Appendix A provides further details motivating our choice of inputs and details on the data collection.

2.1. Key input prices

Our main input prices are based on confidential micro-data collected as a basis for the construction sector PPP computed by the International Comparison Program (ICP). The ICP collects price data for more than 160 countries with the main aim of generating PPP exchange rates to compare GDP across countries (World Bank, 2015b, 2020). To improve measurement of prices in the construction sector, the 2011 edition involved a major revision of the data collected for the construction sector PPP, moving away from an output-based approach toward an input-based approach. We use data from the 2011 round as well as the most recently released 2017 round. The micro-data contains prices paid by builders for a range of inputs, including concrete, sand, bricks and steel, and are intended to be national averages.[9]

An attractive feature of the data is that it is based on precisely defined units of measurement in three key dimensions: first, the ICP specifies who purchases an item so that all prices represent prices paid by builders. Second, the ICP specifies the quantity. It is almost impossible to compare prices as factory-gate prices are not directly comparable to prices paid by contractors, and bulk purchases (i.e., a truck of cement of x tons) are not directly comparable to purchases of smaller units (i.e., a 25 kg bag of cement). Third, the quality

[9]We exclude countries with a population below 100,000 in 2017 throughout the paper.

is precisely defined: for example, the database records the price of ready-mix concrete as a cubic meter of concrete mixed at proportions 1:2:4 (cement:sand:20-40mm aggregate) and with characteristic compressive strength of 20N/mm^2. These definitions do not rule out that there is heterogeneity in quality across space; however, without these clear guidelines it would be impossible to conduct the exercise of this paper.[10] While the data allows us to document comparable prices for a key set of construction sector inputs at a global level, one key limitation of our data is that we only have one price per country.

Our input list is chosen based on two criteria: (i) the input is a core input in the construction sector globally and (ii) the price database has wide coverage across countries of the input. We therefore study the following inputs: concrete and its core constituents (cement, aggregate and sand), softwood, bricks, mild steel reinforcement and structural steel.[11] The highest coverage of countries is for cement and aggregate prices while prices for structural steel are available for at least 63 countries.

Figure 1 plots the log of input prices alongside log GDP per capita in PPP dollars. Prices are measured relative to the total construction sector price index as calculated by the ICP.[12] The figure highlights large orders of magnitudes of price differences. For example, in 2011 cement prices in Chad were over four times those of India. Further, the prices of construction sector inputs tend to be highest in poorer countries. In other words, the countries with the lowest levels of infrastructure and quality of housing are facing the highest construction sector input prices.

Such stark differences are not seen in the aggregate construction sector PPP prices, which show no association with income levels (see Appendix Figure B.3). A plausible explanation is that lower wages in Sub-Saharan Africa mean that higher input costs are masked when the aggregate construction sector price is considered. The disaggregated data therefore reveal price differences in the construction sector which were previously masked in aggregate price

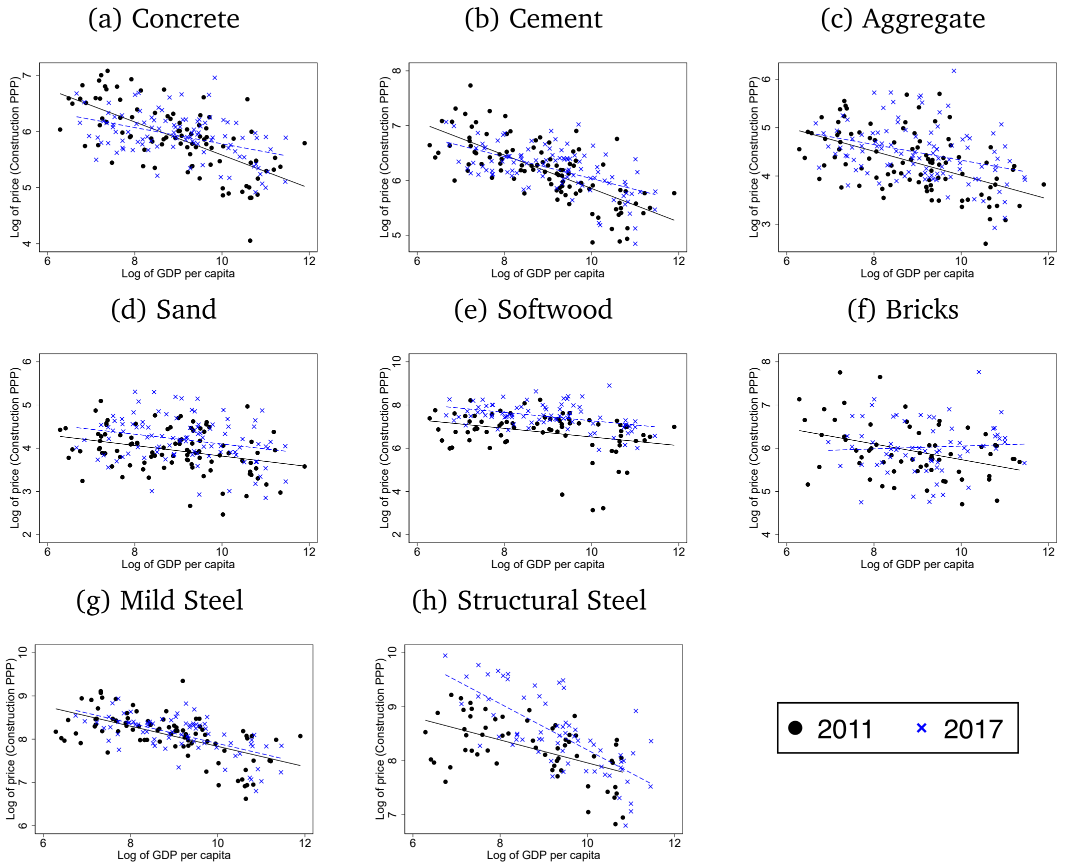
[10]Still, there might be unobserved components of prices, such as the speed of delivery, or how the price would differ if the government instead of a builder purchased the good.

[11]The type of cement recorded is ordinary Portland cement, the most common type of cement (Young, 2001).

[12]For expositional purposes, we exclude 4 countries for softwood due to what appear to be inconsistencies in the measurement of unit prices.

indices. Appendix Figures B.1 and B.2 show similar patterns measuring input prices using PPPs and exchange rates.[13]

Figure 1: Input prices relative to construction sector price level and GDP per capita (PPP)



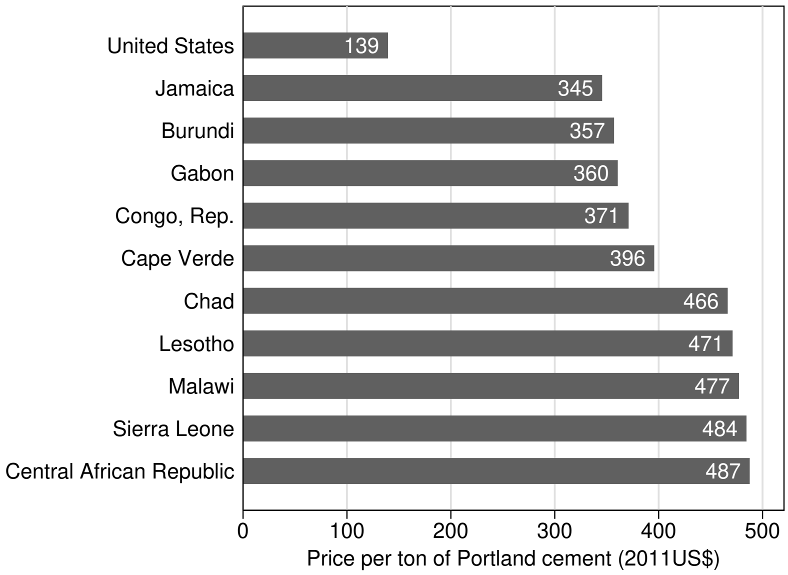
Note: This figure shows the log of key construction sector input prices and log of GDP per capita. Prices are defined relative to a country's construction sector price index from the ICP. Precise definitions of the inputs are listed in Table A.2.

In light of the large differences in prices of cement, the importance of cement as an ingredient for concrete, and the key role of concrete in construction, in the rest of the paper we focus on cement. Figure 2 shows the price per ton of Portland cement in the most expensive countries in the world compared to the United States. Cement is most expensive in the Central African Republic and Sierra Leone, where the average price of a ton of cement is 3.5 times the price in the United States. Nine out of the ten countries listed are located in Sub-Saharan Africa.[14] The price differences are even stronger when we use the PPP exchange rate: the relative price of cement in Sierra Leone and in the Central African

[13] Appendix Table B.1 shows average prices for each of our inputs across regions, which shows significant spatial variation.

[14] This reinforces findings from World Bank (2016) who evaluate cement price data from a range of sources for one time period (around 2014) and found that prices were significantly higher in Africa.

Figure 2: Ordinary Portland cement in the US and the 10 most expensive countries in 2011



Note: This figure shows the average cost of a ton of Portland cement in the 10 most expensive countries compared to the United States in 2011.

Republic compared to the United States increases to a factor 9.7 and 6.5, respectively. In 2017, again using PPP exchange rates, these factors are 3.5 and 4.5 for Sierra Leone and the Central African Republic, respectively.

There are a number of possible explanations for these large price gaps in cement prices. First, it could be that prices for core inputs and machinery are high and there is a lack of qualified personnel, translating into high production costs. A second explanation relates to scale: low demand in the presence of economies of scale could also mean that firms are producing at the portion of the LRAC curve where prices are still high. A third set of explanations relates to the institutional environment: production is costly due to weak quality of institutions. Prices are given by $\ln p = \ln \mu + \ln c$, therefore the sum of markups and marginal costs. While the aforementioned explanations focus on marginal costs, we argue that high markups might also contribute to higher prices in low-income countries. Indeed, cement has been highlighted as one of the sectors that would benefit from more competition in Africa (World Bank, 2016). In the next section we present descriptive evidence of low competition in the cement industry.

2.2. The global cement industry

This section shows key facts on market structure of the cement industry at a global level. To measure market structure, we use data on cement firms across 162 countries from Cemnet, the publisher of the Global Cement Report, a detailed industry analysis of cement companies. For each country, the report contains a chapter discussing production, consumption and market structure of the industry. For 2011 we hand-coded the names of firms present in each of the countries and each firm's capacity in million tonnes. For 2019, we use the plant database that contains the name of all plants, name of the company, and name of the group if the company is part of a group.[15] The data is based on surveys and correspondence with plants and corporate offices, reports, and company disclosures. To define the number of firms, we use the group name if it is provided and otherwise the company name. For example, in Mexico there are 39 plants, owned by 9 companies which are in turn owned by 6 groups. Since price-setting is likely to take place at the level of the group, we are most interested in this variable.

The cement industry is characterized by high market concentration at a global level: 40% of countries have a firm that provides more than 50% of the country's total cement capacity. Taking Mexico's case as an example again, three of the six groups – LafargeHolcim Ltd., Cemex and Cooperativa la Cruz Azul S. C. L. – account for more than three quarters of Mexico's cement capacity. Examining cement firms in the 10 most expensive countries listed in Figure 2 suggests a link between the number of firms and prices: two of the most expensive countries have no cement firms, seven countries had one cement firm, and one country had three firms.

Global cement consumption in 2018 was almost 4000 million tons (Mt), out of which China consumed more than half, followed by India, the United States and Indonesia which account for another 500Mt. Trade is small at an aggregate level, and exports and imports account for 5% of total consumption.[16] Due to its high weight to value ratio, cement is typically not

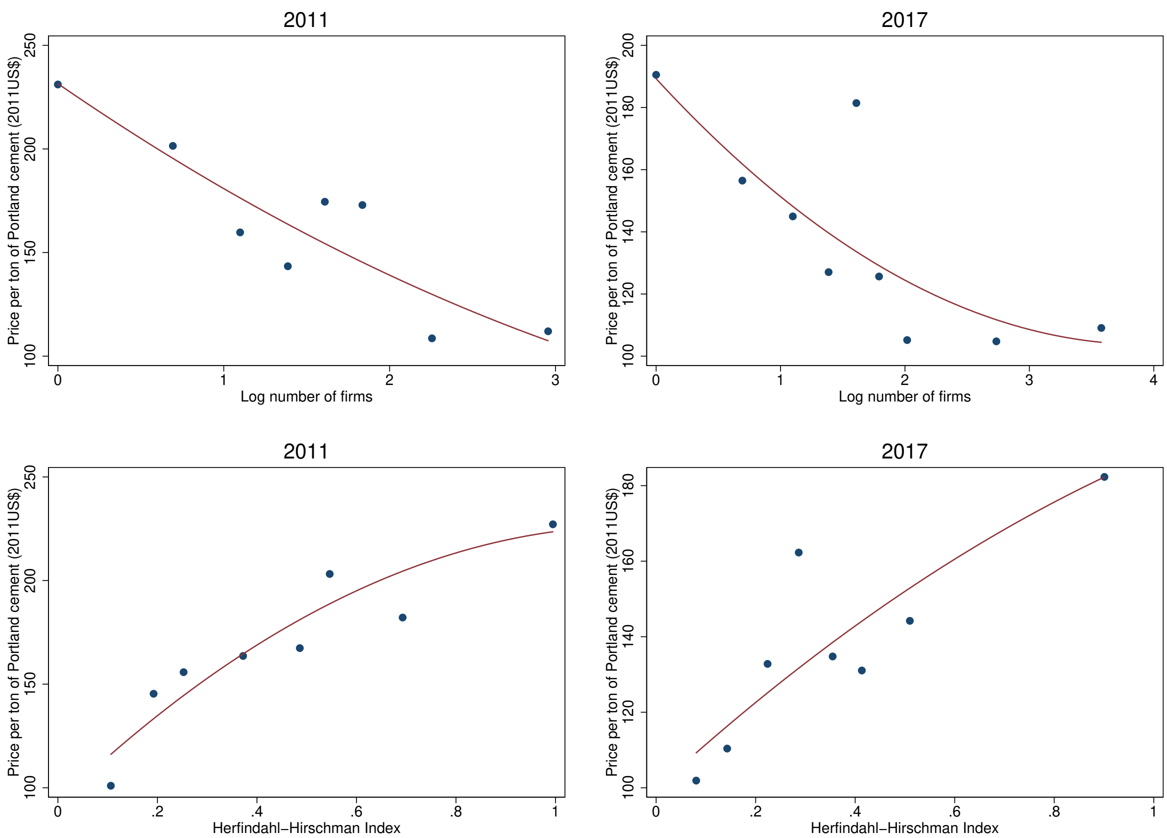
[15]We do not distinguish between grinding and integrated plants for the main purpose of this paper as they both produce the final product cement, but return to this distinction when discussing our second instrumental variables specification in Section 3.3.

[16]This might not the case from the perspective of an individual country. When we examine the role of

transported over land for more than 200-300km (CEMBUREAU, 2020).

To systematically investigate the bivariate correlation between the number of plants and the cement price in the whole sample, the top panel of Figure 3 shows a bin scatter of cement prices and the number of firms per country. The lower panel shows a bin scatter of cement prices and the the Herfindahl-Hirschman index $H = \sum_{i=1}^{N} s_i^2$, where s is proxied using data on the capacity of firms.

Figure 3: Market structure and cement prices, all countries



Note: The top figure shows a bin scatter of the price of cement and the number of firms per country. The bottom figure shows a bin scatter of the price of cement and the Herfindahl-Hirschman index.

The upper graph in Figure 3 shows the negative relationship between the price of cement and the number of firms in a country, while the lower graph shows that cement prices increase as market concentration increases. We acknowledge that these are only bivariate relationships subject to the obvious caveats; in Section 3 we examine this relationship while controlling for a rich set confounding factors. We next turn to the importance of the

market structure on prices we present robustness checks where we account for cement and limestone imports as well as tariffs.

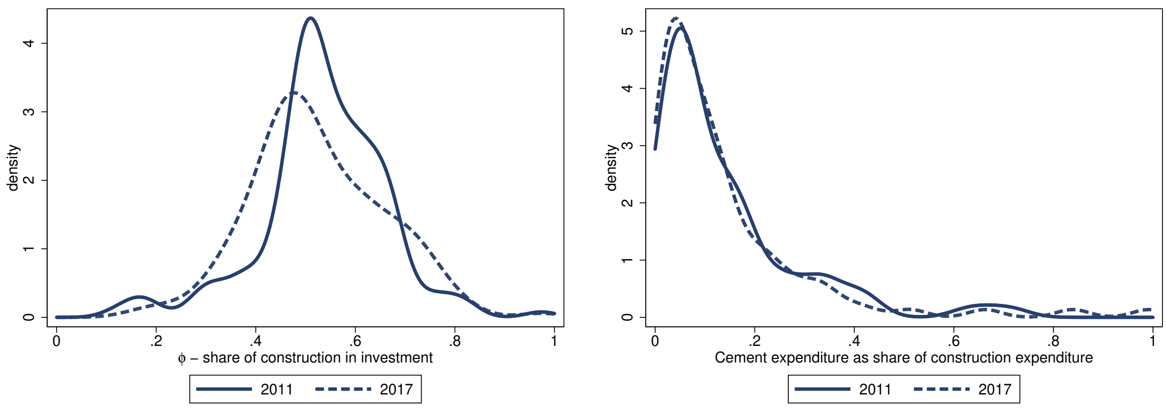
construction sector and cement more specifically.

2.3. Cement consumption

This section presents our third set of motivating facts by providing evidence on the role of the construction sector in investment (gross fixed capital formation) and cement's role in construction expenditures using data from both rounds of the ICP. Figure 4a shows that the share of construction in investment is stable and around 0.5 in both years.[17]

Figure 4: Construction and cement expenditure shares

(a) Construction as a share of investment (b) Cement as a share of construction



Note: Panel (a) shows the distribution of construction as a share of investment expenditures. Panel (b) shows the distribution of cement's share of construction expenditures.

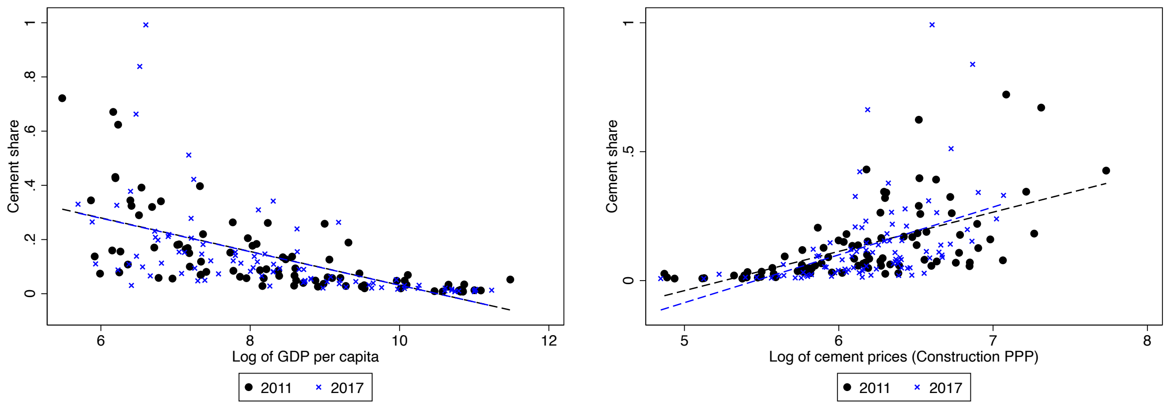
Next we examine the role cement plays in construction sector expenditures. To do this, we compute the share of expenditures on cement as a fraction of construction expenditures, using the ICP prices on cement and cement consumption from Cemnet.[18] Figure 4b highlights that cement accounts for a non-negligible share of construction sector expenditures with median expenditures of 8%. Further, there is large variation, for example, the 75th percentile of countries spends more than 17% of construction sector expenditures on cement.

Figure 5 plots cement's expenditure share of construction expenditures and the log of GDP per capita as well as cement prices.

[17]This is in line with earlier results by Burstein et al. (2004) who also find a share of roughly one half.
[18]We exclude data from Liberia and Comoros for which cement's share of construction sector expenditures exceeds one.

Figure 5: Cement's share of construction expenditures

(a) Cement's share and GDP (b) Cement's share and cement prices



Note: Panel (a) shows cement's share of construction expenditures and log of GDP per capita. Panel (b) shows cement's share of construction expenditures and log of cement prices.

It is clear from the figures that expenditure shares tend to be much larger for some of the poorest countries. Figure 5a shows a clear negative correlation between cement expenditure shares and GDP per capita, suggesting that the industry is of higher importance for low-income countries, precisely the countries with a low capital stock. Figure 5b shows a positive relationship between cement prices and expenditure shares. This is indicative of the essential nature of cement in construction, and its low elasticity of substitution. While cement constitutes a negligible sector for high-income countries countries, this is not the case for low-income countries, where the industry can make up a large share of construction expenditure.

The three main insights from this section are: first, there is large spatial variation in key construction sector inputs across space and the price of cement is particularly high in the poorest countries. Second, measures of market power such as the number of firms and the Herfindahl-Hirschman index are negatively correlated with prices at a global level. Third, cement's share in construction is non-negligible and highest in the poorest countries.

3. The role of competition

We start by specifying a stylised model of Cournot competition which plays two roles. First, it guides our empirical exploration. In particular, it provides a theoretical underpinning for our first and second stages and our choice of instrumental variables. Though we use a Cournot model for illustration, in Appendix C we show that our identification arguments also hold in a more general setting. In this way our strategy is robust to model misspecification. The second role of the model is to provide an expression that allows us to estimate cement's price elasticity of demand via GMM, using instruments motivated by this model. This parameter determines markups in the simple oligopoly model, and plays an important role in our quantification exercise in Section 5. In the final part of this section we examine whether profits in the cement industry translate into economic rents in the accounting data.

We focus our empirical investigation on estimating the causal effect of the number of firms on prices, rather than recovering the full structure of the industry. We favor this approach as our study is across a wide range of markets across all income levels and country sizes in which firms may differ in conduct. For example, Salvo (2010) finds trade acts as a limit price for cement producers in Brazil while Ryan (2012) shows firms are compete in Cournot competition in the US and Röller and Steen (2006) show how cement producers in Norway operate as a cartel. While throughout we assume firms compete in Cournot competition, our identification relies only on uniqueness and monotonicity of entry with respect to entry costs and so would extend to other forms of firm conduct. Further, we are limited in sample size and only observe a single price per country, both for cement and the inputs it uses. Estimating a full model of demand, supply and entry would not only require moment conditions to identify demand, supply and entry but also involve estimating a large number of parameters with a small sample size. We therefore focus on the lower dimensional problem of identifying the causal effect of the number of firms on prices.

3.1. A model of the cement market

The market consists of N firms indexed by i each who produce Q_i units subject to constant marginal costs C. Cement is perfectly substitutable across producers, with CES aggregate market demand

$$P(Q) = \left(\frac{Q}{D}\right)^{-\frac{1}{\varepsilon}}, \quad Q = \sum_{i=1}^{N} Q_i \tag{1}$$

where D are external demand factors cement firms take as given, such as total construction expenditure. We assume that demand is a concave function of prices. Profit maximisation in Cournot competition yields the first order condition for firm i

$$P\left(1-\frac{s_i}{\varepsilon}\right)=C$$

where $s_i=\frac{Q_i}{\sum_i Q_i}$ is the market share of firm i. Taking logs and using the symmetry of firms to $s_i=\frac{1}{N}$, we let lower case letters denote logs to express prices as

$$p=\ln\left(\frac{N\varepsilon}{N\varepsilon-1}\right)+c=\mu(N)+c \tag{2}$$

which implies that per firm profits are given by $\Pi(N)=\frac{PQ}{\varepsilon N^2}$.

There is a large mass of potential firms who enter the market if it is profitable to do so. Firms must pay an entry cost E to enter the market. Firms will enter until profits are equal to the entry cost $\Pi(N)=E$. This, along with our expression for markups in equation (2) implies that the number of firms satisfies

$$n=\frac{1}{2}\left(p+q-e-\ln\varepsilon\right) \tag{3}$$

where we have ignored integer constraints on the number of firms in the market. Equations (1), (2) and (3) define the equilibrium and will form the basis of our empirical strategy.

3.2. Econometric model

We take this market-specific model and apply it across markets k. Suppose marginal costs in country k are given by

$$c_k=\beta' x_k+\nu_k$$

where x_k is a vector of observed costs and ν_k are unobserved costs. Further suppose the elasticity of demand is constant across countries, so $\varepsilon_k=\varepsilon$. Letting $r_k=p_k+q_k$ denote revenue in country k, market demand as defined in equation (1) implies

$$r_k = (1-\varepsilon)\, p_k + d_k + \xi_k$$

where d_k are observable demand shifters and ξ_k are unobserved demand shocks. Combining the demand equation above with the free entry condition (3), we can write the equilibrium compactly as

$$n_k = \frac{1}{2}\left(-\ln\varepsilon + (1-\varepsilon)\, p_k + d_k + \xi_k - e_k\right) \tag{4}$$

$$p_k = \mu(n_k) + \beta' x_k + \nu_k \tag{5}$$

which defines our first stage equation (4) for the number of firms and our second stage equation (5) for prices. Given $\mathbb{E}[n_k \nu_k] \neq 0$ in general as the number of firms endogenously responds to market prices, OLS estimates reflect equilibrium covariance rather than structural relationships. To identify a casual effect of competition on cement prices, we need an instrument. We take two approaches: first, we construct a demand instrument in line with previous literature aiming to estimate structural relationships (e.g., Backus (2020)); second, we develop a novel instrumental variables strategy that exploits the fact that there is natural variation in limestone availability, the key input to produce cement. We outline these two strategies in turn.

3.2.1. Demand elasticity-based markups

First consider an instrument which works through demand, in particular assuming

$$d_k = \delta z_k^D + \tilde{d}_k, \quad \mathbb{E}[z_k^D \nu_k] = 0$$

where z_k^D is a demand-based instrument which is orthogonal to unobserved costs ν_k. Under the assumptions of CES demand and homogeneous costs, a variable z_k^D satisfying the above restrictions is a valid instrument for the number of firms in the market.[19] We use the cost to

[19]Non-constant elasticity of substitution implies that the demand instrument is not strictly exogenous. However under concave demand, a common assumption in the literature, the spurious correlation would bias the

obtain a construction permit (as % of warehouse value) from the Doing Business Indicators as demand instrument. The rationale behind the instrument is that the lower the cost to obtain a construction permit, the higher demand for cement. One might worry that the cost of construction permits might also raise costs in cement, for example by increasing the cost to build a factory. However this an entry cost rather than marginal cost, so in the homogeneous cost case this would not violate the exclusion restriction. Our strategy follows Backus (2020) who uses similar demand-based instruments for competition in US ready-mix concrete markets.

3.2.2. Allowing for a general markup function $\mu(n,r)$ and returns to scale

Demand shocks are valid instruments when the assumptions of the standard model are satisfied, but may not if the model is misspecified. For example, consider the case in which markups are a general function of the number of firms and market revenue $\mu(n,r)$, or costs have a scale component, so that $\nu_k = f(q_k) + \tilde{\nu}_k$. Then the dependence of markups or marginal cost on demand implies that a demand instrument may not be valid. Suppose instead we have a variable z_k^E that is orthogonal to both demand and cost shocks, but moves entry costs, so that

$$e_k = \gamma z_k^E + \tilde{e}_k, \quad \mathbb{E}[z_k \nu_k] = 0, \quad \mathbb{E}[z_k(d_k + \xi_k)] = 0.$$

Such a variable would be a valid instrument for the number of firms in both the parametric model and the more general case. Importantly this instrument should be based on the costs of entry, rather than the fixed costs of operation. The homogeneous marginal costs assumption implies that entry costs, paid before costs are known, and fixed costs paid on a continuous basis are identical. We show in Appendix C that when costs are heterogeneous, fixed costs will raise the cutoff level of costs under which firms will enter, and therefore will be positively correlated with ν_k. It is thus crucial to find an instrument that shifts entry costs, rather than fixed costs of production. In Appendix C we also show that subject to a

effects downwards. With concave demand, demand shocks which raise the number of firms would cause a decrease in markups, attenuating pro-competitive effects.

more general version of the exclusion restriction, this instrument will be valid for a broad class of models.

Our instrumental variables strategy exploits variation in the dispersion of limestone deposits, holding the total level of limestone availability fixed. To construct our instrument for entry we use geospatial data on carbonate rock areas by country from the World Karst Aquifer map, a recently released global dataset documenting the spatial distribution of carbonate rocks (Goldscheider et al., 2020). Limestone is a type of carbonate rock that forms the key ingredient for cement production (Van Oss, 2005). Integrated cement plants – those that take limestone and make cement from it – typically would only locate in places where raw materials are available for at least 50 years and mining is mostly done through quarrying rather than underground exploitation (Van Oss, 2005).[20] Carbonate rocks are present on all continents and all climate zones, but the availability differs by country. Figure 6 shows the global distribution of carbonate rocks (continuous and discontinuous, and mixed carbonate and evaporite rocks). The fact that carbonate rock deposits are geologically determined means that limestone availability is exogenous to other determinants of prices.

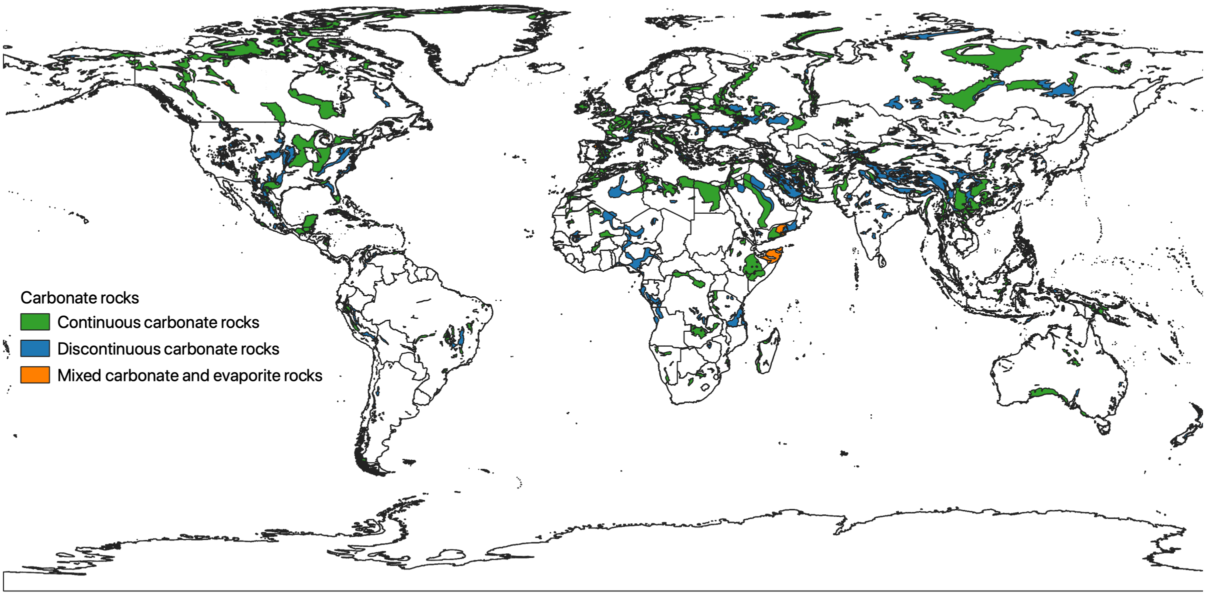
For each country, we compute the number of distinct areas of carbonate rock. The degree of geographical dispersion in a country's total limestone deposit size is correlated with entry, due to plants' desire to locate close to limestone but also away from other plants. A higher number of deposits therefore makes entry more likely, while not affecting fixed costs once a firm has started production.[21] Total limestone availability in a country is an important determinant of costs, which we capture by flexibly controlling for the total area of limestone deposits in a country in all specifications.[22] Contrasting pairs of countries with similar populations, for example, we see that Tunisia has 11 distinct carbonate rock areas and 9

[20]Lime (CaO) from materials such as limestone, cement rock or marl accounts for about 84% of the nonfuel raw materials for clinker and cement manufacture (Van Oss, 2005). Since most deposits are on the surface this implies that unlike in the the cases of oil and gas where knowledge of deposits depends on expensive explorations that are endogenous, this is not the case with limestone deposits.

[21]A further channel is that countries may grant rights for certain deposits or time frames.

[22]In our deposit count measure, naturally, some deposits are smaller and some are larger. Since our instrument should not capture total limestone availability, we prefer a simple and parsimonious count measure rather than using variation in the size of individual deposits which is correlated with the overall deposit size.

Figure 6: Distribution of carbonate rocks



Note: This figure shows the global distribution of continuous and discontinuous carbonate rocks and mixed carbonate and evaporite rocks.

firms, compared to Rwanda that has 2 distinct carbonate rock areas and 2 firms. Austria has 6 distinct carbonate rock areas and 7 firms, compared to Israel that has 2 distinct carbonate rock areas and 2 firms.

3.3. Estimating the role of competition

This section presents our empirical specification to estimate the effects of market power on the price of cement. We start by estimating equation (5) with OLS and then examine the robustness of this correlation. Second, we show the IV results using the demand instrument and third, the entry instrument. Specifically, we estimate the regression

$$p_{k,t} = \delta_t + \mu n_{k,t} + \beta' X_{k,t} + \nu_{k,t} \tag{6}$$

where $p_{k,t}$ represents the log price of cement in country k at time t, $n_{k,t}$ represents the log number of firms in country k at time t, δ_t are year fixed effects; $X_{k,t}$ is a vector of controls for average costs, which we vary across specifications; $\nu_{k,t}$ is an idiosyncratic error term. This implies that our estimand μ is an average of the elasticity of prices to number of firms.[23] As proxies for average costs we include a set of scale controls to take into account the role of market size as pointed out by Sutton (1991), namely the log of population, income (wages) proxied by GDP per capita, and transport costs proxied by area, all taken from the World Development Indicators and the ICP.[24] We also include controls for corruption, political instability and rule of law come from the World Governance Indicators. In further robustness tests we us data on road infrastructure from the Global Roads Inventory Dataset and the Logistics Performance Index. We compute a measure of average plant-level travel time (in mins) to the nearest city of more than 500,000 people and use data from UN COMTRADE on price of machinery and imports of cement and limestone. Appendix Table A.1 summarizes the different data sources.

Table 1 shows our baseline estimates of equation (6). Columns (1)-(2) show the OLS results for different sets of controls that include time fixed effects, scale controls and governance indicators. The estimates in column (2) suggest that doubling the number of firms is associated with a 17% decrease in prices. We next perform a number of robustness tests, starting

Table 1: OLS Estimation. Dependent variable: ln (Price of Cement)

	Baseline		**Market Definition**		**Plants vs firms**	
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln n$	-0.24***	-0.17***	-0.15**	-0.11*	-0.40***	-0.20*
	(0.049)	(0.048)	(0.065)	(0.061)	(0.11)	(0.10)
ln (Number of plants)					0.18	0.037
					(0.12)	(0.11)
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	No	Yes	No	Yes
Fuel	No	Yes	No	Yes	No	Yes
N	172	165	86	83	172	165
R-sq	0.315	0.430	0.177	0.336	0.327	0.431

Note: Reported standard errors are clustered at the country level. All models include time fixed effects. *, **, *** denote significance at 10%, 5% and 1% levels.

with our definition of a market. So far we assumed that each country represents a cement

[23]We show that our results are robust to alternative functional forms.

[24]We use cement prices and GDP per capita expressed in exchange rate terms rather than PPPs.

market. This is not entirely unreasonable given that less than 5% of cement is traded internationally and is consistent with, for example, the view of the competition authority in the United Kingdom (Competition Commission, 2014). However, markets might be more local due to high transport costs.[25] To reflect the geographic segmentation of markets, the USGS divides cement producers in the United States into 26 markets in its Minerals Yearbook. This is a commonly used definition (Hortaçsu and Syverson, 2007), recognizing that part of the motivation for how markets are defined is ensuring that plants are not identifiable in the data and plants are divided equally. While such detailed information on within-country cement markets is not available at a global level, for 2017, we geo-coded the locations of all plants worldwide. For each plant, we then compute the number of different firms within 300km, counting the firm that owns the plant.[26] We compute this measure for every plant and then take an average across plants in a country. We do this assuming either no trade across country borders or allowing for trade across borders. Columns (3) and (4) show our baseline results for this local measure of market power. The number of observations is smaller as we can only use one round of data, so our estimates are slightly less precise. Still, the point estimates are very similar and consistent with our findings so far: a higher number of firms on average is associated with a lower price. Finally, columns (5) and (6) represent our most restrictive specification that controls for both, the number of cement plants, and the number of firms in a country. This means that we only exploit variation in competition, holding the number of plants constant. When we control for the number of plants the coefficient on the number of plants is zero and the coefficient on the number of firms is almost unchanged. This suggests that what matters for cement prices is competition which is determined by the number of firms rather than the number of plants.

We conduct a number of further robustness checks. In Appendix Table B.2, we first show that our results are unchanged when using alternative measures of competition. Next, we show that our results are robust to controlling for various measures of transport costs and infrastructure. In Appendix Table B.3 we show the correlation is robust to the inclusion of

[25]This has been proven to be particularly relevant for the ready-mix concrete industry given the perishability of the good (Syverson, 2008).

[26]We chose this threshold to reflect the fact that cement is typically not transported for more than 200-300km over land (CEMBUREAU, 2020).

a large battery of cost controls, controls for tariffs, whether a country imports limestone, and is not driven by plant scale. We also show that the correlation is robust to other market definitions, including specifications which allow for trade in cement.

Table 2: IV Estimation I (Demand Instrument). Dependent variable: ln (Price of Cement)

	(1)	(2)	(3)	(4)	(5)
$\ln n$	-0.75**	-0.48***	-0.46***	-0.46***	-0.45***
	(0.34)	(0.16)	(0.17)	(0.16)	(0.16)
Scale	No	Yes	Yes	Yes	Yes
Governance	No	No	Yes	Yes	No
Fuel	No	No	No	Yes	No
Construction IV	No	No	No	No	Yes
F-Stat	4.3	9.8	8.4	8.4	4.2
P-value of AR F-Stat	0.000	0.020	0.038	0.018	0.100
N	172	172	172	165	172
R-sq	-1.351	0.185	0.233	0.260	0.243

Note: Reported standard errors are clustered at the country level. All models include time fixed effects. *, **, *** denote significance at 10%, 5% and 1% levels.

The OLS estimates show a remarkably robust correlation of prices and competition in cement across countries that does not seem to be driven by confounding variables. Though suggestive, they nonetheless do not identify a causal effect of competition on prices. To make progress here, Table 2 reports estimates using our demand instrument, the cost to obtain a construction permit as discussed in Section 3.2.1.

As shown by Angrist and Kolesár (2023), screening on values of the F-test introduces bias, so instead we rely on the Anderson-Rubin test to allow for weak instruments. Throughout, we report p-values from an Anderson-Rubin test for all of our IV estimates. Column (1) reports the baseline specification with no controls. The coefficient on the number of firms is larger than what we got in the OLS estimation. In column (2) we add controls for country GDP per capita and scale and the coefficient falls to around -.5 and remains highly significant. Although the F-stat is somewhat weak with a value just below 10, the Anderson-Rubin test suggests that weak instruments are not an issue. These results suggest that OLS results exhibit downwards bias, perhaps due to upward sloping supply curves or attenuation bias. The estimates suggest competition has a strong negative effect on prices, with an elasticity of 0.5. This is a large effect given typical variation in competition. For example, these estimates suggest the entry of a single firm in a monopoly market halves prices in the market. These results are not entirely unreasonable. For example, in Burkina Faso cement prices dropped from US$267 to US$123 per ton when the number of firms increased from 1 to 4 between 2011 and 2017. In Zambia cement prices dropped from US$217 to US$73 per ton when the number of firms increased from 2 to 5 between 2011 and 2017.

One concern with the demand instrument is that it may be correlated with other indicators of governance that are themselves related to unobserved costs if the cost to obtain a construction permit simply reflects institutional quality. Column (3) controls for a set of governance indicators from the WGI, namely rule of law, control of corruption and political stability. We see that the coefficient does not change substantially, allaying concerns of omitted governance variables driving the results. Column (4) adds the cost of fuel as a control, and the results are again unchanged. Finally, we add construction's share of GDP as a potential demand instrument in column (5). Somewhat surprisingly, this has little effect on the coefficient and instead simply adds noise to the first stage. This suggest that the instrument is unrelated to the overall expenditure of the construction industry, instead operating via higher entry costs.

Our final set of results uses the entry instrument based on limestone availability as discussed in Section 3.2.2 that plausibly satisfies the exclusion restriction in a general non-linear model (where our demand instrument might not). In Appendix Section C we show that the entry instrument is robust to non-linearity and model mis-specification, of course conditional on the exclusion restriction holding. However as pointed out by Blandhol et al. (2022), this argument is valid only if the first stage is rich in covariates - that is when controls capture non-linearities in the first stage. To account for possible non-linearities, in some specifications we break our controls into five linear splines and add each to the specification.[27]

Table 3 reports the results using the number of limestone deposits as an instrument for competition. In all specifications we control for the inverse hyperbolic sine of the total

[27]We use splines to reduce information loss and increase efficiency.

Table 3: IV Estimation II (Entry Instrument). Dependent variable: ln (Price of Cement)

	Baseline		Non-linear controls		Integrated	Pop
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln n$	-0.32***	-0.50**	-0.38**	-0.57***	-0.26**	-0.71**
	(0.11)	(0.24)	(0.15)	(0.20)	(0.12)	(0.34)
Country size	No	Yes	No	No	No	No
GDP p.c.	No	Yes	No	No	No	No
Population	No	No	No	No	No	Yes
Governance	No	Yes	No	No	No	No
F-Stat	20.5	4.5	11.1	6.1	18.1	3.7
P-value of AR F-Stat	0.012	0.046	0.042	0.017	0.087	0.035
N	174	172	174	172	69	174
R-sq	0.189	0.099	0.140	0.045	0.230	-0.226

Note: Reported standard errors are clustered at the country level. All models control for the inverse hyperbolic sine of the sum of continuous, discontinuous and mixed evaporite and carbonate rock; all models include time fixed effects. Column (3) includes total carbonate rock area as five splines; column (4) adds splines for per capita GDP and country area; column (5) limits the sample to integrated plants only. *, **, *** denote significance at 10%, 5% and 1% levels.

area of carbonate rock (continuous, discontinuous and mixed). Therefore our instrument captures dispersion of limestone deposits, holding the total availability constant. Column (1) reports our estimates with no additional controls. The estimated coefficient is around -0.3 with a strong first stage. Column (2) reports the same estimates adding controls for country size, average income and governance. The estimated coefficient of -0.5 is very close to those of the previous table, though somewhat less precise. Although the F-stat is low, the Anderson Rubin test is significant at the 5% level. Moreover this is a rather restrictive specification, with seven cost control variables, so an increase in variance is natural. Column (3) reports the results with total carbonate rock area included as five splines to account for non-linearity in the first stage (Blandhol et al., 2022), with the results qualitatively unchanged. Column (4) adds splines for per capita GDP and country area. Again the results are similar to the linear case, with a rise in the estimated coefficient and a slight increase in precision. These results suggest that non-linearity in the first stage is not a major issue and that our instrument is indeed robust to mis-specification.

Our instrument is based on the premise that more dispersed limestone deposits make it less costly to enter the market, by allowing new plants to locate in deposits not already used by existing firms. In general, there are two kinds of cement plants: integrated plants who manufacture cement from limestone and raw materials, and grinding plants who purchase cement "clinker" and grind it into cement. Our instrument is only relevant for integrated plants and does not apply to grinding plants who do not use limestone directly. Column (5) runs our regression using only integrated plants, which we can only separately identify in 2017. We see that the coefficient falls to -0.26, but remains significant and robust to weak instruments. Most of this decline is not due to the distinction between plants but rather selection of years - the coefficient is almost identical (-0.27) if we estimate the model in column (1) only using data for the year 2017 but all plants. This suggests that there is no bias introduced by grinding plants, and thus we include both in the baseline. The models estimated in Tables 1 and 2 also include population as a control for costs possibly linked to economies of scale, while we have excluded it here. Column (6) adds population as a scale control. We see that although the coefficient rises, precision is reduced and the F-stat declines. This is because limestone deposit dispersion and population are correlated, which might be for a number of reasons, including the fact that carbonate rocks frequently occur on coasts (where population is higher) or because they provide a source for drinking water (Goldscheider et al., 2020).[28] Since population can be viewed as a "bad control" in this specification, we exclude it from the baseline specification.

3.4. Estimating the elasticity of substitution ε

Thus far we have focused on estimating the average elasticity of prices to the number of firms in the market, in a manner that does not rely on assumptions of firm conduct. Having established a strong effect of entry on prices, we now use the functional form implied by the oligopoly model to estimate the elasticity of demand ε. This is a key parameter shaping the response of prices to entry in the model, and plays an important role in our quantification exercise in Section 5.

In order to estimate ε, we again estimate equation (5), but rather than letting the esti-

[28] Coastal carbonate rocksper karst makes up roughly 15.7% of the total global coastline (excluding Antarctica) (Goldscheider et al., 2020).

mand be a weighted average of marginal effects $\frac{d\ln\mu}{d\ln n}$, we instead parameterise the markup function. Formally, our price equation is

$$p_k = \log\left(\frac{\varepsilon n_k}{\varepsilon n_k - 1}\right) + \beta' x_k + \nu_k$$

where n_k is the number of firms in country k and ε is the market elasticity of demand for cement.[29] In Appendix Section C we show that this equation also holds when firms are heterogeneous in productivity, where $\beta' x_k + \nu_k$ can be interpreted as representing log average costs across firms in the market. Note that under the exclusion restriction for the limestone-based entry instrument $\mathbb{E}[z_k \nu_k] = 0$, we have the following moment

$$\mathbb{E}\left[\left(p_k - \log\left(\frac{\varepsilon n_k}{\varepsilon n_k - 1}\right) - \beta' x_k\right) z_k\right] = 0$$

from which we can obtain estimates of ε via GMM.[30] We estimate this equation first using all countries in the sample, but also restricting our sample to countries with at least two firms. As our model is primarily one of oligopoly, it will be a poor approximation for situations in which there is a monopolist and the elasticity of substitution is close to one.

Table 4: Estimating ε via GMM

	(1)	(2)	(3)
$\hat{\varepsilon}$	1.43***	0.82**	0.93*
	(0.26)	(0.34)	(0.48)
Time FE	Yes	Yes	Yes
Cost controls	No	No	Yes
N	174	132	125

Note: Reported standard errors are clustered at the country level. In column (1) the parameter space is $\varepsilon \in \{1, \infty\}$ while in column (2) we allow $\varepsilon \in \{1/2, \infty\}$. All models control for the inverse hyperbolic sine of the sum of continuous, discontinuous and mixed evaporite and carbonate rock. Column (1) includes year fixed effects and total limestone deposits as controls; column (3) also adds GDP per capita and the price of fuel as observed costs. *, **, *** denote significance at 10%, 5% and 1% levels.

[29] An alternative approach would be to estimate the demand curve for cement to estimate the elasticity of demand directly. However, this would require an instrument for cement costs that is orthogonal to unobserved demand determinants. Given that almost all inputs for cement are also used directly in the construction industry (and thus effect demand via substitution), it is difficult to find such an instrument.

[30] For this to be uniquely identified, we need to assume $\varepsilon n_k > 1$ for all n_k - if this does not hold, firms face non-concave demand and thus don't have an interior optimum. We therefore restrict the parameter space to be $\varepsilon \in \{1/n_{min}, \infty\}$ where n_{min} is the lowest number of firms we observe.

Table 4 reports estimated parameter values $\hat{\varepsilon}$ from our GMM estimation. Column (1) reports estimates using the entire sample of countries available, controlling for both time fixed effects and total limestone availability. Column (2) repeats this estimation, but focusing on countries with at least two firms in the market. Finally column (3) adds the price of diesel fuel and log of GDP per capita as controls for costs. We see that in all cases the estimated elasticity is close to one, albeit with reasonably large standard errors. These estimates imply marginal effects that are broadly in line with our causal estimates in the previous section, as shown in Appendix Figure B.4. The estimates suggest that cement firms face inelastic demand and markups are sensitive to the level of competition in the market.[31]

3.5. Markups and rents

The previous analysis suggests that markups are an important source of variation in price, with increasing competition leading to large falls in prices. However, as highlighted by (Syverson, 2019), the presence of markups does not necessarily imply that firms have market power, or more precisely, earn economic rents.[32] Whether or not there are rents depends crucially on whether entry is free. If entry is free, then profits are only quasi-rents that are dissipated by fixed costs. In this case firms earn zero rents in the long run and the market cannot sustain a greater number of viable firms. By contrast, when there are barriers to entry firms can earn positive rents and the market could sustain greater competition. Therefore in the latter case, our prior estimates would imply room for entry and competition to reduce prices. In this section we aim to differentiate between these cases by measuring total firm excess returns in the market - a measure of rents. The presence of rents implies some barriers to entry which stop firms from entering a profitable market - therefore we can equate expected rents in the market to entry barriers. We provide a theoretical justification for this measure of rents in Appendix D and show that it corresponds to entry barriers in a

[31] These estimates are broadly in line with Fowlie et al. (2016) who estimate an elasticity of demand between 0.89 and 2. A report by the UK's Competition Commission assumes that demand for cement is inelastic, arguing that "Cement is an intermediate good; it serves as an input to various construction projects, has very few substitutes and the cost of cement represents only a relatively small proportion of the final price of such projects. Therefore, the demand for cement is unlikely to respond much to changes in prices of cement." (Competition Commission, 2014).

[32] To avoid confusion we adopt the following terminology: profits are defined as operating surplus measured over variable costs, and rents or excess returns are defined as the excess of profits over firms' fixed costs.

general model of firm value with free entry.

We measure the total excess return on firms' capital, given by

$$r^{\pi} = \frac{\mathbb{E}[\pi - rK]}{\mathbb{E}[K]} \tag{7}$$

where π denotes firm operating profits, K denotes firm capital and r is the user cost of capital.[33] This concept of excess returns is similar to the user-cost approach used by Barkai (2020) and Gutiérrez and Philippon (2016). We implement this approach using the financial accounts data of publicly listed firms operating in the cement industry between 2010 and 2020 from the Worldscope database. In line with Gutiérrez and Philippon (2016) we interpret "operating surplus less income taxes" as the surplus of revenue over all non-capital related costs, while capital K_{it} is given by "Net property, plant and equipment". Throughout we assume a constant depreciation rate of 6% to avoid excessive depreciation as measured by firms' own accounts. We measure excess returns $r^{\pi}_{i,t}$ of firm i headquartered in country k at time t by

$$r^{\pi}_{i,t} = \frac{S_{i,t}}{K_{i,t}} - \delta - r_{k,t} \tag{8}$$

where $S_{i,t}$ is the operating surplus of the firm after taxes and before depreciation, $K_{i,t}$ is the firm's capital stock, $\delta = .06$ is the depreciation rate and $r_{k,t}$ is the user cost of capital. The key object which we must impute is the user cost of capital, which accounts for firms' risk premia. We use several approaches to measuring this quantity. In the baseline analysis we measure user cost with the average borrowing rate a firm pays on its debt to capture the idiosyncratic risk across countries within a given country. We take the average firm-level excess return between 2010 and 2020 where available, weighted by capital (in US dollars, deflated). This attenuates concerns that annual firm excess returns may compensate for losses or intangible investment in previous years. In Appendix E we show robustness of our results to taking firm-level averages between 1980 and 2020. As our data come from

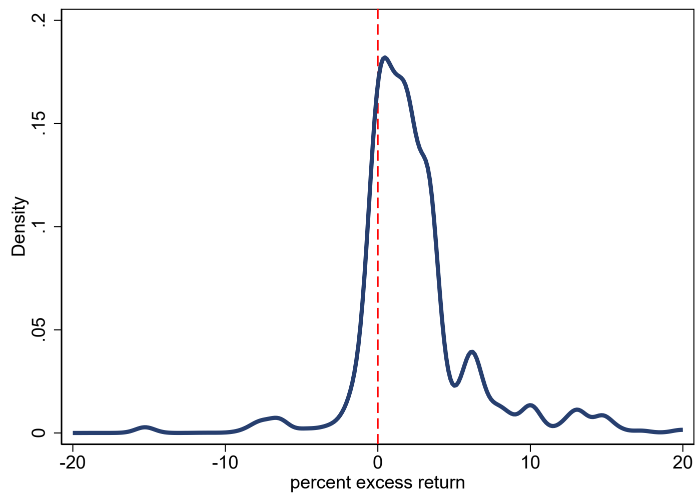
[33] For our exposition we assume that capital represents fixed costs, though as all costs are subtracted from operating surplus as we show below, this is irrelevant.

financial accounts, many of the firms in our data are multinationals, who produce a large share of global output. We therefore measure rents as the (capital-weighted) aggregate excess returns in the global industry, given by

$$r^{\pi} = \sum_i \frac{K_i}{\sum_i K_i}(r_i^{\pi})$$

which is the sample analogue to equation (7). Figure 7 plots the distribution of excess returns under our baseline measure. Under zero rents, this density would be expected to be

Figure 7: The distribution of excess returns in the cement industry



Note: This figure plots the density of firm-level excess returns rates from Worldscope, weighted by a firm's capital stock. Firm-level returns are calculated as the average of annual excess returns between 2010 and 2020.

roughly centered around zero. In fact, the density is heavily skewed, with little mass below zero excess returns. This suggests that not only are excess returns positive in expectation, earning a return less than the market rate is rare for cement firms.

Table 5 reports the aggregate excess returns r^{π} for our various measures of user costs. In the baseline scenario, we see that returns are over 2.5% in excess of the market rate.[34] Using uniform user costs reduces excess returns, presumably because larger firms face lower risk premia. The excess returns are nonetheless substantial even with conservative measures of user costs.[35] In Appendix E we show these results are only strengthened when we consider

[34]For reference on scale the US risk-free rate was less than 2% on average over this time period, while the equity premium is around 6%.

[35]For example, the average firm borrowing rate is over 11%, while country-specific measures are over 13%

Table 5: Excess returns for different user costs

	Firm r	US r, RP=6%	country r, RP=6%	US r, county RP	country r, country RP
$\hat{\pi}$	2.62	1.44	1.25	1.50	0.97
	(0.20)	(0.21)	(0.23)	(0.20)	(0.21)
N	431	439	351	438	349

Note: Standard error of mean in parentheses. 'Firm r' denotes user cost measured by firm level borrowing costs. 'US r' denotes risk free rates measured by US real rates, 'country r' denotes risk free rates country specific. 'RP=6' denotes an equity premium of 6% applied, while 'country RP' denotes the use of country specific equity risk premia from Damodaran (2021).

a longer time-span or use market betas to calculate firm-specific risk premia for a subset of firms. All results point to cement firms making significant returns on their capital in excess of market rates in aggregate. A potential entrant can expect to earn significant rents once operating in the market, which implies the presence of barriers to entry to ensure such entry is not profitable.

4. Understanding the costs of low competition in the cement industry

The presence of rents alone is not sufficient to infer whether these rents increase or reduce allocative efficiency in general equilibrium, since this depends on the cement industry's position in the production network.[36] To answer this question, we embed a production network into a two-sector neoclassical growth model that we can take to the data. Crucially, the model allows for network effects through both intermediate inputs and capital investments. We outline the model here and provide a full derivation in Appendix F.

4.1. Model outline

The dynamic block of the model is a continuous-time two-sector neoclassical growth model. Consumers purchase consumption and investment goods, facing a constant depreciation rate δ, discount rate ρ, and log utility.[37] We let the price of the consumption index be the

on average since 2010.

[36]Indeed rents are not necessary for marginal changes in competition to have a positive effects - even in the zero rent economy, we show entry in cement can yield significant benefits.

[37]Log utility is assumed for ease of notation. The steady-state analysis is unchanged with an arbitrary continuously differentiable utility function such that $u'(c) > 0$ and $u''(c) < 0$.

numeraire, such that $p_c = 1$. Consumer optimisation results in the usual Euler equation

$$\frac{\dot{c}}{c} = \frac{r^k}{p_I} + \frac{\dot{p_I}}{p_I} - \delta - \rho \tag{9}$$

where p_I is the price of investment goods. We normalise the population such that $L = 1$, which implies all variables are in per capita terms.

The static block of the model is a standard Cobb-Douglas network model. There are N intermediate goods, each produced by a representative firm. Firm i uses capital k_i, labour l_i and intermediates $\{m_{i,j}\}_{j=1}^N$ to produce final goods according to a constant returns to scale Cobb-Douglas production function. Firms minimise costs, charging a constant markup μ_i, which translates into a firm-level profit rate of $\tau_i = 1 - \mu_i^{-1}$. We denote the vector of all firm profit rates as $\tau = \{\tau_i\}_{i=1}^N$. In our exposition we assume profits are rebated to the household, and thus profits correspond to economic rents. Most of the results would be unchanged if instead we assumed profits pay for fixed costs instead.

Firm i's output q_i can be used for consumption c_i, investment x_i or as an intermediate $m_{i,j}$ in sector j. We define nominal output as

$$P_y Y = wL + rK + \Pi$$

where $\Pi = \sum_i \tau_i p_i y_i$ denotes aggregate profits. Letting $\pi = \Pi/(P_y Y)$ be the aggregate profit share, we can express nominal output as

$$P_y Y = \frac{Y^F}{1 - \pi}$$

where $Y^F = wL + rK$ is income paid to the factors of production. The revenue-based input-output table $\mathbf{\Omega}$ is given by

$$\mathbf{\Omega} = [\omega_{i,j}] = \left[\frac{p_j m_{j,i}}{p_i q_i}\right]$$

which captures each sector's expenditure on other sectors. The presence of markups μ_i

implies that there are wedges between the elasticity of production to inputs and the inputs' expenditure shares. The elasticity or cost-based input-output matrix $\mathbf{\Sigma}$ is given by

$$\mathbf{\Sigma} = [\sigma_{i,j}] = \left[\mu_i \omega_{i,j}\right]$$

which captures each sector's elasticity to intermediate goods. Both investment and consumption are Cobb-Douglas combinations of intermediate goods. We define the final expenditure shares as

$$\beta_i = \frac{p_i c_i}{p_c C}, \quad \lambda_i = \frac{p_i x_i}{p_I I}, \quad \gamma_i = \frac{p_i q_i}{PY}$$

such that the vector β_i gives the share of final consumption expenditure on good i, λ_i gives the share of final investment expenditure on good i, and γ_i gives total expenditure on good i as a share of nominal output.

4.2. Equilibrium

The equilibrium of the economy is described in the usual way, such that all agents are optimising subject to their constraints, while markets clear and aggregation holds. Here we specify some key equilibrium quantities.

I. Steady-state output

Following vom Lehn and Winberry (2021) we define the aggregate price index according to a Divisa index so that changes in the GDP deflator P_y are given by

$$d\ln P_{y,t} = s_t d\ln P_I$$

where $s_t = \frac{p_{I,t} I_t}{P_{Y,t} Y_t}$ is the savings rate at time t. The definition of the Divisa index implies that deflated output is defined relative to a base year. The Cobb-Douglas form of this economy allows us to express real output according to the following proposition:

Proposition 1 *Define $\tilde{Y}$ and $\tilde{k}$ to be the steady-state values of Y and k in the efficient economy.*

Starting from a base period output deflator $P_{y,t_0} = s_{t_0} p_I + (1 - s_{t_0}) p_c$, steady-state output is given by

$$\frac{Y}{\tilde{Y}} = \frac{\prod_{i=1}^{N}(1-\tau_i)^{\psi_i^Y}}{1-\pi}\left(\frac{k}{\tilde{k}}\right)^{\alpha} \tag{10}$$

$$\frac{k}{\tilde{k}} = \left(\prod_{i=1}^{N}(1-\tau_i)^{\psi_I}\right)^{\frac{1}{1-\alpha}} \tag{11}$$

where $\psi^{C\prime} = \beta'(I - \Sigma)^{-1}$, $\psi^{I\prime} = \lambda'(I - \Sigma)^{-1}$ and $\psi^Y = s_{t_0}\psi^I + (1 - s_{t_0})\psi^C$ define the sensitivity vectors in consumption, investment and output respectively.

Equation (10) shows that we can express output losses for a given capital stock as an aggregate wedge. For a constant capital stock micro distortions impact aggregate efficiency through their relative level. If, for example, $\prod_{i=1}^{N}(1-\tau_i)^{\psi_i^Y} = 1-\pi$, there is no efficiency loss from distortions with a constant capital stock. By contrast, expression (11) shows that the absolute level of markups reduces investment and the long-run capital stock. This highlights the key insight the model captures: markups in investment are much more detrimental than those in consumption. Therefore, when evaluating the cost of markups across sectors, it is important to understand their relative importance for consumption and investment goods.

II. Marginal changes

While Proposition 1 provides a closed form expression for output, this expression includes the profit rate π which is determined endogenously. Although we can express this term analytically, calculating the marginal changes in steady-state output is useful for two reasons. First, marginal changes show the core intuition of the model. Second, the expression for marginal changes in output applies to a network model with a general production structure with a few minor modifications. The following proposition gives the marginal elasticity of output to changes in markups in any sector j:

Proposition 2 *The marginal effect of changes in markups in sector j on steady-state output* *is given by*

$$\frac{d\log Y}{d\log \mu_j} = -\psi_j^Y - \frac{\alpha}{1-\alpha}\psi_j^I + \gamma_j\left(\frac{1-\sum_{k=1}^N \tau_k \mathscr{L}_{j,k}}{1-\pi_c}\right) \tag{12}$$

where $\mathscr{L} = (I-\boldsymbol{\Omega})^{-1}$ *is the expenditure-based Leontief inverse and* $\pi_c = \beta'(I-\boldsymbol{\Sigma})^{-1}\tau$.

Crucially, this expression accounts for the effect of changes in cement throughout the production network. Changes in markups exert two conflicting forces on output. On the one hand, increased markups imply reduced payments to factors. This network effect has both a static and dynamic component. The static component is the term $-\psi_j^Y$ in equation (12) which determines the impact of increased markups on factor income keeping the capital stock of the economy fixed. This is the term captured by Liu (2019), who analyses changes in factor income in a general setting. The dynamic component comes from the second term $-\frac{\alpha}{1-\alpha}\psi_j^I$, which captures the impact of changes in the capital stock resultant from a change in markups. This is given by the elasticity of production to capital α, times the sensitivity of investment to the sector ψ_j, times the capital multiplier $\frac{1}{1-\alpha}$. On the other hand, increasing markups increase profits which we have assumed are rents rebated to the consumer. The last term of this expression captures the effect of markups on profits, which is given by the industry's expenditure share γ_j times a reallocation term. The increase of markups reallocates resources along the supply chain, which impacts aggregate profit rates.

Finally, we can define the long-run counterpart of the distortion centrality introduced by Liu (2019)

$$\xi_j = -\frac{dY^F/d\tau_j}{Y d\pi/d\tau_j}\bigg|_{\tau=0} = \frac{\psi_j^Y + \alpha(\psi_j^I - \psi_j^Y)}{\tilde{\gamma}_j}.$$

where $\tilde{\gamma}_j = \frac{1-\tau_i}{1-\pi}\gamma_j$ is the expenditure share adjusted for the presence of profits, so $\tilde{\gamma}_j$ is a measure resource allocation to industry j. This statistic reflects the trade-off between factor income and profits in an economy with zero rents, where profits simply pay for fixed costs and entry is free. The numerator in this expression is proportional to the elasticity of factor income to profit rates τ_j, while the denominator tells us how profits change due to changes in profit rates, scaled by the capital multiplier. This relation captures a sector's effect on steady-state output relative to its size: the value-added weighted mean of ξ is equal to one $\mathbb{E}_{\ell_i}[\xi_i] = \sum_i \xi_i \ell_i = 1$. When this expression is greater than one, increased profits in sector j will reduce aggregate output and conversely when it is less than one they will increase aggregate output. This expression provides a summary statistic for changes in profit rates in an economy where rents are close to zero, and therefore shows robustness to our results to assuming zero economic rents.

5. Quantification

We now evaluate the macroeconomic impact of distortions in the cement sector through the lens of this model. Our theory alone is not informative about whether profits in cement or any other industry are costly or beneficial in the aggregate. Instead, it tells us how to determine this in the data. We proceed in three steps: first, we rank sectors by the marginal long-run impact of markups in each sector, showing cement's relative position. Second, we compute the estimated wedge generated by markups in cement, defined as the percentage loss in aggregate steady-state output as a share of initial cement expenditures.[38] Third, we turn to quantifying the costs of inefficient levels of entry and common ownership, both of which reduce competition. We measure the cost of low entry by calculating the benefit of extra firms entering the market. The cost of common ownership is measured by the output gain if all plants competed as independent entities. We also show the robustness of the latter to increased fixed costs for independently operating plants. Throughout we assume that the marginal entrant earns zero profits in cement, and so entry must be subsidized. This is a conservative approach; given the large positive excess returns observed in Section 3.5, removing entry barriers would yield even larger benefits.

To do this, we combine data on the input-output structure of countries with firm-level estimates of markups to parameterize the model. We apply our results to four countries: the USA, Brazil, India and Indonesia. These countries differ in their geographic location,

[38]As shown by Liu (2019), even non-rebated profits that pay for fixed costs can generate output losses in a network structure.

economic structure and level of development. Cement markets in these countries range in their levels of competition, from 7 firms in Indonesia, 15 in Brazil, 17 in the USA to 45 in India. We outline our main choices here and provide further details in Appendix G.

We use data from the World Input Output database compiled by Timmer et al. (2015) to measure revenue shares in the production network $\mathbf{\Omega}$.[39] When combined with measures of markups, we can recover the cost share matrix $\mathbf{\Sigma}$. Our baseline measure of firm-level markups is the same as that used in Section 3.5, based on Gutiérrez and Philippon (2016) and we show that our results are robust to a host of alternative measures. We estimate markups in cement as the model-implied markups, using the demand elasticity $\hat{\varepsilon}$ estimated in Section 3.4. In order to measure the costs of additional cement plants, we assume that fixed costs of entry ensure cement firms make zero profits. Finally, we choose macro parameters α, ρ and δ to ensure steady-state income differences are due to technology and misallocation alone. Table 6 summarizes the data sources and parameter values used to calibrate the model.

Table 6: Calibration summary

Parameter	Description	Value
ε	Cement elasticity of demand	$\hat{\varepsilon} = 0.93$ (Table 4)
α	Capital share of value added	$\alpha = .3$
ρ	Discount rate	$\rho = 0.1 - \delta$
δ	Depreciation rate	match US saving rate ($\approx 6\%$)
$\mathbf{\Omega}$	Expenditure share matrix	WIOT tables
$\boldsymbol{\mu}$	Markup vector	Worlscope estimates
$\mathbf{\Sigma}$	Cost share matrix	$\sigma_{i,j} = \mu_i \omega_{i,j}$
E_{cem}	Fixed costs in cement	zero profit condition

5.1. Network position of cement

We begin by investigating the network position of cement, which measures the importance of the cement sector for development in our model. We summarize this by the long-run distortion centrality measure introduced in the previous section. The economy in our model

[39] We impute cement as a distinct sector by assuming all of its output is used as an intermediate in the construction sector; see Appendix G for details.

features inelastic labour supply, which implies that distortions reduce efficiency by changing the allocation of labour across sectors. It is entirely possible that reducing distortions in cement could actually decrease aggregate efficiency, if cement is a sector that is over-supplied in the distorted economy.

Table 7 lists the top five sectors in each country by the long-run distortion centrality, denoted by ξ^{LR}. In this table "Cement" refers to the aggregated construction supplying NMM sector, as this captures cement's position in production.[40] The table also displays the corresponding short-run distortion centrality calculated in a static model with constant capital stock ξ^{SR}. The difference between these two amounts to accounting for investment when calculating the network effects of cement. These measures are only weakly correlated across industries, with a correlation in the US of just .17. Remarkably, cement is in the top two sectors by

Table 7: Rank of sectors by the long-run distortion centrality ξ

USA Top 5	ξ^{LR}	ξ^{SR}	India Top 5	ξ^{LR}	ξ^{SR}
Construction	1.85	0.87	**Cement**	1.79	1.14
Cement	1.84	0.89	Construction	1.53	0.97
Machinery & Equip	1.74	1.03	Fabricated Metals	1.43	0.99
Publishing	1.71	1.24	Machinery & Equip	1.40	1.05
Scientific	1.71	1.21	Mining	1.36	1.18

Brazil Top 5	ξ^{LR}	ξ^{SR}	Indonesia Top 5	ξ^{LR}	ξ^{SR}
Cement	2.24	1.09	**Cement**	1.66	1.05
Construction	2.08	1.00	Construction	1.63	1.02
Computer programming	1.82	1.23	Basic Metals	1.49	1.02
Machinery & Equip	1.66	0.96	Machinery & Equip	1.47	1.03
Engineering	1.53	0.96	Fabricated Metals	1.45	1.03

Note: This table reports the short-run ξ^{SR} and long-run ξ^{LR} distortion centrality for the top 5 sectors. The short-run distortion centrality is calculated in a static model with fixed capital stock.

long-run distortion centrality across all four countries, with construction following closely behind. The position of cement is likely a consequence of its distinct treatment as a supplier

[40] This is equivalent to assuming markups in cement and NMM are identical. One could calculate this for cement separately using the formula

$$\frac{d\ln\mu_C}{d\ln\mu_{cem}} = \left(\frac{\mu_C}{\mu_{cem}} + (1-\varepsilon)\frac{\tau_c - \tau}{1-\tau}\right)\omega_{cem}$$

where $\tau_i = 1 - \mu_i^{-1}$ denotes the profit rate and ω_{cem} denotes cements share of revenue in the sector.

of construction. However the table displays a robust pattern: a stark difference between the distortion centrality in the short and long run, with the centrality of cement doubling when moving from the short to long run. More generally, the top sectors in terms of long-run centrality are investment-intensive industries, such as construction and machinery and equipment. Although these sectors feature some of the highest marginal effects on steady-state output, in the static model these costs are relatively modest. This is intuitive: in a static sense these sectors produce final goods, and thus are downstream. From a long-run perspective they are upstream, since investment goods are used as intermediates for future production.

Table 8 reports the elasticity of output to a reduction in markups in cement from Proposition 2, normalised by cement's expenditure share.[41] The short-run effects simply treat the capital stock as fixed.

Table 8: Marginal effects of cement markups

	USA	Indonesia	India	Brazil
$d\ln Y$: Short run	-0.05	0.25	0.08	0.18
$d\ln Y$: Long run	2.14	1.74	1.56	2.49

Note: This table reports the marginal effects of markups on steady-state output, normalised by cement expenditure. The profit rate of cement is defined as $\tau_{cem} = 1 - \mu_{cem}^{-1}$. The marginal effects are given by Proposition 2.

This table clearly shows the striking disparity between the short- and long-run elasticity. In the short run, markups in cement have a negligible effect on output and are even slightly beneficial for the US. However this is a poor measure of importance for development: the long-run elasticity of output to markups in cement is between 1.5 and 2.5 across countries, implying that a one percent increase in markups results in a roughly two percent fall in output, measured as a share of cement. When markups are close to one, a percent increase

[41] We normalise by expenditure share in order to make our comparisons invariant to the scale of the sector, because a markup change in a larger sector mechanically translates into larger effects. The markup normalised by expenditure share is given by

$$-\frac{d\ln Y}{d\ln \mu_{cem}} = \frac{1}{1-\alpha}\left(\xi_{cem} - \frac{1-\sum_{k=1}^{N}\tau_k \mathscr{L}_{cem,k}}{1-\pi_c}\right)$$

so the differences between marginal effects and centrality arise from whether the sectors supplying cement have higher profits than aggregate consumption.

in markups corresponds to a percent increase in profits and therefore we can view this elasticity as approximately capturing the marginal rate of transformation between profits in cement and output. Under this interpretation, profits in the cement market are very costly for aggregate output, with each extra dollar of cement leading to a loss of two dollars in aggregate.

5.2. The macro markup wedge

We now turn to quantifying the long-run costs of markups in cement on output. We do this by calculating the "wedge" generated by markups in cement, given by the change in steady-state output if cement profits were zero. We express this change as a share of expenditures in cement. Recall that in a competitive model, Hulten's theorem implies that a sector's marginal contribution to output is measured by its size. Therefore this normalisation gives us a TFP-equivalent measure so that these "wedges" can be viewed as the percent TFP shock in cement production which would generate the same losses as profits in a competitive model. It is important to note that we calculate these wedges assuming markups are rebated back to the consumer. This is equivalent to a subsidy which ensures cement is priced at marginal costs, where here the cost of the subsidy is equivalent to lost profits from eliminating markups.

Table 9 reports expenditure shares and cement TFP-equivalent wedges for our four countries. The first row reports cement expenditure as a share of output in all four countries, showing a negligible expenditure share in the USA and shares of one half to one percent for the developing countries.

Despite cement having large long-run distortion centrality in the US, such profits are unsurprisingly unimportant for aggregate outcomes due to the small size of the sector. This is not true for less developed countries; the share in Brazil is ten times that of the US, and a factor of 20 larger in India.

The second to fourth rows of Table 9 give the loss in steady-state output due to markups in cement, or wedge, normalised by the expenditure share of cement. For the US, the TFP-equivalent wedge is around 15% while in Brazil it is slightly higher ranging from 20% to

Table 9: Cement expenditure shares and macro markup wedge (in percent)

	USA	Indonesia	India	Brazil
Expenditure Share	0.06	0.72	1.25	0.63
Wedge: Lerner Index	16.80	49.26	9.72	20.16
Wedge: User Cost (firm)	14.13	49.31	5.76	21.47
Wedge: Uniform 10% profit	18.75	53.20	7.49	24.07

Note: This table reports the expenditure share of cement alongside the wedge in steady-state output generated by markups in cement for various markup measures. The expenditure share of cement is the expenditure in the cement sector as a percentage of nominal GDP γ_{cem}. The wedge generated by markups in cement is given by the percentage difference in real steady-state output Y^* and its value with zero profits in cement $Y^*_{\tau_{cem}=0}$, normalised by cement's share of total output.

25%. In Indonesia, where competition is lower, the wedge is around 50%. By contrast, in India, where cement's expenditure share is largest, higher levels of competition imply that the wedge is between 5% and 10%. This reflects wedges as approximately the sum of Harberger triangles - the deadweight loss is large when the sector is large or the distortion is large. By accounting for their effect through the production network, the model uncovers the magnitude of such losses. These losses are stark: in Indonesia, a model-implied profit rate of around 13% generates up to a 50% cement TFP-equivalent output loss. This is despite the fact that we assume that profits are rebated to households and labor is inelastically supplied, so any losses are purely from labor misallocation.[42] These numbers show that the wedge tends to be higher when (i) expenditure on cement is relatively high, (ii) cement markets are less competitive and (iii) when cement has a higher distortion centrality.

5.3. Sources of competition: Entry versus common ownership of plants

We next turn to the contribution of low entry and common ownership of plants to the wedge. Common ownership is defined as the extent to which several plants in the same

[42]We can also compare these numbers with those implied by the marginal effects presented in Table 8: the first order approximation says the wedge is simply $\frac{d\log Y}{d\ln\mu_i}\log\mu_i$ while when profits are small, $\log\mu \approx \tau$. Therefore multiplying the numbers in Table 8 gives an approximation of the wedge. This provides a robustness check of the non-linear results, as the marginal effects will hold approximately for any neoclassical production structure (Baqaee and Farhi, 2020). This calculation results in a wedge of 30% in Indonesia, 19% in Brazil, 15% in the USA and 4% in India. While these are somewhat smaller than the values reported in Table 9, they show a very similar pattern.

market are owned by a single firm. Our definition of common ownership is with respect to plants rather than firms. We consider three changes: (i) the entry of one firm, (ii) a single plant operating independently, (iii) the maximal benefit of entry (iv) all plants operating independently.[43] These changes help us quantify the costs of low entry versus common ownership, on the margin and in total. Changes (i) and (ii) quantify the marginal cost of low entry and common ownership, while (iii) and (iv) measure the respective total costs. In our baseline we assume that fixed costs of entry are at the plant level. Our results are robust to firm-level fixed costs of entry, which create increasing returns to scale for multi-plant firms. Appendix Section G outlines the calculation of these counterfactuals in detail.

Table 10 presents the change in steady-state output following each policy, as a percentage of the total output gap due to markups in cement. We see that for all countries, both com-

Table 10: Costs of low entry and common ownership

	USA	Indonesia	India	Brazil
Entry: 1 firm	2.97	8.52	1.23	4.13
Common Ownership: 1 plant	5.67	13.17	2.20	6.45
Entry: total	10.91	19.88	11.89	17.55
Common Ownership: total	84.96	73.19	79.46	84.98

Note: This table shows the costs of insufficient entry and common ownership as a percent of the wedge generated by markups in cement $100\left(Y^*_{\tau_{cem}=0}/Y^*-1\right)$. "Entry" refers to the costs of fewer firms entering the market than is optimal, while "common ownership" refers to many plants being owned by the same firm in a market.

mon ownership and insufficient entry are costly. Recall we have assumed that entry is not profitable for firms. Therefore the results show that the positive network externalities from cement imply entry is beneficial in aggregate even if it is unprofitable for firms. However for all countries, common ownership is on aggregate much more costly than low entry. This is due to the nature of fixed costs - we have assumed that there are zero profits in cement. Therefore for a new firm to enter in practice, the government must subsidize this fixed cost. By contrast, lower common ownership simply changes the conduct of existing plants. Therefore, if fixed costs are at the plant level, common ownership reduces markups without

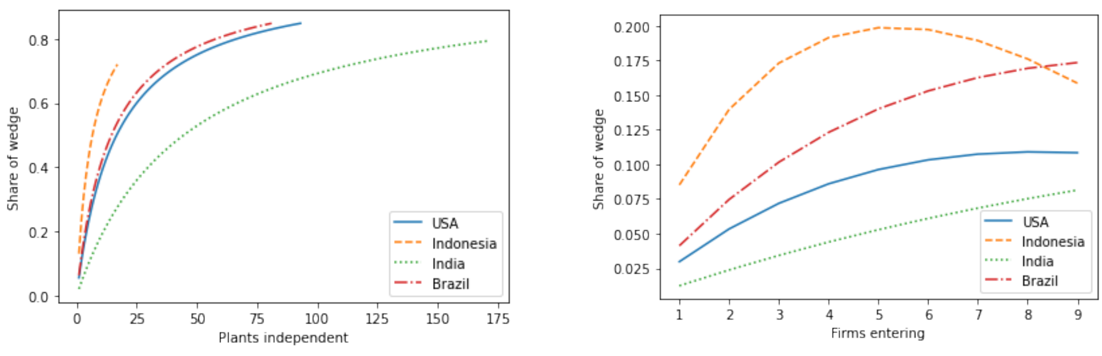
[43] We assume that the entry costs are such that profits in the market are equal to discounted entry costs exactly, which is an upper bound on entry costs in the model. Our entry counterfactuals implicitly assume the government provides lump-sum transfers to firms so they operate with an extra firm in the market.

incurring fixed costs - as long as the newly independent firms are profitable. In practice, this is always the case for our calibration. This is intuitive: the most efficient way to increase competition is for existing plants/firms to compete rather than paying fixed costs to create new plants.

In Indonesia, a single extra plant operating independently can close 13% of the markup wedge. All plants doing so closes 80% of this wedge in India, 73% in Indonesia and around 85% in Brazil and the USA. Figure 8a plots the share of the wedge closed as a function of the number of new plants which operate independently. In all countries, the marginal benefits are diminishing as the number of newly independent plants increases. We see that although the marginal costs of common ownership are highest in Indonesia, the total cost is much lower due to fewer plants in the country. In the other countries, common ownership is less costly for a given plant due to higher levels of initial competition, but has greater total costs as more multi plant firms are present. Figure 8b plots the same graph for firm entry. There costs are much more limited, since given constant cost of entry, the initial benefits of extra entrants are diminishing as their number increases. Thus far we have assumed that

Figure 8: Impact as extent varies

(a) Plants operating independently (b) New firms entering



Note: These figures show the change in steady-state output from (a) reversing common ownership and (b) new entry, as the number of firms they are applied to varies.

all costs are at a plant level, so that common ownership does not affect costs. However it is possible that some fixed costs of entry may accrue at the firm rather than plant level, for example due to marketing or accounting expenses. Appendix Figure B.5 shows that the costs of common ownership are positive unless plant-level fixed costs are close to zero.

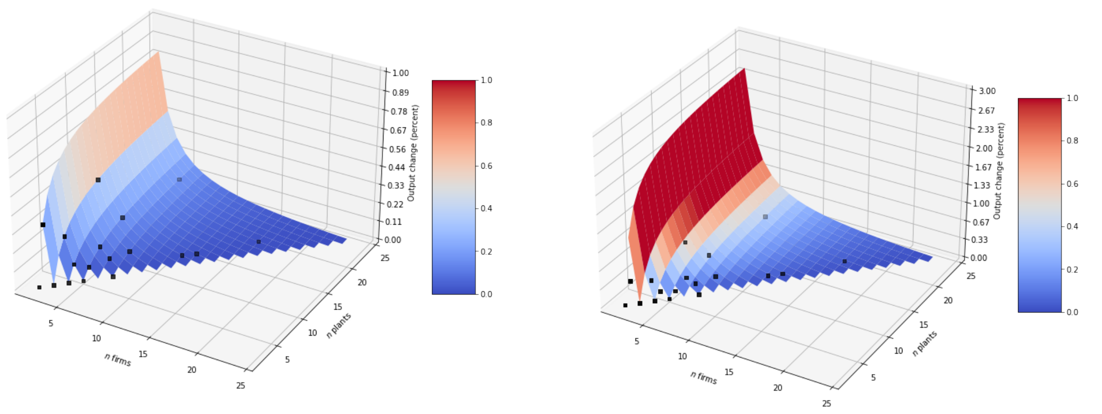
Since cement is a homogeneous good manufactured in large facilities, it is reasonable to expect that the fixed costs of building a new plant exceed any marketing or administrative costs at the firm level.

Unfortunately, due to data constraints in requiring both sector-level markups and input-output data, we can not carry out these calculations for all countries analysed in Section 3. Our results can nonetheless shed some light on the potential costs of lack of entry and common ownership for countries with less competitive markets. We have shown that the distortion centrality of cement is high in all four case study countries. Moreover, common ownership is more costly in countries with low levels of competition and high levels of cement expenditures, which is the case in many Sub-Saharan African countries. To investigate this prospect more rigorously, we analyse how the costs of common ownership vary as market structure varies. Figure 9 uses Indonesian I-O and markups data and shows that the costs of common ownership are convex in market concentration, with costs of up to one percent of steady-state output for very concentrated markets. Using Tanzanian input-output

Figure 9: Cost of common ownership for different market structures

(a) Indonesian input-output and markups data

(b) Tanzanian input-output data and 10% profit rate



Note: These figures shows the cost of common ownership, using Indonesian input-output and markups data (left panel) and Tanzanian Input-Output data (right panel). The squares indicate combinations of number of firms and plants found in Sub-Saharan Africa in 2017.

data from Tanzania National Bureau of Statistics (2021) shows a very similar pattern, but larger magnitudes. This is primarily due to the high expenditure share of cement in Tanzania. Overall our results suggest that the costs of common ownership are likely to be large in many Sub-Saharan African countries.

6. Conclusion

This paper makes three contributions. First, we establish a novel set of motivating facts. We show that there is a large dispersion of construction sector input prices across countries, with Sub-Saharan African countries having the highest prices for many goods. Such stark differences are not visible in the aggregate construction sector PPPs, possibly due to the fact that lower wages in Sub-Saharan Africa mean that higher input costs are masked when the aggregate construction sector price is considered. Knowledge of such differences is surely an area of concern for policymakers, suggesting the possibility of benefits from removing domestic bottlenecks and barriers to trade. We then link our data on prices with a database of market structure in the cement industry that we have compiled. We show that cement prices are highest in countries with a small number of firms and with the highest level of firm concentration. Further, the construction sector accounts for a significant fraction of investment and cement's share of construction expenditures is non-trivial for a set of countries.

The second part of the paper focuses on the role of market power in cement. We estimate a highly tractable model of oligopoly using both, a demand-based instrument, and a novel entry instrument that exploits exogenous differences in the dispersion of limestone deposits across space. We show robust evidence that lower competition leads to higher prices. Our results are robust to different functional forms, extensive controls for input prices, alternative definitions of market power, controlling for trade in limestone and cement as well as tariffs. We use firm's financial accounts data to document substantial excess returns, which we interpret as economic rents.

Third, our dynamic general equilibrium network model shows that the long-run social costs of profits in cement are amongst the highest of any sector. There is an asymmetry between these long-run costs and the immediate impact of an increase in cement profits, due to cement's role as an intermediate input in investment production. Distortions in investment production are particularly harmful, reducing investment by acting like a tax on capital and ultimately reducing output. In the short run, profits in the cement sector have little effect on output, but in the long run the elasticity of markups to output is -2. Roughly, for an extra dollar in profits in cement, two are lost in aggregate output. Common ownership accounts for a large share of these costs: between 75% and 85% in our baseline calibration. Accounting for investment changes the relative costs of distortions between sectors in quantitatively important ways.

In the paper we provided a detailed case study on cement. If other key construction sector inputs are also distorted, the macroeconomic effects can be expected to be significantly larger. Policymakers concerned with scaling up investment will want to pay particular attention to the location of distortions in the network of sectors involved in the production of capital.

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Appendix (For Online Publication)

A. Data

Table A.1 summarizes the different source of data we use in the paper. Below we provide more details on the individual datasets.

International Comparison Program (ICP) We use price data collected in the context of the ICP 2011 and 2017. The price surveys contain detailed instructions and guidelines for those reporting prices, and aim to report the prices paid by builders for material inputs, machine inputs (hire rates) and categories of labour. This price data is then used to calculate sector wide PPP's, using quantity weights for several "representative" standard project types. The OECD method of project based prices, i.e. an output based approach, is not undertaken primarily due to cost constraints. The World Bank provides clear guidelines for the input prices gathered in the survey. For example, items that are not commonly available or used in a country should not be included, respondents should consider geographical conditions, site context and project sizes when reporting prices, stating that prices are intended to be national averages for medium sized projects with reasonable site access. The guidelines also state that labour costs should reflect the true cost of labour, e.g., including "off the books" payments. Finally, if a direct substitute is commonly used, then its price should be included in the dataset (World Bank, 2015a). Our focus on input prices is motivated by the fact that materials represent the largest portion of construction value, typically 50-75%, although this may not hold for civil engineering works (World Bank, 2015a). We chose inputs based on two critera: they are widely used in the construction sector and the ICP has a broad coverage of countries.[44] Table A.2 lists all inputs used in this paper.

[44]Our choice of commonly used construction materials is based on Bacchini et al. (2003), Herczeg et al. (2014), World Steel Association (2018), and UNECE (2012).

Table A.1: Data Summary

Variable	Source
Country-level data	
Ready-mix concrete	ICP (2011 and 2017)
Ordinary Portland cement	ICP (2011 and 2017)
Aggregate for concrete	ICP (2011 and 2017)
Sand for concrete and mortar	ICP (2011 and 2017)
Softwood for carpentry	ICP (2011 and 2017)
Common bricks	ICP (2011 and 2017)
Mild steel reinforcement	ICP (2011 and 2017)
Structural steel sections	ICP (2011 and 2017)
GDP	ICP (2011 and 2017)
Number of firms	Global Cement Report 10 and 13, online database
Number of plants	Global Cement Report 10 and 13, online database
Area	World Development Indicators
Population	World Development Indicators
Risk-free rate of interest	World Development Indicators
Governance	World Governance Indicators
Cost to obtain a construction permit	Doing Business Indicators*
Km of roads	Global Roads Inventory Dataset
Quality of trade-related infrastructure	Logistics Performance Index**
Price of coal	UN COMTRADE (2011 and 2017)
Price of machinery	UN COMTRADE (four-year average)
Limestone imports	UN COMTRADE (2011 and 2017)
Cement imports	UN COMTRADE (2011 and 2017)
Input-output network	World Input-Output Database
Country and equity risk premia	Damodaran (2020) and Damodaran (2021)
Carbonate rocks	Goldscheider et al. (2020)
Plant-level data	
Plant capacity	Global Cement Report 13, online database
Firm-level data	
Operating surplus after taxes and before depreciation	Worldscope
Net property, plant and equipment	Worldscope
Interest payments	Worldscope
Debt	Worldscope

Note: This table summarizes the various sources of data used in the paper, by level of observation. *For 11 countries the Doing Business Indicators are only available from 2014 onward so we use 2014 data instead of 2011 data to have a more complete sample. **The Logistics Performance index is available every two years. We use the 2010 index for 2011 and the 2016 index for 2017.

Table A.2: Key construction inputs

Input	Unit of measurement
Ready-mix concrete	Cubic meter:1:2:4; cement:sand:20-40mm aggregate, 20N/mm2
Ordinary Portland cement	Tonne: ordinary Portland cement in bags or bulk delivery
Aggregate for concrete	Cubic meter: clean, hard, strong crushed stone or gravel free of impurities and fine materials in sizes ranging from 9.5 to 37.5mm in diameter.
Sand for concrete and mortar	Cubic meter: fine aggregate washed sharp sand
Softwood for carpentry	Cubic meter: sawn sections for structural use 50mm x 100mm
Common bricks	Cubic meter: 215mm x 100mm x 65mm thick (715 bricks/m3)
Mild steel reinforcement	Tonne: reinforcing bars up to 16mm diameter
Structural steel sections	Tonne: mild steel beams approx 150mm deep and 19 kg/m

Note: Item list provided by the ICP Global Office at the World Bank.

Market structure To identify the market structure of the cement industry in each individual country for 2011 we manually coded the information contained for each country in the Global Cement Report 10 (International Cement Review, 2013). The report and databases are based on a range of sources, including surveys and correspondence with plants/corporate offices; plant reports in publications, i.e. the International Cement Review; equipment suppliers; conference presentations; company disclosure: press releases, reports, financial filings and annual reports; and industry associations. The report was published in 2013 and its information refers to the years 2010-2012, with most of its information from 2011. In addition to the number of groups, we also record the number of plants per group and the group's capacity in million tons per year.[45]

To match the 2017 ICP prices with market structure we use the global plant database (International Cement Review, 2019b).[46] The database contains information on group ownership, company name, facility name and location of the plant as well as capacity at a plant

[45]For 5 countries (India, Iran, Myanmar, the United States, and Vietnam) in 2011 only the key production base is given, and residual firms are combined in a category "Other firms". We exclude these as we lack knowledge on their ownership structure and these are typically fringe firms or plants. We also exclude 3 countries for which we have gaps in reporting of the industry structure (Laos, Myanmar and Nepal in 2011).

[46]For ease of discussion we refer to this later round of data to "2017" data.

level. To compute alternative measures of market power that take into account geography we geo-coded each plant's location using the command opencagegeo in Stata combining the city and the country of each plant to extract the coordinates of the location in Google Maps. We manually replaced coordinates of plants with empty fields for the city or mismatches between the variables country and g_country. For each firm, we compute the number of different firms within 300km, counting the firm itself, assuming either no trade across country borders or allowing for trade across borders.[47] We compute this measure for every plant and then take an average across plants in a country. When a country only has one firm we define the country as the market.

Cement imports and tariffs from UN COMTRADE The HS2007 (H3) classification for cement is 252321 for white cement, whether/not artificially coloured and 252329 for Portland cement (excl. white cement, whether/not artificially coloured), whether/not coloured. Since the ICP measures the price of ordinary Portland cement which is typically grey we use 252329 as the main code. To measure tariffs we compute the trade-weighted average tariff in a given tariff year using effectively applied bilateral tariff duties listed in the TRAINS database. If the data was missing for 2011 or 2017 we used 2010 or 2016 instead.

Other data from UN COMTRADE To measure limestone imports we use product code 27322 (S3), for coal we use code 321 (S4), and for clinkers we use product code 66121 (S3).

Price of machinery To proxy for the price of machinery, we use product code 7283 SITC Revision 4: "Machinery for sorting, screening, separating, washing, crushing, grinding, mixing or kneading earth, stone, ores or other mineral substances, in solid (including powder or paste) form; machinery for agglomerating, shaping or moulding solid mineral fuels".

[47] For example, the largest integrated plant in the database in the United States is a plant owned by Lafarge Holcim located in Bloomsdale. There are six further plants within 300km from this plant, two further plants owned by Lafarge Holcim and two plants owned by Buzzi Unicem. This means that there are three other competitor firms in the vicinity of the Lafarge Holcim plant located in Bloomsdale (CRH, Buzzi Unicem and Summit Materials) such that the number of firms in this local market is four.

Market structure of the main trading partner We compute the trade-weighted market structure in the following way: for each country we use data on the countries from which a country imports cement, and keep the main importer in terms of value of imports. We only use data for countries that import more than 1500 tons of Portland cement, equalling the amount of cement needed for about 100 single-family homes.[48] We exclude countries that are mainly importing from China due to lack of complete data on the market structure in China.

Transport infrastructure To measure the quality of transport infrastructure we use data from the Global Roads Inventory Dataset on the km of roads from Meijer et al. (2018) and information on the quality of trade-related infrastructure from the Logistics Performance Index. We use data on the location of capitals and cities with more than 10.000 inhabitants from the World Cities Database to compute plant-level travel times. If the country does not have a city of more than 500,000 inhabitants we use the travel time to the capital.

2005 ICP construction components From the 2005 ICP we selected the composite components that were listed as using concrete for residential housing and civil engineering works. These include exterior sidewalk, structural footing, structural column round, structural column square, aluminium frame window, masonry interior wall, exterior wall cement plaster, interior ceiling plaster, interior wall plaster, round bridge pier, bridge spread footings and concrete air field. The construction sector inputs which we would not expect to be affected by the price of cement include skilled and unskilled labor, a vibratory plate compactor and an aggregate base.

Building construction costs Our data for building construction costs is put together by a leading global construction consultancy firm as part of their Africa construction handbook, which lists data on different building types for 2011 and 2017. These include residential building types (i.e. average multi-unit high-rise, luxury unit high-rise, individual

[48] One single-family home requires about 100 tons of concrete for the basement and cement makes up 15% of concrete. See here for more information http://www.fao.org/3/y3609e/y3609e08.htm.

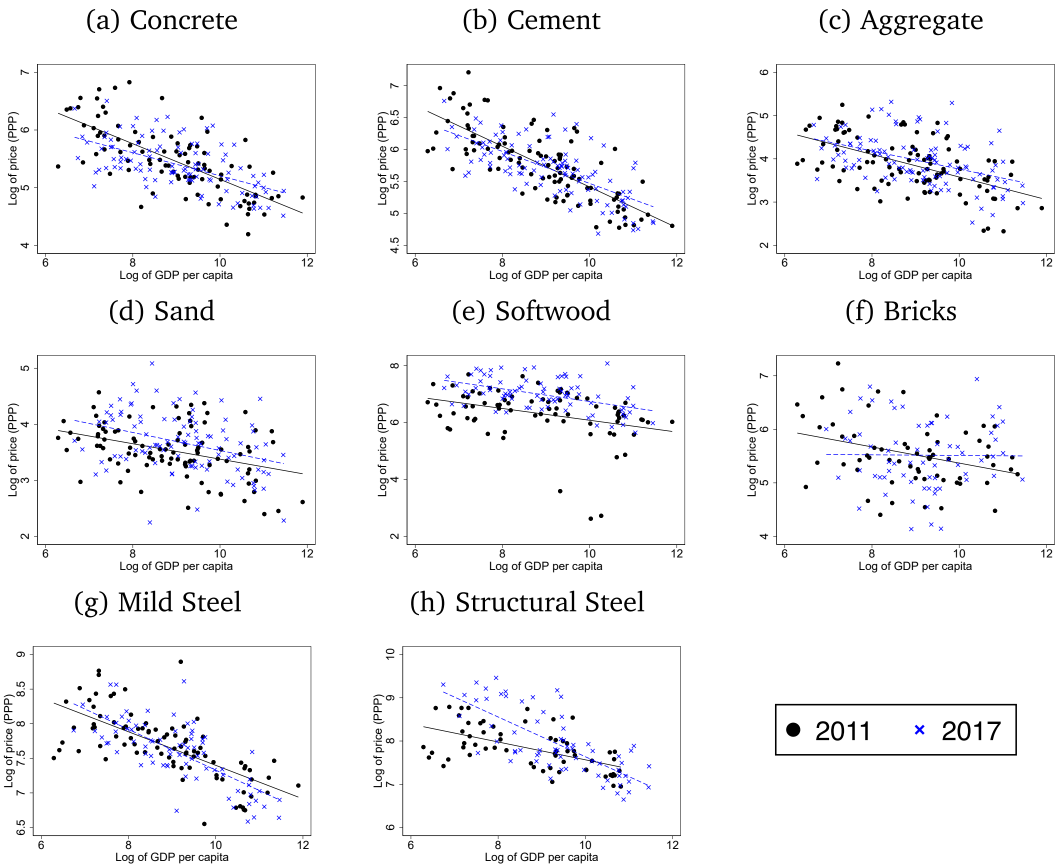
prestige houses, commercial/retail units (i.e. average standard office high-rise, prestige office high-rise), industrial buildings (i.e. light and heavy duty factory), hotels (i.e. budget, luxury, resort style), and other infrastructure (i.e. multi-story car park, district hospital, or primary/secondary schools). Typically prices exclude land, site works, professional fees, tenant outfit and equipment. We exclude prices that include any of the above, as well as additional costs such as parking, external works, or raised flooring and ceiling. Applying these restrictions we have 683 costs across 14 types of building projects in 27 locations worldwide across 26 countries.

Worldscope In Section 3.5 we use all firms operating in the cement industry (SIC code: 3241) while in Section 4 we use all firms.[49]

[49]Thomson Reuters provides this data commercially and it was obtained via Wharton Research Data Services.

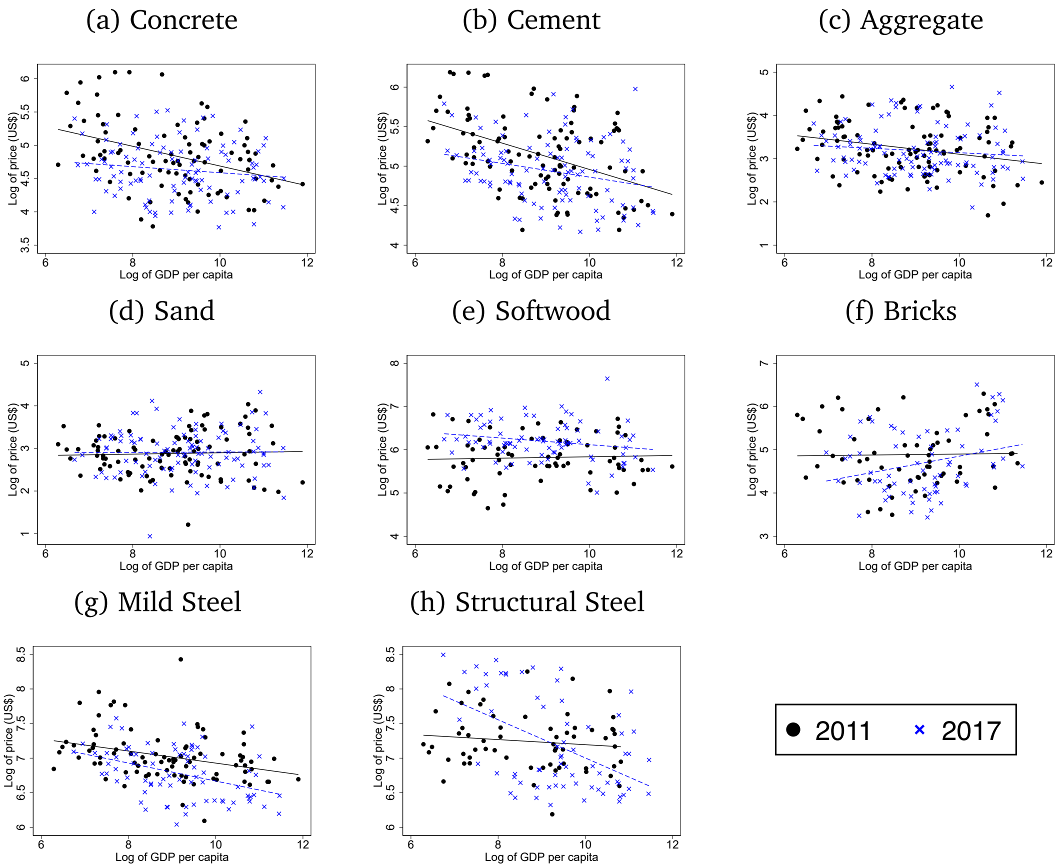
B. Additional tables and figures

Figure B.1: Input prices in PPP dollars and GDP per capita (PPP)



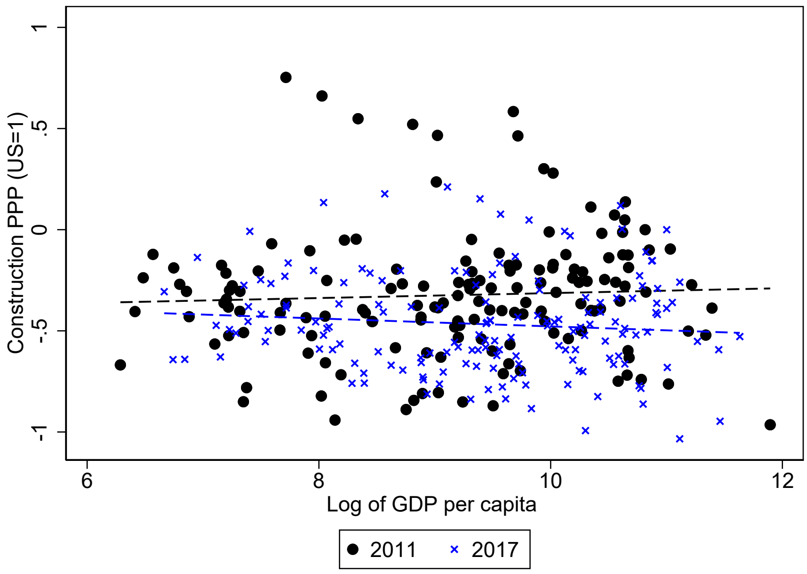
Note: This figure shows the log of key construction sector input prices and log of GDP per capita. Prices are measured in PPP dollars as defined by the ICP. Precise definitions of the inputs are listed in Table A.2.

Figure B.2: Input prices in US dollars (market rate) and GDP per capita (PPP)



Note: This figure shows the log of key construction sector input prices and log of GDP per capita. Prices are measured in US dollars at market exchange rates. Precise definitions of the inputs are listed in Table A.2.

Figure B.3: Aggregate Construction sector PPP and GDP per capita (PPP)



Note: This figure shows the aggregate construction sector PPP as defined by the ICP and log of GDP per capita.

Table B.1: Prices of key construction sector inputs in 2011 and 2017, Construction PPP (US$=1)

	concrete (m^3)	cement (ton)	aggregate (m^3)	sand (m^3)
Panel A: ICP 2011				
East Asia and Pacific	389.4	290.0	72.7	53.3
Europe and Central Asia	210.1	135.4	31.9	28.3
Latin America and Caribbean	471.1	386.0	67.3	56.2
Middle East and North Africa	378.0	306.8	50.9	47.8
North America	177.6	157.2	56.1	55.7
South Asia	562.8	476.7	92.4	78.6
Sub-Saharan Africa	827.0	625.3	133.2	71.0
Panel B: ICP 2017				
East Asia and Pacific	458.8	342.7	98.2	69.6
Europe and Central Asia	311.8	197.7	67.3	56.0
Latin America and Caribbean	544.8	431.4	94.1	66.6
Middle East and North Africa	418.0	336.7	72.5	71.9
North America	233.8	196.1	73.2	65.5
South Asia	647.5	590.8	192.9	111.3
Sub-Saharan Africa	619.7	456.1	114.8	86.9

	softwood (m^3)	bricks (m^3)	mild steel (ton)	struc. steel (ton)
Panel C: ICP 2011				
East Asia and Pacific	1329.6	242.5	3036.0	921.8
Europe and Central Asia	550.7	354.1	1402.1	2049.0
Latin America and Caribbean	23.0	292.5	3676.8	3881.6
Middle East and North Africa	1318.8	457.1	3139.7	3589.5
North America	132.5	425.7	1022.7	1273.2
South Asia	2143.0	307.8	4315.8	
Sub-Saharan Africa	1228.6	734.5	4692.7	5212.5
Panel D: ICP 2017				
East Asia and Pacific	2258.8	374.9	3210.0	3959.3
Europe and Central Asia	1384.1	726.5	1793.0	2289.2
Latin America and Caribbean	1870.9	434.6	3486.9	4328.8
Middle East and North Africa	1582.9	376.7	3322.6	4543.4
North America	1094.4	466.1	1125.1	1167.5
South Asia	4167.0	471.2	4403.1	4858.6
Sub-Saharan Africa	2116.4	530.8	4418.8	12270.2

Note: This table shows average prices for eight key inputs across space. Precise definitions of the inputs are listed in Table A.2.

Table B.2: Robustness I. Dependent variable: ln (Price of Cement)

	$1/n$		**HHI**		**Infrastructure**	
	(1)	(2)	(3)	(4)	(5)	(6)
1/n	0.58***	0.35***				
	(0.13)	(0.13)				
Herfindahl-Hirschman			0.61***	0.39***		
			(0.14)	(0.13)		
$\ln n$					-0.23***	-0.17***
					(0.048)	(0.057)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	No	Yes	Yes	Yes
Fuel	No	Yes	No	Yes	Yes	Yes
Infrastructure	No	No	No	No	Yes	Yes
N	172	165	172	165	156	137
R-sq	0.291	0.414	0.290	0.419	0.379	0.458

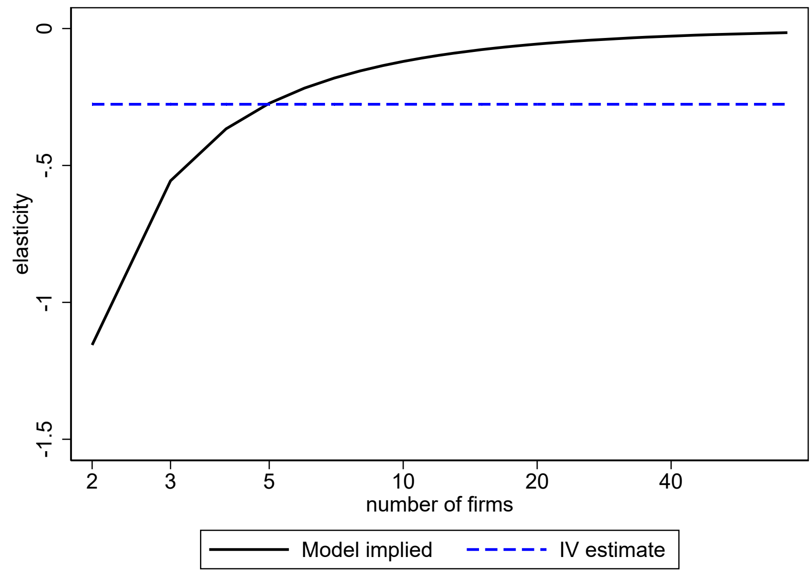
Note: Reported standard errors are clustered at the country level. *, **, *** denote significance at 10%, 5% and 1% levels. Columns (1) and (2) measure competition using the inverse of the number of firms. Columns (3) and (4) measure competition using the Herfindahl-Hirschman index. Column (5) includes the following measures of transport costs: the km of roads in each country, the quality of trade-related infrastructure and the log of the average plant-level travel time (in mins) to the nearest city of more than 500,000 people. Column (6) controls for the km of main, secondary and tertiary road separately.

Table B.3: Robustness II. Dependent variable: ln (Price of Cement)

	Robustness						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln n$	-0.14*	-0.13**	-0.13*		-0.17***		
	(0.079)	(0.063)	(0.068)		(0.057)		
$\ln n$ (trade-wgt)				-0.092*			
				(0.053)			
$\ln n$ (< 300km) FT						-0.15***	-0.12**
						(0.054)	(0.049)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Governance	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fuel	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Input costs	Yes	No	No	No	No	No	No
Sm capacity	No	Yes	No	No	No	No	No
Importer	No	No	Yes	No	No	No	No
Trade-weighted	No	No	No	Yes	No	No	No
Tariffs	No	No	No	No	Yes	No	No
N	99	83	113	110	141	86	83
R-sq	0.503	0.357	0.465	0.438	0.466	0.212	0.366

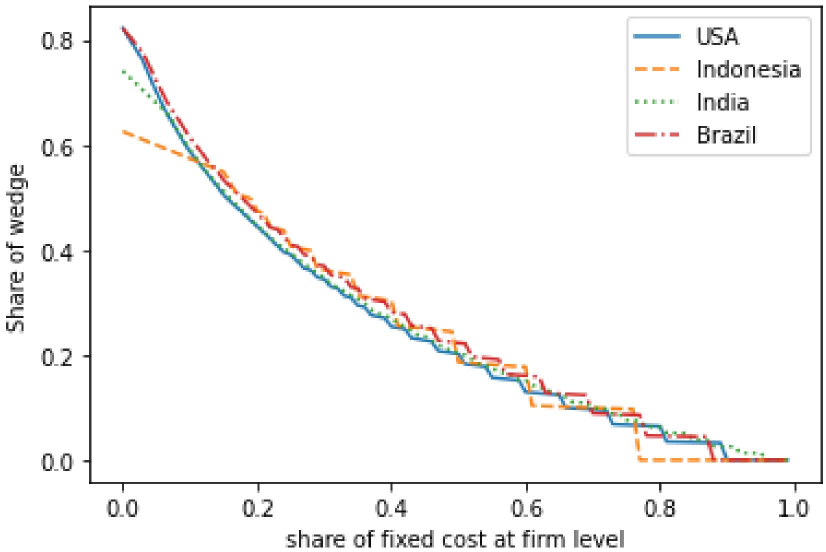
Note: Reported standard errors are clustered at the country level. *, **, *** denote significance at 10%, 5% and 1% levels. Column (1) uses an extensive set of input prices including the cost of electricity, coal and machinery. Column (2) includes a dummy variable that is equal to one if more than 50% of plants in the country operate below a capacity of 1 MT per year. Column (3) controls for whether countries are net importers of cement or limestone. For column (5) we compute a trade-weighted measure of competition so that each country's trade-weighted competition is a combination of their own competition and the competition of the main trading partner, weighted by the proportion of cement consumption that is imported. Column (5) controls for the trade-weighted average tariff rate of countries to test whether high prices are due to high tariffs. In columns (6) and (7) we compute our local measure of market power used in columns (3) and (4) of Table 1, but now allowing for trade across borders.

Figure B.4: Comparing the model-implied and directly estimated marginal effects



Note: This figure shows the estimated marginal effects implied by the estimates reported in Table 4 $\frac{d \ln \hat{\mu}(n)}{d \ln n} = -\frac{1}{\hat{\varepsilon}n-1}$ as a function of the number of firms n. Also reported is the point estimate of $\frac{d \ln p}{d \ln n}$ from our baseline IV regression using countries with at least two firms.

Figure B.5: Cost of common ownership as firm-level fixed costs increase



Note: This figure shows the impacts of reducing common ownership of multi-plant firms, while varying the share of total fixed costs faced by new plants that are at the firm rather than plant level.

C. Oligopoly model extensions

C.1. Extension I: Heterogeneous firms and arbitrary concave demand

In this section we extend our oligopoly model to allow for heterogeneous firms and an arbitrary concave demand function. This structure is similar to that of Bekkers and Francois (2013), who study the impacts of oligopolistic structure with CES demand on trade.

We model the entry game as a three stage process: Firm i first pays an entry cost E to enter into the market and draws a marginal cost C_i from distribution $G(C)$. After observing all cost draws, it then must pay a fixed cost F to operate in the market. Finally, after observing the active firms in the market, firms first compete in Cournot competition. At each stage of the game, firms move simultaneously, taking others' strategies as given. The equilibrium is described as a SPNE to the Cournot entry game.

Let N denote the number of operating firms in equilibrium. Define Q_i to be firm i's production and let c_i denote its marginal costs, which we assume are constant (after fixed costs have been paid). Cement is perfectly substitutable across producers, with a demand function $P = P(Q)$ where $Q = \sum_i Q_i$ is total quantity supplied by the market. We assume that demand is downward sloping, continuously differentiable and convex, so $P'(Q) < 0$ and $P''(Q) < 0$, which ensures existence of a pure strategy equilibrium to the Cournot game.[50] We restrict our focus to equilibria that feature positive selection such that

$$Q_i > Q_j = 0 \Rightarrow C_i < C_j$$

which requires more productive firms always enter before less productive firms.[51] Therefore, we can make this restriction with minimal impact on our analysis. The SPNE can be characterised by the following proposition

Proposition 3 *The positive selection market equilibrium for a given sequence of cost draws C_i*

[50] In the CES case, concavity implies $\varepsilon > 1$.

[51] As shown by Berry (1992), although the identity of firms is not uniquely determined in equilibrium, the number of firms is. Quint and Einav (2005) provide a simple model that ensures positive selection with gradual sinking of entry costs.

and parameters exists and is unique.

Proof

We proceed by backward induction. First consider the problem of a firm choosing Q_i to maximise profits conditional on being active, which is a traditional Cournot problem. As prices are concave in the firm's output, so too are profits. Therefore there is a unique interior equilibrium for prices given a set of active firms.

Next we show that for a given number of entrants and cost draws, a unique number of firms enter the market. We can define a reaction function as the solution to the firm's first order condition for a given market output Q as follows

$$q(Q,C_i) = \text{argmax}_{Q_i}\{Q_i(P(Q)-C_i)\}$$

so $q(Q,C_i)$ is the level of output that maximised profits for a given Q and C_i. Concave prices $P''(Q) < 0$ imply that his reaction function is downward sloping in Q. This allows us to define the equilibrium profit function given by

$$\tilde{\pi}_i(Q,C_i) = q(Q,C_i)(p(Q)-C_i)-F$$

which is also downward sloping in Q from the concavity of the price function. A firm will choose to operate as long as this function is positive. Let $\{C_i\}$ denote the set of cost draws of existing firms, and order them so that $C_1 \leq C_2 \leq ... \leq C_m$. If a firm enters this implies all lower cost firms enter too $Q_i > 0 \quad i > j \Rightarrow Q_j > 0$ in the positive selection SPNE.

Now consider the operation decision of the marginal firm. First note that an additional firm operating will always reduce the price and thus increase Q, because the reaction function is downward sloping. Let Q_N denote the output when N firms enter the market, so $Q_N < Q_{N+1}$. For N to be an equilibrium, we must have

$$\tilde{\pi}(Q_N,C_N) > 0 > \tilde{\pi}(Q_{N+1},C_{N+1})$$

so the fact that the profit function $\tilde{\pi}(Q, C)$ is downward sloping in C and that Q increases with entry ensures that this condition is satisfied for a unique N. Therefore the set of firms entering is unique.

Finally, we show that the number of firms entering is unique. As firms are ex ante identical, the entry strategy of other firms can be summarised by the number of firms who enter n^e. In equilibrium expected profits must satisfy

$$\mathbb{E}[\tilde{\pi}(Q, C)|n^e] < E$$

To show that an equilibrium exists and there is a unique n^e, it is sufficient to show that expected profits are decreasing in n^e. Suppose not. Letting $\mathbf{Z}_k = \{C_j\}_{j=1}^k$ denote the realisation of k cost draws, there would exist some k such that

$$\mathbb{E}_{\mathbf{Z}_k}[\tilde{\pi}_k(Q, C)] \leq \mathbb{E}_{\mathbf{Z}_{k+1}}[\tilde{\pi}_{k+1}(Q, C)] \tag{C.1}$$

where $\pi_k(Q, C)$ denotes the profits for any sequence of cost draws given the first k are potential producers. We have already shown that $\pi(Q, C_i)$ is non-decreasing with entry, which implies that

$$\tilde{\pi}_k(Q, C) \leq \tilde{\pi}_{k+1}(Q, C)$$

for any realisation of cost draws. Moreover, there is some interval of cost draws of positive measure such that the inequality is strict. Taking the expectation over all cost draws, this implies

$$\mathbb{E}_{\mathbf{Z}_{k+1}}[\tilde{\pi}_k(Q, C)] > \mathbb{E}_{\mathbf{Z}_{k+1}}[\tilde{\pi}_{k+1}(Q, C)]$$

Notice that $\tilde{\pi}_k(Q, C)$ is constant for any C_{k+1}, so we can re-write this inequality as

$$\mathbb{E}_{\mathbf{Z}_k}[\tilde{\pi}_k(Q, C)] > \mathbb{E}_{\mathbf{Z}_{k+1}}[\tilde{\pi}_{k+1}(Q, C)]$$

which contradicts (C.1). Therefore, expected profits must be decreasing in the number of entrants, ensuring equilibrium entry exists and is unique. Q.E.D.

Now suppose demand can be written as a function of quantities and exogenous demand shifters D, so $P = P(Q)D$. Demand shifters D are constant within markets and thus the above proof is unchanged. Comparative statics on D, E and F are straightforward.

Corollary 1 *In equilibrium the expected number of firms is monotonically increasing in D and monotonically decreasing in E and F.*

The proof follows from the fact that expected profits from entry are decreasing in entry costs E, and thus so are the number of entrants. As entry costs play no further role in the determination of equilibrium, this increases the number of firms in expectation. Fixed cost reduce ex ante profits in the same way, but also change selection into the market. In particular, higher fixed costs imply lower net profits $\tilde{\pi}(Q,C)$ for any cost draw, and thus reduce the cutoff cost C^*. This also reduces the number of firms in the market, by reducing the number of entrants who actually operate. This logic extends to demand shifters, as one can write realised firm net surplus as $\tilde{\pi}(Q,C)-E = D(q(Q,C)(P(Q)-C)-F/D-E/D)$. Therefore an equilibrium with demand shifter D is isomorphic to one with fixed costs F/D and entry costs E/D.

C.2. Extension II: Extending identification arguments to the non-linear case

We now show that our identification arguments are virtually unchanged for the general case. Let $\mathcal{N}(D,F,E) = \mathbb{E}[N|D,F,E]$ denote the expected number of firms for a given set of D, E and F. A valid instrument $Z \in \mathscr{Z}$ must satisfy the following conditions from Imbens and Angrist (1994)

$$\begin{aligned} \text{exclusion} \quad & Z \perp \{\mathcal{N}(D,F,E)\}_{Z\in\mathscr{Z}}, \{P(N)\}_{n=1}^{N} \\ \text{relevance} \quad & COV(N,Z) > 0 \\ \text{monotonicity} \quad & \forall Z, Z'z \in \mathscr{Z}, \quad \mathcal{N}(Z) \geq \mathcal{N}(Z') \Rightarrow Z \geq Z' \quad \text{or} \quad Z \leq Z' \end{aligned}$$

Given that the function $\mathcal{N}$ is monotonic in each of its arguments, this implies that any component of D, F or E which satisfies the exclusion restriction is a valid instrument for estimating a LATE of competition on prices. When Z satisfies these conditions only conditional on some covariate X, Blandhol et al. (2022) show that a necessary and sufficient condition for identification of a casual effect is the the first stage is rich in covariates. That is, the first stage should equal the conditional expectation function of $\mathbb{E}[N|X]$. The degree of bias is determined by the degree of non-linearity in the first stage, for which we provide robustness checks.

First let's consider the demand instrument. Note that in the heterogeneous costs case, the demand instrument no longer satisfies the exclusion restriction. This is because demand determines the cutoff cost in the market, thus affecting the average productivity. Therefore demand-based instruments will be positively correlated with unobserved costs in the market, or $P(N)$ in the conditions above. Intuitively, higher demand reduces the degree of positive selection. This selection effect will bias IV estimates using demand instruments, but towards zero.[52]

Now consider the entry instrument. First note that fixed costs of operation do not satisfy the exclusion restriction, as they too determine the cutoff level of cost in the same way as demand. This implies that a valid entry instrument should be based on the costs of entering the market and be unrelated to any costs involved in ongoing production and demand. Therefore the reasoning applied to the linear model in the main text is largely unchanged for the general case, which accounts for non-linearity. Indeed, all that is needed for Z_k^E to identify a causal effect of n on p are the monotonicity restrictions on $\mathbb{E}[N|E]$ and the usual exclusion restrictions. Therefore Z_k^E will be a valid instrument for any model of competition with the free entry condition $\mathbb{E}[\pi|N] = E$ and profits weakly decreasing in N. This holds regardless of the price setting behaviour by firms.

[52]If production features returns to scale outside of fixed costs, demand instruments may be biased in either direction, depending on the scale elasticity.

D. Theoretical motivation of excess returns

Our measure of excess returns can be motivated from a general model of firm value subject to entry costs. Suppose that in order to operate, firms must invest K_i units in a factory, where K_i is a random variable. Time is continuous. Firms face a risk-free interest rate i and a constant Poisson probability of closure ρ while operating. Upon closure, firms can sell a fraction $\eta_i < 1$ of their capital, which captures heterogeneity in firm borrowing rates. This implies that the value of an active firm i is given by

$$iV_i = \pi_i - \eta_i \rho K_i - \rho V_i + \dot{V}$$

where π_i is the firm's profit earned operating in the market, net of depreciation. Suppose we are in steady state, so $\dot{V} = 0$. This implies we can write the value of an active firm as

$$V_i = \frac{\pi_i - \eta_i \rho K_i}{i + \rho}$$

Now suppose that new entrants face a constant probability Φ of immediate failure. This reduced form parameter captures possibly complex sources of market power, from political corruption to strategic deterrence. Here the cost of capital $(i + \eta\rho)K$ corresponds to fixed cost of operation F in Appendix Section C, while ΦK represents entry barriers E. Free entry now implies

$$V = \frac{\mathbb{E}[\pi - \rho\eta K]}{i + \rho} = (1 + \Phi)\mathbb{E}[K].$$

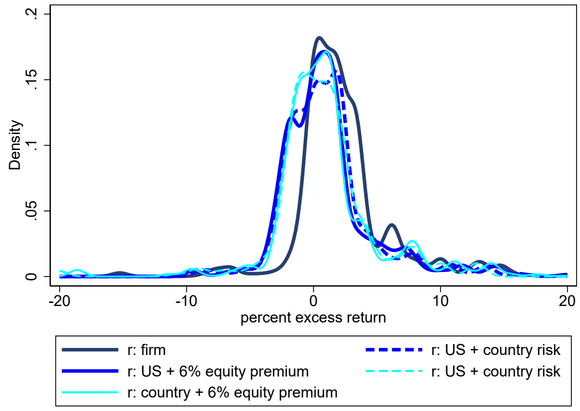
Letting $r^{\pi} = \Phi(i + \rho)$ denote entry costs and $r = i + \rho(1 + \eta)$ be the firms' user cost of capital, we can rearrange the above expression to obtain

$$r^{\pi} = \frac{\mathbb{E}[\pi - rK]}{\mathbb{E}[K]}$$

which gives our measure of excess returns or rents. These rents are returns on firms' capital, in excess of the risk-free rate i plus the firms risk premium $\rho(1 + \eta_i)$.

E. Robustness of excess returns

Figure E.1: Excess returns r^{π}, different user cost measures



Note: This figure shows the returns in excess of the market rate, calculated using alternative measures of the user cost of capital.

Table E.1: Excess returns since 1980

	Firm r	US r, RP=6%	country r, RP=6%	US r, county RP	country r, country RP
$\hat{\pi}$	4.60 (0.39)	1.52 (0.42)	1.68 (0.43)	1.61 (0.42)	1.38 (0.43)
N	448	457	365	457	366

Notes: Standard error of mean in parentheses. 'Firm r' denotes user cost measured by firm level borrowing costs. 'US r' denotes risk free rates measured by US real rates, 'country r' denotes risk free rates country specific. 'RP=6' denotes an equity premium of 6% applied, while 'country RP' denotes the use of country specific equity risk premia from Damodaran (2021).

Table E.2: Excess returns - CAPM adjustment

	US r, RP=6%	country r, RP=6%	US r, county RP	country r, country RP
$\hat{\pi}$	2.58 (0.58)	3.48 (0.33)	2.92 (0.59)	3.72 (0.33)
N	89	63	89	64

Notes: Standard error of mean in parentheses. 'Firm r' denotes user cost measured by firm level borrowing costs. 'US r' denotes risk free rates measured by US real rates, 'country r' denotes risk free rates country specific. 'RP=6' denotes an equity premium of 6% applied, while 'country RP' denotes the use of country specific equity risk premia from Damodaran (2021).

F. General equilibrium network model

Time is continuous. There are two factors, capital k and labour ℓ, which are used to produce N intermediate goods. There are two composite final goods, consumption and investment which are combinations of the N intermediate goods.

F.1. Economic environment

We assume consumption and investment are both Cobb-Douglas composites of the form

$$C = \prod_{i=1}^{N} c_i^{\beta_i}, \quad I = \prod_{i=1}^{N} x_i^{\lambda_i}$$

where c_i and x_i denote the amount of intermediate good i used for final consumption and investment, respectively. Intermediate goods are produced according to

$$q_i = \frac{A_i}{B_i}(k_i^{\alpha}\ell_i^{1-\alpha})^{1-\sum_{i=1}^{N}\sigma_{i,j}} \prod m_{i,j}^{\sigma_{i,j}} \tag{F.1}$$

where $m_{i,j}$ denotes industry i's use of intermediate input j and B_i is a normalising constant $B_i = \prod_{j=1}^{N} \sigma_{i,j} \ln \sigma_{i,j}$ which does not impact the results. The assumption that the production function is Cobb-Douglas, and of constant α implies constant capital labour ratios across all sectors, which simplifies the analysis. Capital evolves according to

$$\dot{k} = I - \delta k$$

where δ is a constant depreciation rate.

F.2. Producers

We model producers at an industry level. We assume that firms charge markups μ_i over marginal costs, while choosing inputs to minimize marginal costs from the production function (F.1). Markups can be microfounded from the two-stage entry game considered in Section 3, and so profits are equal to fixed cost payments plus entry costs/rents. Excess returns are rebated lump sum to households, while we model fixed costs simply as deadweight losses. The producer's budget constraint takes the form

$$\Pi_i = p_i q_i - \left(\sum_{i=1}^{N} p_j m_{j,i} + r k_i + w \ell_i + F_i \right) \tag{F.2}$$

where p_i denotes the price of good i, F_i are fixed costs and Π_i are profits rebated to households. In the baseline model, we assume all $F_i = 0$ and so profits are rents and thus rebated for simplicity.

F.3. Households

The household side is standard. The economy consists of a representative household, with preferences

$$\mathbb{E} \sum_{t}^{\infty} e^{-\rho t} \ln(C_t)$$

where C_t is the composite consumption good and ρ is the discount rate. Capital is the only asset in the economy and is held by household, who take prices as given. Households maximise utility subject to the budget constraint

$$p_I \dot{k} = (r + \dot{p_I} - \delta) k + w + \Pi - p_c C$$

where p_I denotes the price of investment faced by the household and p_C is the ideal price index of the consumption bundle. Maximisation of utility subject to this budget constraint yields the Euler equation

$$\frac{\dot{C}}{C} = \frac{r}{p_I} + \frac{\dot{p_I}}{p_I} - \delta - \rho.$$

F.4. Aggregation

Market clearing implies that

$$P_Y Y = wL + rk + \Pi - P_Y F = p_I I + p_c C \tag{F.3}$$

which is simply the sum of households' expenditures. Letting $\pi = \frac{\Pi}{Y}$, it is straightforward to show that $\frac{rK}{Y} = \alpha(1-\pi)$.

F.5. Input-output definitions

We now turn to some input-output definitions. Let the revenue-based input-output matrix $\mathbf{\Omega}$ be

$$\mathbf{\Omega} = [\omega_{i,j}] = \left[\frac{p_j m_{j,i}}{p_i q_i}\right] \tag{F.4}$$

while we define the consumption, investment and final good expenditure shares as $\beta_i = \frac{p_i c_i}{p_c C}$, $\lambda_i = \frac{p_i x_i}{p_I I}$ and $\eta_i = \frac{p_i(c_i+x_i)}{p_Y Y}$. We can therefore define the expenditure Domar weight as $\gamma = \eta'(I-\mathbf{\Omega})^{-1}$. It can be easily shown that $\gamma_i = \frac{p_i q_i}{P_Y Y}$ is the expenditure share of good i, while the profit share of the economy is given by

$$\pi = \sum_{i=1}^{N} \gamma_i \left(1 - \frac{1}{\mu_i}\right) = \gamma' \tau. \tag{F.5}$$

We also define the consumption Domar weight vector as $\gamma^c = \beta'(I-\mathbf{\Omega})^{-1}$ and equivalently for investment $\gamma^I = \lambda'(I-\mathbf{\Omega})^{-1}$, while the profit share of consumption is given by $\pi_c = \sum_{i=1}^{N} \gamma_i^c \left(1 - \frac{1}{\mu_i}\right)$. We similarly define the cost-based input-output matrix $\mathbf{\Sigma}$, or production elasticity matrix, as

$$\mathbf{\Sigma} = \left[\mu_i \omega_{i,j}\right] \tag{F.6}$$

where Shepard's lemma and exogenous markups imply that this matrix gives the elasticity of good i's production to intermediate j. We define the influence vector for consumption and investment in the usual way $\psi^{C\prime} = \beta'(I-\mathbf{\Sigma})^{-1}$ and $\psi^{I\prime} = \lambda'(I-\mathbf{\Sigma})^{-1}$ while letting $s = \frac{p_I I}{P_y Y}$ be the savings rate. We define the influence vector for total output with respect to a base year t_0 as follows

$$\psi^Y = s_{t_0} \psi^I + (1 - s_{t_0}) \psi^C \tag{F.7}$$

which is necessary due to the use of the Divisa index.

We now turn to proving the main propositions in the paper in Section 4. Throughout, we define aggregate productivity by $A_j = \prod_{i=1}^N A_i^{\gamma_i^j}$ for sector $j \in \{C, I, Y\}$ and similarly aggregate distortion as $D_j = \prod_{i=1}^N \mu_i^{-\gamma_i^j} = \prod_{i=1}^N (1-\tau_i)^{\gamma_i^j}$ for consumption C, investment I and aggregate output Y. These definitions allow us to easily map the general production network structure into a two sector neoclassical growth model.

F.6. Proofs of general equilibrium model

Lemma 1 *The equilibrium price vector is given by*

$$\ln \mathbf{P} = -(I - \mathbf{\Sigma})^{-1}(\ln \boldsymbol{A} - \ln \boldsymbol{\mu}) + \mathbb{1}_N(\alpha \ln r + (1-\alpha)\ln w - \ln D) \tag{F.8}$$

where $\ln D = \alpha \ln \alpha + (1-\alpha)\ln(1-\alpha)$ *and* $\mathbb{1}_N$ *is a vector of ones of length* N*. The price of investment goods is given by*

$$p_I = \frac{D_c A_c}{D_I A_I}$$

where $D_j = \prod_{i=1}^N \mu_i^{-\gamma_i^j}$ *and* $A_j = \prod_{i=1}^N A_i^{\gamma_i^j}$ *for* $j \in \{c, I\}$ *define aggregate markups and productivity in each sector.*

Proof Firms minimize costs subject to a Cobb-Douglas production function, given by

$$\ln q_i = \ln A_i + \left(1 - \sum_{j=1}^N \sigma_{i,j}\right)(\alpha \ln k_i + (1-\alpha)\ln \ell_i) + \sum_{j=1}^N \sigma_{i,j} \ln m_{i,j}$$

Cost minimisation subject to a markup μ_i yields the following expression for prices

$$\ln p_i = \ln \mu_i - \ln A_i + \sum_{j=1}^N \sigma_{i,j} \ln p_j + \left(1 - \sum_{j=1}^N \sigma_{i,j}\right)(\alpha \ln r + (1-\alpha)\ln w - \ln D)$$

which can be written in matrix form as

$$\ln \mathbf{P} = \mathbf{\Sigma} \ln \mathbf{P} - \ln \boldsymbol{A} - \ln \boldsymbol{\mu} + (I - \mathbf{\Sigma}) \mathbb{1}_N (\alpha \ln r + (1-\alpha) \ln w - \ln D)$$

where $\mathbb{1}_N$ is a vector of ones of length N. Some algebra yields

$$\ln \mathbf{P} = -(I - \mathbf{\Sigma})^{-1} (\ln \boldsymbol{A} - \ln \boldsymbol{\mu}) + \mathbb{1}_N (\alpha \ln r + (1-\alpha) \ln w - \ln D). \tag{F.9}$$

The Cobb-Douglas form of investment goods implies that $\ln p_I = \lambda' \ln \mathbf{P}$. Therefore the log price of investment goods can be written as

$$\ln p_I = (\beta - \lambda)(I - \mathbf{\Sigma})^{-1} (\ln \boldsymbol{A} - \ln \boldsymbol{\mu}).$$

We can alternatively write this expression in price levels. Using $\psi^{C\prime} = \beta'(I - \mathbf{\Sigma})^{-1}$, $\psi^{I\prime} = \lambda'(I - \mathbf{\Sigma})^{-1}$ and the definition $\mu_i^{-1} = 1 - \tau_i$ we have

$$p_I = \frac{\prod_{i=1}^N A_i^{\psi_i^c} (1-\tau_i)^{\psi_i^c}}{\prod_{i=1}^N A_i^{\psi_i^I} (1-\tau_i)^{\psi_i^I}} = \frac{D_c A_c}{D_I A_I}$$

where the second equality follows from the definition of A_c, D_c, A_I and D_I.

Q.E.D.

Lemma 2 *Consider an environment in which markups change due to an instantaneous MIT shock to policy in period t_0. Then the Divisa index, defined as $d \ln P_{y,t_0} = s_{t_0} d \ln p_{I,t_0}$ in the base period is given by*

$$P_{y,t} = p_I^{s_{t_0}} \tag{F.10}$$

where s_{t_0} is the savings rate in the base period.

Proof We consider an environment in which productivity is exogenous and constant, with only instantaneous MIT shocks to markups considered. As mentioned in the text, we assume a Divisa price index, such that $d\ln P_{y,t} = s_t d\ln p_I$. This implies that from our base price $\ln P_{y,t_0} = s_{t_0} \ln p_{I,t_0}$, the output deflator after a shock at t_0 is given by

$$\ln P_{y,t_0} = s_{t_0} \ln p_{I,t_0}.$$

Therefore after a shock at time t_0, we have that

$$\begin{aligned} \ln P_{y,t} =& s_{t_0}(\ln p_{I,t_0} + d\ln P_{y,t_0}) \\ \ln P_{y,t} =& s_{t_0} \ln p_{I,t}. \end{aligned}$$

Taking the exponential of the second expression yields the result. Q.E.D.

Proof of Proposition 2

Part 1 By our choice of numeraire, $\ln P_c = 0$. We can use Lemma 1 to obtain

$$\begin{aligned} \ln p_c = \beta' \ln \mathbf{P} =& 0 \\ \alpha \ln r + (1-\alpha)\ln w =& \psi^{C\prime}(\ln \boldsymbol{A} - \ln \boldsymbol{\mu}) \end{aligned} \tag{F.11}$$

where the second relation follows from Lemma 1. This relates the productivity in consumption $\ln A_c = \psi^{C\prime} \ln \boldsymbol{A}$ and the total distortion in consumption $\ln D_c = \psi^{C\prime} \ln \boldsymbol{\mu}$, following from our choice of numeraire.

We now use this to obtain an expression for deflated aggregate output. Equal factor intensities across sectors imply that capital labour ratios across sectors are constant, given by

$$rk = \frac{\alpha}{1-\alpha} wL.$$

From this and the definition of factor income $Y^F = wL + rk$, we have that

$$\ln Y^F = \alpha \ln r + (1-\alpha)\ln w + \alpha \ln k + (1-\alpha)\ln L + \ln D$$

where $\ln D = \alpha \ln \alpha + (1-\alpha)\ln(1-\alpha)$ is a constant. Using equation (F.11), we can therefore define factor income in logs as

$$\ln Y^F = \psi^{C\prime}(\ln \boldsymbol{A} - \ln \boldsymbol{\mu}) + \alpha \ln k + (1-\alpha)\ln L$$

or equivalently in per capita levels (we normalize L=1 throughout)

$$Y^F = D_c A_c k^\alpha.$$

From this we can obtain nominal output from the expression $PY = \frac{Y^F}{1-\pi}$. It is straightforward to see that $\frac{D_c A_c}{P_y} = A_y D_y$ from the definition of ψ^y in equation (F.7). This implies aggregate output can be written as

$$Y = \frac{D_y}{1-\pi} A_y k^\alpha. \tag{F.12}$$

Noticing that in perfect competition $D_y = 1 - \pi = 1$ gives the first result.

Part 2 Constant capital labour ratios imply that

$$Y^F = \frac{rk}{\alpha} \tag{F.13}$$

which can be rearranged to obtain an expression for the interest rate

$$r^* = \alpha D_c A_c k^{\alpha - 1}.$$

In steady state, consumption is constant $\dot{c} = 0$ which combined with the Euler equation (9) implies

$$\frac{r^*}{p_I^*} = \delta + \rho$$

which can be combined with our expression of real interest rates to obtain

$$\alpha D_I A_I k^{\alpha-1} = \delta + \rho$$

where this expression follows from the definition of p_I from lemma 1. Rearranging we obtain

$$k^* = \left(\frac{\alpha D_I A_I}{\delta + \rho}\right)^{\frac{1}{1-\alpha}} \tag{F.14}$$

which completes the proof.

Corollary 2 *We can express the steady-state expenditure share vector γ as the following function of model primitives*

$$\gamma' = (I - \chi\tau(\lambda - \beta)'\mathscr{L}(\tau))^{-1}(\chi\lambda + (1-\chi)\beta)'\mathscr{L}(\tau) \tag{F.15}$$

where $\mathscr{L}(\tau) = \left(I - (I - diag(\tau))\mathbf{\Sigma}\right)^{-1}$ is the expenditure-based Leontief inverse matrix and $\chi = \alpha\delta/(\delta+\rho)$ is the efficient investment rate.

Proof Combining the definition of the savings rate $s = p_I I / P_Y Y$ with our expression for the capital stock (F.14), our expression for output (F.12) and the steady-state condition that $\delta k^* = I^*$, we obtain the following expression for the savings rate

$$s^* = (1-\pi)\frac{\delta\alpha}{\delta + \rho} = (1-\pi)\chi. \tag{F.16}$$

Using this expression of the savings rate, we can express expenditure shares $\gamma = \eta(I - \mathbf{\Omega})^{-1}$ as a function of distortions τ

$$\begin{aligned}\gamma' =& ((1-s)\beta + s\lambda)'\mathscr{L}(\tau)\\ =& ((1-(\chi(1-\gamma'\tau))\beta + (1-\gamma'\tau)\chi\lambda)'\mathscr{L}(\tau)\end{aligned}$$

where the second equality follows from the fact that $\pi = \gamma'\tau$. Rearranging we can obtain

$$\begin{aligned}\gamma' =& ((1-\chi)\beta + \chi\lambda)'\mathscr{L}(\tau) + \chi\gamma'\tau(\lambda-\beta)'\mathscr{L}(\tau)\\ \rightarrow \gamma' =& (I - \chi\tau(\lambda-\beta)'\mathscr{L}(\tau))^{-1}(\chi\lambda + (1-\chi)\beta)'\mathscr{L}(\tau)\end{aligned}$$

which completes the proof. Q.E.D.

Proof of Proposition 3 Taking the derivative of equation (F.12) combined with (F.14), we obtain

$$\frac{d\ln Y}{d\ln\mu_i} = \psi_i^Y + \frac{\alpha}{1-\alpha}\psi_i^I - d\ln(1-\pi).$$

We therefore need to understand how changes in markups affect profits to obtain the elasticity of output to profits in sector i. We start by analysing how expenditure shares change in response to a change in markups. Totally differentiating the expression for Domar weights $\gamma = \nu'(I - \mathbf{\Omega})^{-1}$ in matrix form yields

$$d\gamma' = d\eta'\mathscr{L} + \eta' d\mathscr{L} \tag{F.17}$$

where $\mathscr{L} = (I - \mathbf{\Omega})^{-1}$. The definition of final expenditure $\eta = S\beta + (1-S)\lambda$ along with the Cobb-Douglas structure of demand implies that

$$d\eta = (\lambda - \beta)dS. \tag{F.18}$$

This relation has an intuitive interpretation. As within-good expenditure shares are fixed, changes in final expenditure shares are driven by changes in the savings rate. Positive (negative) changes in savings reallocate final expenditure toward (away from) investment producing sectors.

We now turn to quantifying expenditure changes within the production network. Using the definition of $\mathscr{L}$, we have

$$d\mathscr{L} = \mathscr{L} d\mathbf{\Omega}\mathscr{L}$$

while we can use the definition of $\Omega = diag(\mu)^{-1}\Sigma$ and the fact that Σ is constant to express this as

$$\begin{aligned}
d\mathscr{L} =& \mathscr{L} d(diag(\mu)^{-1})\mathbf{\Sigma}\mathscr{L} \\
d\mathscr{L} =& -\mathscr{L} diag(\mu)^{-1} diag(d\mu) diag(\mu)^{-1}\mathbf{\Sigma}\mathscr{L} \\
d\mathscr{L} =& -\mathscr{L} diag(d\log\mu))\mathbf{\Omega}\mathscr{L}
\end{aligned}$$

where the last relation follows from the fact that $d\log\mu_i = \frac{d\mu_i}{\mu_i}$. Substituting this and (F.18) into equation (F.17) gives

$$d\gamma' = (\lambda' - \beta')\mathscr{L} dS - \eta'\mathscr{L} diag(d\log\mu))\mathbf{\Omega}\mathscr{L}$$

which using $\mathbf{\Omega}\mathscr{L} = \mathscr{L} - I$ along with the definition of γ^I and γ^c can be expressed as

$$d\gamma' = (\gamma^I - \gamma^c)' dS - \gamma' diag(d\log\mu)(\mathscr{L} - I).$$

Now from the definition of π we have that

$$\begin{aligned}
d\pi =& d\gamma'\tau + \gamma'\tau \\
d\pi =& (\gamma^I - \gamma^c)' dS\tau - \gamma' diag(d\log\mu)(\mathscr{L} - I)\tau - \gamma' d\tau.
\end{aligned}$$

From the definition of industry profit rates $\pi_j = \gamma^{j\prime}\tau$ and the fact that $d\tau = diag(d\log\mu)(1N - \tau)$ we can express the above equation more concisely as

$$
\begin{aligned}
d\pi =& (\pi^I - \pi^c)' dS - \gamma' diag(d\log\mu)\mathscr{L}\tau + \gamma' diag(d\log\mu)\mathbb{1}_N \\
=& -(\pi^I - \pi^c)' \frac{s}{1-\pi} d\pi - \gamma' diag(d\log\mu)\mathscr{L}\tau + \gamma' diag(d\log\mu)\mathbb{1}_N
\end{aligned}
$$

where the latter expression follows from differentiating equation to find $ds = -d\pi\frac{s}{1-\pi}$. Rearranging and exploiting the fact that $\pi = s\pi_I + (1-s)\pi_C$ we can in turn express changes in profit rates as

$$
d\pi = -\frac{1-\pi}{1-\pi_c}\gamma' diag(d\log\mu)(1_N - \mathscr{L}\tau)
$$

letting $d\ln\mu_j = 0$ for $j \neq i$ we can then insert this into the equation to yield the result

$$
\frac{d\ln Y}{d\ln\mu_i} = -\psi_i^Y - \frac{\alpha}{1-\alpha}\psi_i^I + \frac{d\pi}{1-\pi}.
$$

G. Calibration

G.1. Details on calibration

Markups In order to estimate cost shares from observable data on expenditures, we need estimates of distortions in each sector. We assume markups in excess of total costs are the only form of distortion in the economy. Following Baqaee and Farhi (2020), we assume that industry output is a homothetic aggregate of firm-level outputs, with each firm having identical production functions up to a Hicks-neutral productivity shifter. This allows us to express each sector in terms of a representative firm. We then define industry-level markups as the revenue-weighted harmonic average of firm-level markups.[53]

In order to measure markups at a sector level, we use firm-level accounting data from Worldscope. Our baseline measure of firm-level markups is the same as that used in Section 3.5, based on Gutiérrez and Philippon (2016). This measures excess returns as opposed to markups, and so these are likely to be relatively conservative estimates. As measuring firm-level markups is subject to well-documented difficulties, we show that the results are robust to using a host of other measures of markups, namely the lerner profits from the World Input-Output Database and a uniform ten % profit rate.[54] We use a range of markup estimates to show our results are mainly driven by the structure of the production network. We choose 2011 as the baseline year in our analysis, as we observe both input-output linkages and ICP price data in this year.

Macro parameters α, δ, ρ For our calibration, we assume that $\alpha = \frac{1}{3}$ and set $\delta + \rho = .1$. This ensures that differences in steady-state income levels are driven entirely by productivity and distortions. In order to reconcile the large differences in savings rates in the data, we assume that countries are on different parts of their transition paths. Therefore in order to quantify impacts we first calculate steady-state income under the existing parameters and treat this as our baseline. We can then separate ρ and δ by matching observed savings rates

[53] Following Liu (2019), we take the average markup of a country for sectors with missing markup data.
[54] We also used a production function approach following De Loecker and Eeckhout (2018) and find much larger effects.

in the US.[55] It should be noted that if profits were not rebated and instead were dissipated by fixed costs, the choices of δ and ρ would be irrelevant. These parameters only matter in determining the changes in profits and have little quantitative impact.

Incorporating cement To obtain the expenditure matrix $\mathbf{\Omega}$ we use input-output data from the 55-industry-level World Input-Output Database (WIOT) compiled by Timmer et al. (2015). We follow Liu (2019) in modelling trade as a fictitious sector which transforms exports to imports in a one-to-one fashion. Any trade surplus or deficit is interpreted as a lump-sum transfer. Cement in this data is part of the "Manufacture of other non-metallic mineral products" (NMM) sector.[56] In order to account for the cement sector, we split the NMM sector in two: one sector which supplies construction and another supplying the rest of the economy. As we do not have data on cement expenditure on other inputs, we assume it has the same input shares as the wider NMM sector.[57] We combine cement consumption data from the global cement report with ICP price data to obtain an estimate of cements' share within the construction supplying sector, ignoring domestic production for export. This means we model the portion of NMM supplying construction as a single sector entering in the Cobb-Douglas production network.

In the model we assume a Cobb-Douglas production structure, yet our oligopoly model presented in Section 3 allows for non-unitary elasticity. We account for this by assuming that cement is combined with other material inputs in construction according to a CES aggregator with elasticity ε. As cements' production structure is identical to the rest of the sector, this only effects markups and thus aligns with the Cobb-Douglas structure of the model. Moreover, changes in cement's expenditure share within this sector depend only

[55] The results are almost identical if we assume each country is at steady state and calibrate accordingly.

[56] Other products included in this category are, e.g., glass and glass products, tiles and baked clay products.

[57] These assumptions appear reasonable from inspection of the detailed 405 industry group supply use table for 2012 for the US which includes cement manufacturing as a distinct industry (Bureau of Economic Analysis, 2021). Over 70% of manufactured cement is used by either the construction sector directly or by ready-mix concrete manufacturing or other concrete manufacturing. About 84% of ready-mix concrete is used by the construction sector. Further, the top five inputs in terms of cost shares at the three-digit summary industry level (71 industry groups) used for cement account for between 40-62% of input cost shares in the largest three industries of the non-metallic minerals sector (clay product and refractory manufacturing, glass and glass product manufacturing and ready-mix concrete manufacturing). At the two-digit level, this figure amounts to about 67-82% for the same set of industries.

on changes in its markup, and so we can calculate counterfactual markup changes in the composite sector easily.

Let $i = NMM$ denote the non-metallic mineral products sector and let $i = C$ denote the new sector which captures supply to construction, which is produced competitively (or inside the construction sector). We define this new sector so that it has the same expenditure bundle $\omega_{C,j} = \omega_{NMM,j}$, while the sector only supplies construction $\omega_{i,C} = 0 \quad \forall i \neq con$. Let ω_{cem} be the expenditure share of cement within our new sector. We can calculate the initial sector-level markup as

$$\mu_C = \omega_c \mu_{cem}^{-1} + (1 - \omega_c)\mu_{NMM}^{-1}$$

where μ_{cem} denotes the markup in cement. Now we assume that within this new sector, cement faces a constant elasticity of substitution. This implies that we can write ω_c as

$$\omega_c = D\left(\frac{\mu_{cem}}{\mu_{NMM}}\right)^{1-\varepsilon}$$

where D is a constant. Therefore, for a given proportional change in cement markups $\Delta\mu_{cem}$, we can write the new expenditure share as

$$\hat{\omega}_c = \omega_{cem}(\Delta\mu_{cem})^{1-\varepsilon}$$

from which we can calculate the markup of the composite sector and apply it to the Cobb-Douglas model.

We estimate markups in cement as those implied by our baseline oligopoly model, given by

$$\mu_{cem} = \frac{\hat{\varepsilon} n}{\hat{\varepsilon} n - 1}$$

where we use our estimate of ε from column 3 of Table 4. This yields relatively conservative estimates given the moderate to high levels of competition in the four countries. The elasticity of substitution plays a role in determining the size of the wedge generated by cement. However the contribution of entry and common ownership to this wedge is largely invariant to this parameter.

Finally, in order to perform counterfactuals regarding entry in cement, we must account for the additional fixed cost of a new firm in the market. We treat cement differently to other sectors and assume that there are zero rents for the marginal firm in cement - that is, that total entry costs to enter the market are equal to total profits. This allows our counterfactuals about market structure to account for the cost of introducing new firms. We assume that marginal firms in the cement market face zero profits, and so fixed costs of entry are given by

$$E_{cem} = \frac{R_c}{\hat{\varepsilon} n^2}$$

where R_c is revenue in the cement market and n is the number of firms operating. We assume entry costs are paid in units of the consumption good and are not rebated. That is, our calibration does not depend on the existence of rents in cement found in Section 3.5, instead treating entry barriers sustaining such rents as fixed costs of production.

G.2. Calculating counterfactuals

Our results on marginal sensitivities depend only on cost shares and profits and therefore can be calculated directly from the data. However in order to perform counterfactuals with respect to discrete changes in markups, we also need to account for the fact that the economy's savings rate is determined by profits.

Steady-state output We calculate steady-state output for a given profit vector $\hat{\tau}$ according to the following steps:

1. Calculate the new expenditure share vector $\hat{\gamma}'$ according to equation (F.15):

$$\hat{\gamma}' = (I - \chi\tau(\lambda-\beta)'\mathscr{L}(\hat{\tau}))^{-1}(\chi\lambda + (1-\chi)\beta)'\mathscr{L}(\hat{\tau})$$

   where $\mathscr{L}(\tau) = \big(I - (I - diag(\tau))\Sigma\big)^{-1}$.

2. Calculate the new aggregate profit rate as

$$\hat{\pi} = \hat{\gamma}'\hat{\tau}.$$

3. Calculate the new steady-state output according to Proposition 1

$$\ln \hat{k}(\hat{\tau}) = \frac{1}{1-\alpha}\psi_I' \ln(\mathbf{1}-\hat{\tau})$$
$$\ln \hat{Y}(\hat{\tau}) = \psi_Y' \ln(\mathbf{1}-\hat{\tau}) + \alpha(\ln \hat{k}) - \ln(1-\hat{\pi})$$

where $\ln(\mathbf{1}-\hat{\tau})$ is a vector with elements $\ln(1-\tau_i)$ and we have normalised output and capital in the perfectly competitive economy to one.

Firm entry We calculate the benefits of firm entry as the change in steady-state output moving markups in cement from $\tau = 1-\hat{\mu}(n)^{-1}$ to $\hat{\tau} = 1-\hat{\mu}(n+1)^{-1}$, less the cost of entry E_{cem}. Therefore the output change is given by

$$\Delta Y^{entry} = \hat{Y}(\hat{\tau}) - E_{cem} - Y.$$

Common ownership

1. Calculate the new expenditure shares when Δn existing plants operate independently.

2. Verify that these $n+\Delta n$ firms are profitable in the new equilibrium:

$$\frac{\hat{R}_c}{\varepsilon(n+\Delta n)^2} \geq E_{cem}$$

If not, choose maximum $\Delta m < \Delta n$ such that the new firms are profitable.

3. Calculate the new steady-state output according to Proposition 1, less fixed costs at the firm level

$$\hat{Y} - \Delta n * s_f * E_{cem}$$

where s_f denotes the share of fixed costs that accrue at the firm rather than plant level.

H. Pass-through of cement to building costs

In this section we examine the extent to which higher cement prices are reflected in higher construction costs. To answer this question, ideally we would use detailed data on comparable construction projects across a large number of countries, such as unit costs per km of roads as used by Collier et al. (2016). These should be priced by an expert, and in addition to estimated costs, contracted and final costs would be required since the construction sector is known for notoriously large cost overruns. Unfortunately, such data is difficult to obtain for buildings. This is due to a combination of factors: different building codes, building practices and the absence of a central body who is able to request such data and disaggregate them in a comparable way. Whether certain amenities such as an air conditioning system, security systems or smoke detection systems are included has an important impact on the price per m^2. We can still provide suggestive evidence on the link between cement prices and construction costs in two ways using data from an earlier round of the ICP and from a leading construction consultancy firm. Details on the data are provided in Appendix A.

The 2005 ICP data used a "Basket of Construction Components (BOCC)" approach in which prices for 22 construction components and 12 input prices were collected. We have access to these data for the 18 "Ring" countries of the ICP. We selected the composite components that were listed to use concrete for residential housing and civil engineering works. We also test whether there is a correlation between cement prices and construction sector inputs that we would not expect to be affected by the price of cement such as skilled and unskilled labor.

We start by regressing the log cost of the composite construction component on log cement prices. Only ten of the 18 ring countries report cement prices in 2005 and we show the correlation between cement prices and construction components for these countries in Columns (1) and (2) in Table H.1. We also use the 2011 ICP cement prices to examine the correlation in Columns (3) and (4). Column (1) in Table H.1 shows that a 1% increase in the price of cement is associated with a 0.36% increase in costs of the composite component,

Table H.1: Dependent variable: Log of cost of component

	2005 ICP cement price		2011 ICP cement price	
	cem comp	non-cem comp	cem comp	non-cem comp
	(1)	(2)	(3)	(4)
ln (cement)	0.36**	0.091	0.65**	-.182
	(0.178)	(0.114)	(0.277)	(0.396)
Type FE	Yes	Yes	Yes	Yes
Obs.	114	35	162	47
No. Countries	10	10	14	14
R^2	0.841	0.951	0.791	0.915

Note: Reported standard errors are clustered at the country level. *, **, *** denote significance at 10%, 5% and 1% levels.

suggesting a tight link between cement prices and costs. When we use our non-cement construction sector prices in column (2) on the other hand, we do not see any relationship. Reassuringly, cement prices are not correlated with the cost of hiring skilled and unskilled construction sector labor. In columns (3) and (4) we use the 2011 ICP cement prices where we find an even higher coefficient and very similar patterns.

The second way we explore the relationship between cement prices and building cost is by extracting data collected by a leading global construction consultancy firm. Table H.2 presents a regression of log costs per square meter on log cement prices. All models include building type and time fixed effects. Given that we have variation across time as well as a larger number of countries compared to the ICP 2005 data we can explore the role of additional controls such as scale controls or the World Governance Indicators. Column (1) suggests a tight link between cement prices and building costs: a 1% increase in the price of cement is associated with a 0.8% increase in the cost per square meter. Column (2) includes our scale controls which lead an elasticity above one. In column (3) we control for the institutional quality. Since cement could just proxy for high construction prices overall, in column (4) we control for the price of aggregate, sand, softwood, bricks, mild steel reinforcement bars, structural steel and fuel. The number of observations drops sharply as the set of countries for which all of these input prices are available is much smaller. The inclusion of these controls reduces the coefficient somewhat but the elasticity is close to

Table H.2: Dependent variable: Log of cost per square meter

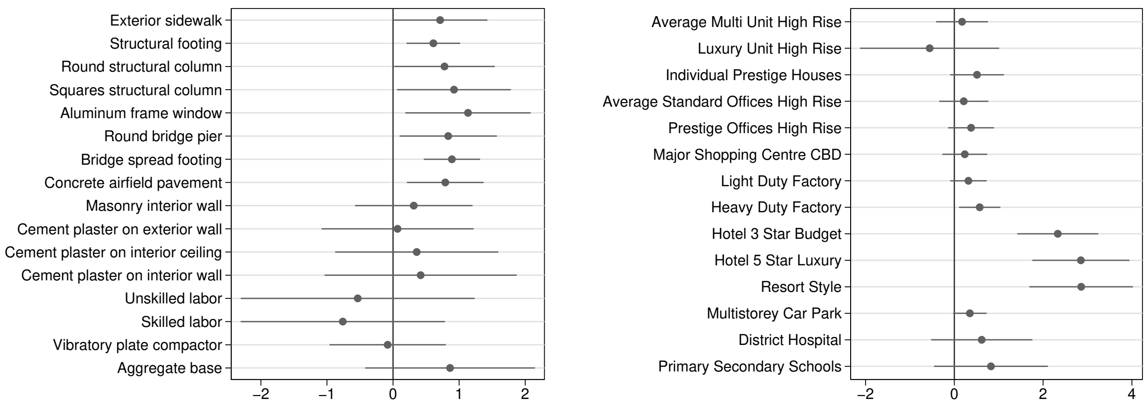
	(1)	(2)	(3)	(4)	(5)
ln (cement)	0.793***	1.171***	0.878**	0.92***	1.170***
	(0.216)	(0.251)	(0.387)	(0.284)	(0.279)
Time FE	Yes	Yes	Yes	Yes	Yes
Building Type FE	Yes	Yes	Yes	Yes	Yes
Scale Controls	No	Yes	Yes	Yes	Yes
WGI	No	No	Yes	Yes	Yes
Other costs	No	No	No	Yes	No
Country FE	No	No	No	No	Yes
Obs.	578	578	578	327	578
No. Countries	24	24	24	14	24
R^2	0.706	0.717	0.72	0.804	0.757

Note: Reported standard errors are clustered at the country level. *, **, *** denote significance at 10%, 5% and 1% levels.

one and remains significant. Finally, since we have prices and costs at two time periods, in column (5) we include country fixed effects. Overall, the coefficient is remarkably stable and shows a tight link between building costs and cement prices.

To further explore these patterns, Figure H.1 shows the distribution of coefficients from a regression that uses each component or building type separately. Given the data constraints,

Figure H.1: Cement prices and construction costs per square meter



Note: The figure on the left shows the coefficients from a regression of log cement prices on construction composites using 2005 ICP data. The figure on the right shows the coefficients from a regression of log cement prices on construction costs per square meter.

each regression of the figure on the left has between 12 and 14 observations. Still, several of these composite construction costs correlate significantly with cement prices, in particular the goods for which we would expect cement to account for a significant fraction such as sidewalks, structural footings, columns, bridge piers and a concrete air field. Prices for other inputs - labor, a vibratory plate compactor and aggregate base - show little correlation again. The sample size of the data underlying the construction costs per square meter in the figure on the right is again modest (between 26 and 46 locations in 14 to 24 countries). Still, the figure shows that all but one of the coefficients are positive, and particularly the cost of hotels and resorts is higher when cement prices are high. While more research is needed to pin down the precise relationship between particular input prices, such as cement, and output prices, the evidence presented here suggests that there is a significant link.