CONCRETE THINKING ABOUT DEVELOPMENT[*]

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Abstract

This paper uses new micro-data on key input prices in the construction sector and market structure to understand the reasons for price differences and their implications for capital accumulation. Our key motivating facts are that (i) there is large dispersion in prices of eight key construction sector inputs and that cement prices were particularly high in Sub-Saharan Africa compared to the rest of the world; (ii) using data on the market structure of the cement industry at a global level, cement prices are highest in countries with few firms; (iii) cement plays a significant role in construction sector expenditures, particularly in the poorest countries. Estimates from our model of oligopoly suggest that lower levels of competition lead to significantly higher prices. Financial accounts data point toward substantial pure profits, and there is no evidence from plant size distributions that minimum efficient scale is driving high prices. Finally, we embed the oligopoly model into a dynamic network model to measure the macroeconomic impact of distortions and evaluate the benefits of different competition policies on steady-state output.

1. Introduction

A large body of recent literature in macroeconomics highlights the importance of key sectors which can cause bottlenecks in the productive efficiency of economies (Baqaee and Farhi, 2019; Baqaee, 2018; Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi, 2012; Jones, 2011; Liu, 2019). This paper focuses on the construction sector, an important yet often overlooked component of investment, accounting for half of investment expenditure on average. More specifically, we focus on the role of distortions in the production of construction sector intermediate goods. We pay particular attention to one of the most important inputs to the construction sector at a global level: cement. It is a core ingredient of concrete, has few or no substitutes, and is used abundantly, for example to build houses, dams, canals and roads. The cement industry is also known to have considerable market power, both in developed and developing countries (Röller and Steen, 2006; McBride, 1983; Miller and Osborne, 2014; World Bank, 2016; Global Competition Review, 2020). In this paper we argue that distortions in such a sector are particularly detrimental to the poorest countries.

The paper makes three contributions. First, we present new evidence at a global level on (i) price dispersion of precisely defined key construction sector inputs including ready-mix concrete, ordinary Portland cement, aggregate for concrete, sand for concrete and mortar, softwood for carpentry, common bricks, mild steel reinforcement bars and structural steel beams; (ii) market power in the cement industry across time and space; and (iii) the role of construction in capital formation as well as the role of cement in construction sector expenditures. To do this, we use confidential micro-data collected as part of the 2011 and the recently released 2017 round of the International Comparison Project (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. Second, we focus on market power as an example of a particular type of distortion in cement by modelling the cement sector as an oligopoly and estimating a market-level price equation using cross-country data. Third, we analyse the role of cement in a dynamic production network model with distinct consumption and investment goods. We use the model to quantify the costs of distortions in cement and evaluate the long-run macroeconomic effects of different competition policies.[1]

Why is the construction sector important? Goods produced in the construction sector, which we will henceforth refer to as structures, are used in the production of almost all physical investment: most firms require buildings as a key input to produce goods; core infrastructure

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[1]Throughout the paper we use the term "distortion" to refer to a range of situations that result in off-marginal-cost pricing, for example, firms earning excess profits 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.

such as roads, bridges, ports and airports is used to transport goods and link workers and firms. Evidence suggests that the cost of physical investment is high in low-income countries (Caselli and Feyrer, 2007; Restuccia and Urrutia, 2001). From a national accounts perspective, investment (gross fixed capital formation) consists of (i) machinery and equipment, (ii) construction, and (iii) other investment. The construction sector accounts on average for about half of investment, with the remainder split between machinery and equipment (accounting for about 38 percent) and other investment (accounting for about 9 percent). Low-income countries tend to import a large fraction of their machinery and equipment (Alfaro and Ahmed, 2010; Eaton and Kortum, 2001). In contrast, structures and some of their key inputs are produced domestically such that high domestic construction and intermediate input prices necessarily translate into high investment prices, creating bottlenecks as highlighted by Jones (2011). Despite the importance of the sector, we know little about efficiency in construction and its intermediate inputs in low-income countries.

We show that spatial price dispersion in key construction sector inputs is large and previously masked in aggregate price indices even at a sector level: in 2011 the price of a cubic metre of ready-mix concrete is highest in Africa (US$202), compared with US$148 in North America and US$83 in East Asia and Pacific. When examining the price of the key ingredients of concrete – cement, aggregate and sand – we find that cement is the ingredient that shows the highest price in Sub-Saharan Africa compared to any other region in the world. The order of magnitude is striking: in 2011 a ton of Portland cement cost US$487 in the Central African Republic compared to US$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 21 for Sub-Saharan African countries. In other words, the region with the lowest level of infrastructure also faces the highest prices of an essential input. Data from the 2017 round show that average prices have come down at a global level, decreasing from a median price of US$166 in 2011 to a median price of US$139 for a ton of cement in 2017. However, price dispersion persists. The price of cement in Sub-Saharan Africa is 1.5 (3.6) times the price of cement in the United States when we use market (PPP) exchange rates. Turning to our second set of inputs, we show that softwood is most expensive in South Asia in 2011 and particularly expensive in North America in 2017. Bricks are most expensive in North America in both years and cheapest in South Asia, with Sub-Saharan Africa somewhat in the middle. A ton of mild steel reinforcement costs more than US$1,000 in Latin America and the Caribbean, North America as Sub-Saharan Africa. Dispersion in structural steel prices was moderate in 2011 and has increased substantially in 2017, with Sub-Saharan African price levels about three times the North American prices.

Several of these price differences 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.[2] 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, it is the classic example of a non-tradable good due to its low value to weight ratio. 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 and this is even more pronounced in poor countries. For instance, some of Africa's greatest fortunes were made based on cement. One interesting example is Nigeria. Dangote Cement accounts for about 60 percent of cement capacity in Nigeria (International Cement Review, 2019a). Dangote's profit margin in 2015 was 42.3 percent compared to the average global cement profit margin of 17.2 percent (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 percent of the Nigeria's capacity. The remaining 20 percent of capacity are produced by plants owned by LafargeHolcim, the second largest cement producer world-wide.

Using data on the number of firms active in each of the countries as well as firm capacities for both time periods, we explore this relationship systematically. Our second motivating fact is that there is a strong positive relationship between cement prices and market power that goes beyond anecdotes. 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.

We next turn to examining construction's share of investment and the role cement plays in overall construction sector expenditures, using data on both rounds of the ICP data as well as data on cement consumption. 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 eight percent of construction sector expenditures on cement, and the 75th percentile of countries spend more than 17 percent of their overall construction expenditures on cement. We show that predominantly the poorest countries, largely in Sub-Saharan Africa, have high expenditure shares on cement.

In light of the large differences in cement prices and the key role cement plays in the pro-

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[2]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).

duction of concrete, we use cement as an important intermediate input for which we can explore the role of market power as a source of distortions. To discipline the empirical analysis we develop a simple model of the production of cement to recover an estimate for the distortion. We assume that cement is produced in oligopoly and used by the construction sector to produce structures using a CES production function. We derive a simple market-level price equation following Bekkers and Francois (2013) and examine the bias due to free entry.

To estimate the oligopoly model for cement we use the data on the price of cement from the ICP, data on the market structure of the industry that we collected, prices of key inputs in the production of cement such as fuel, basic country characteristics such as population, income and area to capture differences in scale, income and transport costs, data on political stability, corruption and rule of law. We also show extensions where we control for further input costs in the production of cement such as limestone availability, the cost of electricity, coal and machinery. To account for free entry, in our preferred instrumental variables specification we use the cost to obtain a construction permit as a proxy for entry costs.

We find that there is a strong relationship between the market structure of cement in a country and cement prices. A lower number of firms is significantly correlated with higher cement prices in a country. We show that this relationship is robust to different functional forms, a range of measures for competition, an extensive list of controls for input prices and controlling for whether a country imports cement or limestone. Under very mild assumptions, we show that the OLS estimates of the role of market power are biased toward zero - underestimating the true impact. This is due to an intuitive force: when prices rise and costs stay constant, marginal firms enter the market. Using data on the precise location of plants we define markets locally within countries, opening or shutting down trade across borders in the empirical model, and find that our results are consistent across varying market definitions.

We also examine two alternative explanations for high prices: first, it could be that demand in certain countries is low and firms operate below minimum efficient scale. Second, firms might charge high markups to cover fixed costs of production. To address the concern that plants are operating below minimum efficient scale, we examine data on each plant's capacity. We show that the distribution of plant capacities is similar across regions, and that there is no evidence that countries with a large demand have plants of much larger scale. This is consistent with the fact that transporting cement across space is costly, therefore bounding plant size from above. To examine the role of fixed costs, we use financial accounts data from Worldscope of all firms active in the cement industry. Accounting measures of pure profits similar to Gutiérrez and Philippon (2016) suggest substantial profits after paying for fixed costs.[3] This result is robust to using four different measures of the user cost of capital

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[3]Markups estimated using production function approaches following De Loecker, Eeckhout, and Unger

and suggests that high prices are not driven by firms operating below efficient scale.

We then formulate a simple neoclassical model of capital accumulation which distinguishes between investment and consumption goods, and allows for a production network. The data required to parameterise the model are fairly stringent as we need data on both sector-specific markups as well as input-output linkages in the economies. We use Brazil, Indonesia, India and the United States, for which we have these pieces of information, as case studies representing a range of concentration levels in the cement industry from concentrated (Indonesia) to highly competitive (India). We use data from Worldscope and follow Gutiérrez and Philippon (2016) to estimate sector-specific markups and use the World Input-Output Database to characterize the production network.

Recognizing consumption and investment goods as distinct, produced in different sectors, is the key to understanding the construction sector's importance for capital accumulation. This distinction was first made by Uzawa (1963). The standard model assumes investment and consumption are generated by the same production structure and thus are perfectly substitutable. We instead consider an environment in which consumption and investment are produced for their specific purpose. This assumption appeals to intuition, as industrial machines cannot be put on the shelves of retail stores to be used as consumption.

Allowing for distinct production of investment means that the steady-state level of capital depends only upon the sectors which produce capital, and is independent of the consumption sector's productivity. This implies that the long-run cost of markups will not equal their immediate cost in terms of output. Over time, the changes in investment efficiency will reduce investment and the capital stock, thereby reducing the productive capacity of an economy. In this way, distortions in investment-producing sectors act like a tax on capital, reducing rates of return, investment and ultimately steady-state output. Edmond, Midrigan, and Xu (2019) find that markups act like a uniform output tax in a one-sector model. We add to their work by showing that distortions in investment production play a unique role in determining steady-state output.

Our model also allows for arbitrary intermediate goods sectors, thereby mapping a static production network block into a dynamic neoclassical investment block. 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). This implies that the dynamics of the investment rate, and markups' role in determining it play an important role in allocating resources in this economy. Our network model is also an application of Lehn and Winberry (forthcoming) who analyse the role of investment on real business cycles and labour supply. Our analysis applies their framework to the context of investment and long-run income differences.

(2020) suggest even larger pure profits.

The main addition of our framework to the static network literature is that the investment rate is decreasing in the profit rate in the economy. This implies that goods used for investment are under-produced. Liu (2019) demonstrates that in a static network, upstream (intermediate goods supplying) sectors are smaller than their optimal size. This represents potential efficiency gains by stimulating production in these sectors. The intuition for the dynamic setting is identical. Investment goods are used for future production. Therefore, investment-producing sectors are input suppliers for future output, or in other words, are upstream to the future. This implies that in an economy with distortions, investment goods are under-produced and the investment rate is lower. We find that in the USA cement expenditure as a share of GDP is around 25% smaller than what it would be in an efficient economy. This gap is even larger for Brazil, Indonesia and India, the developing countries we consider. This gap between observed and efficient size is the largest amongst all 55 sectors we consider in Indonesia and India, and second largest in Brazil.

Embedding our oligopoly model into the network of production, we analyse the impacts of (i) entry subsidies and (ii) anti-trust policy, specifically, breaking up of multi-plant firms, on steady-state output. We find that the potential benefits of entry subsidies, though positive, are far smaller than those from anti-trust. Breaking up multi-plant firms is beneficial in terms of increased competition and production. Its downside is that it reduces scale economies. The impact of entry subsidies turns negative rather quickly as more firms enter the market due to large entry costs implied by the data. On the other hand, breaking up of the maximum number of feasible firms entails substantial benefits. For example, in Indonesia, the benefits of breaking up firms amounts to a 0.05% increase in steady-state output, which corresponds to over 7% of expenditure in cement. These effects are increasing in the size of the cement sector and its concentration. Simulations using Tanzania's input-output structure and a 10% uniform markup show that effects are non-linear and range from 0.025 to about 1% of steady-state output for different levels of observed market concentration. This suggests such policies can be particularly beneficial in developing countries in which markets are highly concentrated. Further, the effects are going to be larger, the larger cement's expenditure share. In our set-up we treat entry barriers as outside the reach of policy. It should be noted that if countries could simply remove entry barriers (instead of providing a costly subsidy, for example), the positive effects would be even larger.

Finally, a key mechanism in our model is that cement prices pass through to the price of construction goods. Using micro-data from the 2005 ICP on construction components and digitizing data on costs per square meter across cities and countries we present evidence suggesting that there is significant pass-through of cement prices to building costs with an elasticity between 0.4 and one.

Our paper is at the intersection of several literatures: macro, development and industrial organization. It relates to the literature on the cost of capital (Caselli and Feyrer, 2007;

Caunedo and Keller, 2021; Collier, Kirchberger, and Söderbom, 2016; Hsieh and Klenow, 2007; Jones, 1994; Restuccia and Urrutia, 2001), input-output linkages in production networks (Baqaee and Farhi, 2019; Kremer, 1993; Jones, 2011; Demir, Fieler, Xu, and Yang, 2021; Grassi, 2018; Carvalho, 2014; Carvalho, Nirei, Saito, and Tahbaz-Salehi, 2020; Liu, 2019), the role of firm-level markups in general equilibrium (Gutiérrez and Philippon, 2016; De Loecker et al., 2020; Edmond et al., 2019; Mongey, 2019), and misallocation in developing countries (Boehm and Oberfield, 2020; Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008; Schmitz Jr, 2001; Bartelsman, Haltiwanger, and Scarpetta, 2013; Peters, 2020; Buera, Kaboski, and Shin, 2011). Our key contribution is to bring new micro-data to investigate distortions in a specific sector that is crucial in the production of investment.

Cement and ready-mix concrete have been the subject of a large body of literature, including Collard-Wexler (2013), Syverson (2008), Syverson (2004), Hortaçsu and Syverson (2007), Miller and Osborne (2014), Salvo (2010) and Ryan (2012). 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, Macchiavello, and Reed (2021) estimate a similar model to the one we outline in Section 3, also using data from the International Comparison Project and cement firms. The focus of their paper is on estimating the full industry equilibrium model using a GMM approach while paying particular attention to the widespread decline in prices between 2011 and 2017. Instead of considering the growth impacts of market power, they carry out two counterfactual exercises intended to assess the impacts on cement prices of road density and rule of law. We take a different approach by using the oligopoly model to establish the existence of market power, and then examining firms' financial accounts data and plant size distributions to investigate the sources of markups and the role of minimum efficient scale. Further, we embed our oligopoly model into a general equilibrium model with a production network to study the equilibrium effects of distortions in the investment sector on capital accumulation. Finally, we relate to a scarce literature on the role of competition in developing countries (Atkin and Donaldson, 2015; De Loecker, Goldberg, Khandelwal, and Pavcnik, 2016; Bergquist and Dinerstein, 2020; Besley, Fontana, and Limodio, forthcoming). 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.

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 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 policy evaluations. Section 6 discusses pass-through of cement to

building costs. Section 7 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 Project (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.[4]

An attractive feature of the price 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 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. 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.[5]

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,

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

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

aggregate and sand), softwood, bricks, mild steel reinforcement and structural steel.[6] The highest coverage of countries is for cement and aggregate prices while prices for structural steel are available for at least 65 countries.

We start by showing a large dispersion in the price of key inputs in Table 1. Panels A and B show the price of concrete, cement, aggregate and sand for 2011 and 2017. In 2011, concrete prices are lowest in East Asia and the Pacific where a cubic meter of concrete costs $US83, compared to $US202 in Sub-Saharan Africa. The price of concrete in Africa is 1.4 times the price in North America where a ton of concrete costs on average US$148. The next three columns show that cement is the ingredient of concrete that is relatively more expensive in Sub-Saharan Africa; cement costs on average 40 percent more than in the US, and about twice the price it costs in East Asia and the Pacific and in South Asia. This is 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. Aggregate is more expensive in Sub-Saharan Africa than in Asia but slightly cheaper than in North America. Sand is relatively cheap in Sub-Saharan Africa with $21 per cubic metre compared to slightly below $US20 in Asia. The pairwise correlation between concrete, cement, sand and aggregate also shows that the highest correlation in prices is between concrete and cement with a correlation coefficient of 0.72 and a p-value of 0.000. The data for 2017 shows that cement prices for all countries but those in Latin America and the Caribbean have come down considerably between 2011 and 2017. However, price differences persist: a ton of cement in Sub-Saharan Africa still costs 32 percent more than a ton of cement in the US.

Table B.1 in the Appendix shows the differences in PPP terms benchmarked to the United States ($US =1). Unsurprisingly, taking into account the local price level makes price differences even starker.[7] In PPP terms, concrete cost 3.2 times the price in Sub-Saharan Africa that it costs in the United States in 2011; this factor is only reduced to 2 in 2017; however, cement is 3.3 times as expensive in Sub-Saharan Africa than it is in North America in 2011 and this barely reduces to 3.2 in 2017. The differences we show in Table 1 can therefore be viewed as conservative measures of the differences.

Panels C and D of Table 1 show the prices of softwood, bricks, mild steel reinforcement and structural steel. Coverage of countries is somewhat lower for these inputs (between 63 countries for structural steel and 78-89 countries for mild steel reinforcement). Panel C shows that for softwood, price differences are much smaller between East Asia and the Pacific, Europe and Central Asia and Sub-Saharan Africa. Softwood prices are highest in South Asia in 2011. They increase in all regions but most in North America. Bricks are by

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

[7]Table B.2 shows that the results are very similar when we use the construction sector PPP instead.

Table 1: Prices of key construction sector inputs in 2011 and 2017, US$

	concrete (m^3)	cement (ton)	aggregate (m^3)	sand (m^3)
Panel A: ICP 2011				
East Asia and Pacific	83.0	114.6	22.3	18.2
Europe and Central Asia	109.4	174.3	25.9	22.6
Latin America and Caribbean	158.2	196.1	26.2	22.3
Middle East and North Africa	90.0	107.4	14.7	14.6
North America	148.1	189.4	51.6	49.0
South Asia	100.5	129.6	22.3	18.8
Sub-Saharan Africa	201.9	258.2	41.1	20.5
Panel B: ICP 2017				
East Asia and Pacific	66.8	93.4	20.3	15.1
Europe and Central Asia	99.7	162.2	34.4	29.0
Latin America and Caribbean	145.4	199.0	29.2	22.4
Middle East and North Africa	85.6	102.8	19.4	17.6
North America	148.3	127.3	23.0	17.3
South Asia	116.6	117.9	36.9	19.4
Sub-Saharan Africa	121.5	167.4	30.8	23.9

	softwood (m^3)	bricks (m^3)	mild steel (ton)	struc. steel (ton)
Panel C: ICP 2011				
East Asia and Pacific	426.8	92.2	894.5	1648.9
Europe and Central Asia	421.1	282.0	1077.0	1627.2
Latin America and Caribbean		101.3	1411.6	1524.5
Middle East and North Africa	365.2	130.1	878.5	1003.9
North America	139.9	425.7	1077.6	1355.4
South Asia	524.0	65.1	900.1	
Sub-Saharan Africa	366.4	214.9	1422.0	1650.4
Panel D: ICP 2017				
East Asia and Pacific	475.9	74.0	618.0	793.9
Europe and Central Asia	562.2	331.3	807.0	1206.3
Latin America and Caribbean	591.7	137.2	1133.6	1334.1
Middle East and North Africa	399.8	91.4	799.1	1043.6
North America	1394.3	466.1	1125.1	1167.5
South Asia	732.6	81.8	778.0	883.0
Sub-Saharan Africa	563.6	142.0	1169.8	3346.9

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

far most expensive in North America, followed by Europe and Central Asia.

Turning to steel, we find that a ton of mild steel reinforcing bars is most expensive in Latin America and the Caribbean and Sub-Saharan Africa; in 2017, prices have come down to the level of North America. On the other hand, in 2011, structural steel beam prices were similar for East Asia and Pacific, Europe and Central Asia, and Sub-Saharan Africa. However, in 2017, prices in Sub-Saharan Africa were about 3 times the price observed in North America. In PPP terms, softwood is most expensive in South Asia by a large margin, and bricks, mild steel reinforcing bars, and structural steel beams are most expensive in Sub-Saharan Africa. In 2017, the largest remaining price differences are in mild steel reinforcement which is more than double the price in South Asia and Sub-Saharan Africa and in sand which is considerably more expensive in Sub-Saharan Africa.

Such stark differences are not seen in the aggregate construction sector PPP prices, possibly, since 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 indices.

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 1 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 the price in the United States. Nine out of the ten countries listed are located in Sub-Saharan Africa. 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 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

$$\ln p = \ln \mu + \ln c$$

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-

Figure 1: Ordinary Portland cement in the US and the 10 most expensive countries in 2011
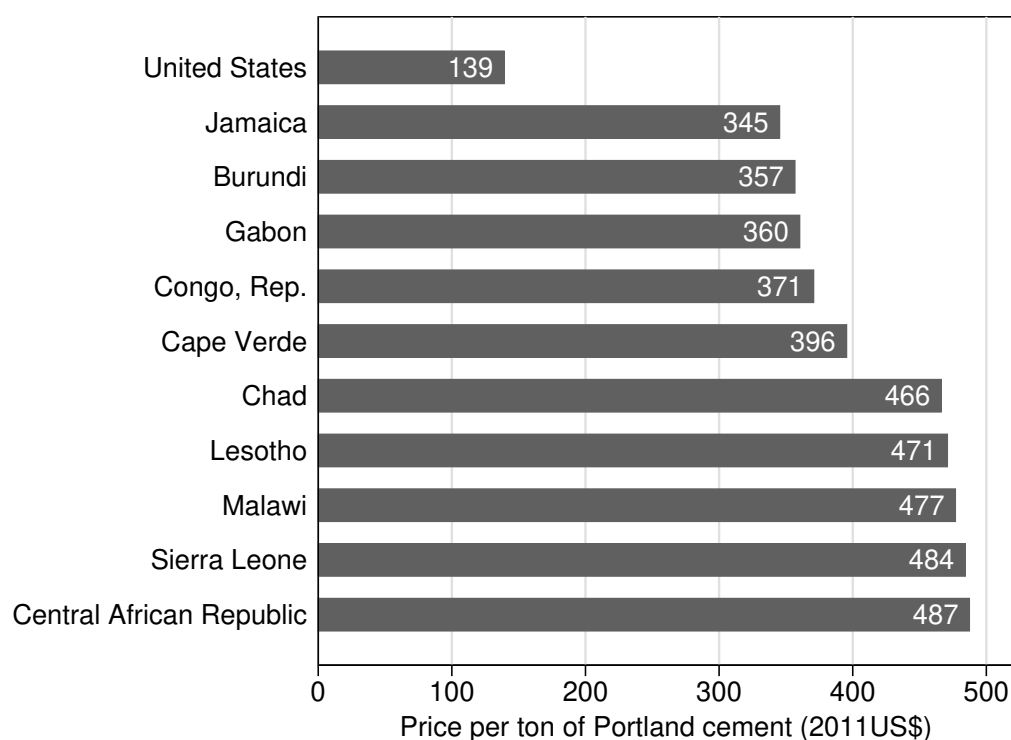
Note: This figure shows the average cost of a ton of Portland cement in the 10 most expensive countries compared to the United States in 2011.

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 evidence that market structure is a key correlate of price differences. We then turn to isolating the impact of $\ln\mu$ from that of $\ln c$, by controlling for the cost of input prices, scale and the institutional environment. We also examine profit margins of cement firms and the role of minimum efficient scale of individual plants.

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.[8] The data is based on surveys and correspondence

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[8]We do not distinguish between grinding and integrated plants for the main purpose of this paper as they both produce the final product cement. We nevertheless show differences by work types when examining the role of scale economies.

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 percent of countries have a firm that provides more than 50 percent 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 1 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 five percent of total consumption. This might not the case from the perspective of an individual country. When we examine the role of market structure on prices we present robustness checks where we account for cement and limestone imports.

To systematically investigate the bivariate correlation between the number of plants and the cement price in the whole sample, we divide the number of plants per country into deciles. Each decile contains between 8 and 15 country observations. We then run a kernel-weighted local polynomial regression of the price of cement on plant deciles. We also compute the Herfindahl-Hirschman index $H = \sum_{i=1}^{N} s_i^2$ where s is proxied using data on the capacity of firms. The upper graph in Figure 2 shows the negative relationship between the price of cement and the deciles of 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 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 gross fixed capital formation and cement's role in construction expenditures. To do this we use data from both rounds of the ICP and define the construction sector's share as its fraction of expenditure on gross fixed capital. Figure 3a shows that the share of construction in investment (gross fixed capital formation) is very stable around 0.5 in both years, in line with earlier results by Burstein, Neves, and Rebelo (2004) who

Figure 2: Market structure and cement prices, all countries
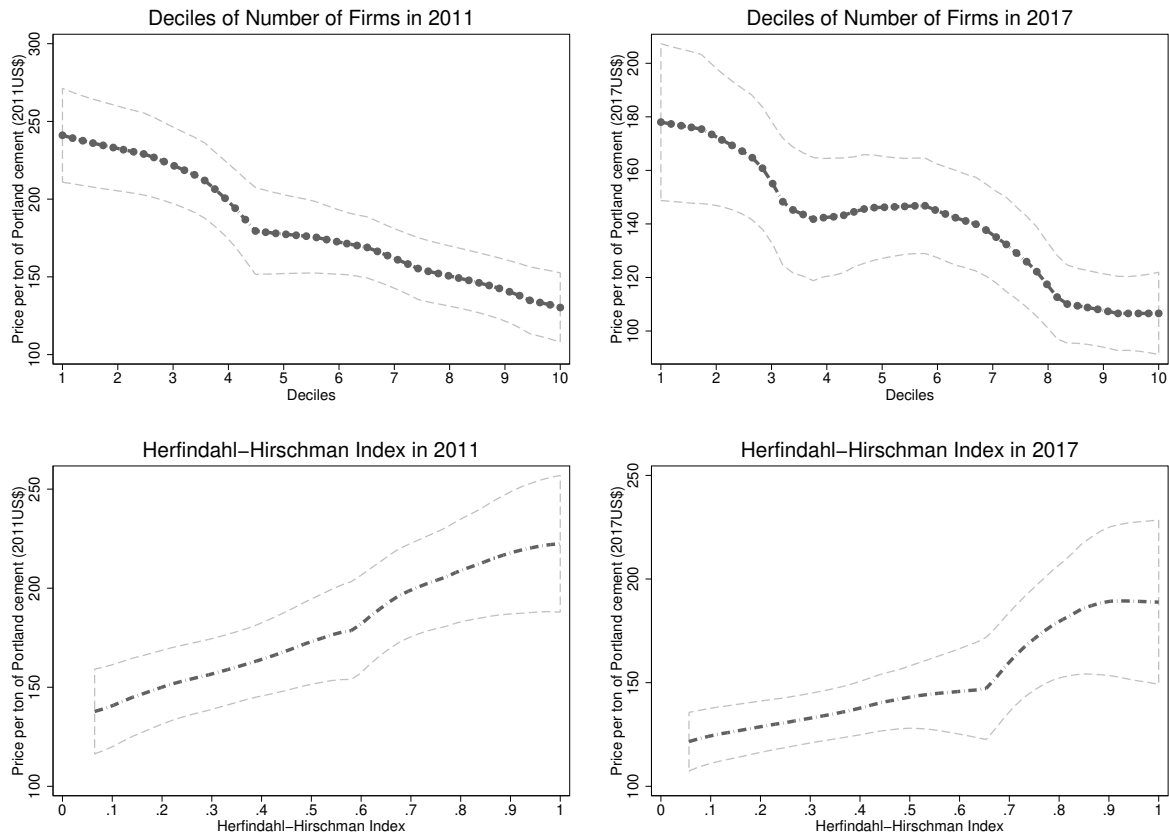
Note: The top figure shows a local polynomial regression of the price of cement on the deciles of the number of firms per country. The bottom figure shows a local polynomial regression of the price of cement on the Herfindahl-Hirschman index. All figures plot a 95 percent confidence interval.

also find a share of roughly one half.

Next we examine the role cement plays in construction sector expenditures using data on cement consumption for each country from Cemnet. We compute the share of expenditures on cement as a fraction of construction expenditures, using the ICP prices on cement and data on construction sector expenditures and total investment expenditures. As before, a main limitation is that we only have one price per country and therefore are implicitly assuming that it applies universally across space within the country. Second, the consumption data are derived using data on production, imports and exports and are thereby subject to measurement error in these components.[9] However, we argue that the figures are still providing useful aggregate information about cement's share in construction across countries and the relationship between the share and prices.

Figure 3 highlights two facts: first, cement accounts for a non-negligible share of construction sector expenditures with median expenditures of eight percent. Second, there is large variation, such that the 75th percentile of countries spends more than 17 percent of con-
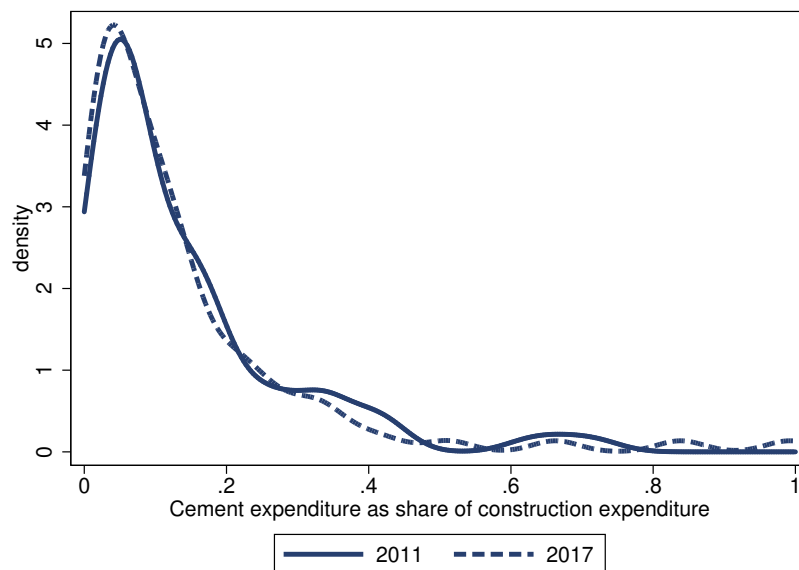
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[9]We exclude data from Liberia and Comoros for which cement's share of construction sector expenditures exceeds one.

Figure 3: Construction and cement expenditure shares

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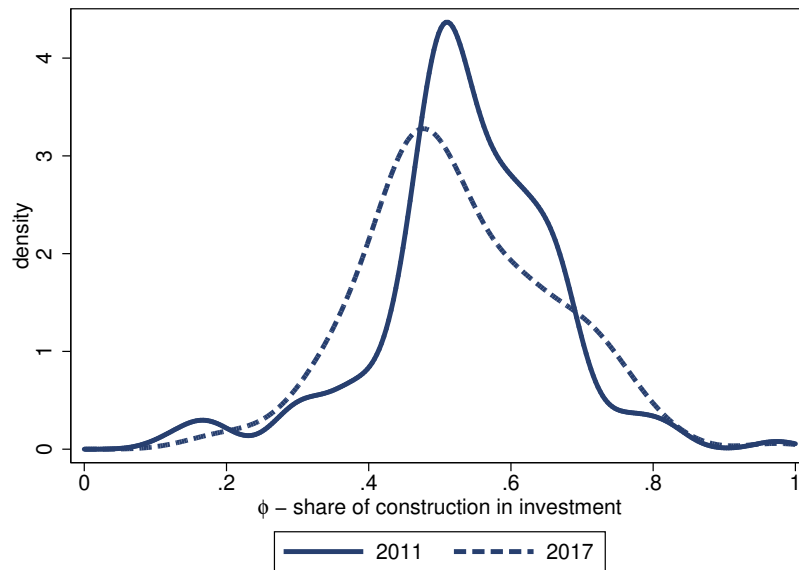
(b) Cement share of construction expenditures

Note: The top figure shows the distribution of construction as a share of investment expenditures. The bottom figure shows the distribution of cement's share of construction expenditures.

struction sector expenditures on cement. Figure 4 plots cement's expenditure share, against cement prices and also the log of GDP per capita, with Sub-Saharan African countries in red. It is clear from the figures that expenditure shares tend to be much larger for Sub-Saharan African countries. The top figures show a clear negative correlation between cement expenditure shares and GDP per capita, suggesting that the industry is of higher importance for developing countries, precisely the countries with low levels of capital stock. The bottom figures shows a clear positive relationship between the price of cement and its expenditure

Figure 4: Cement's share of construction expenditures
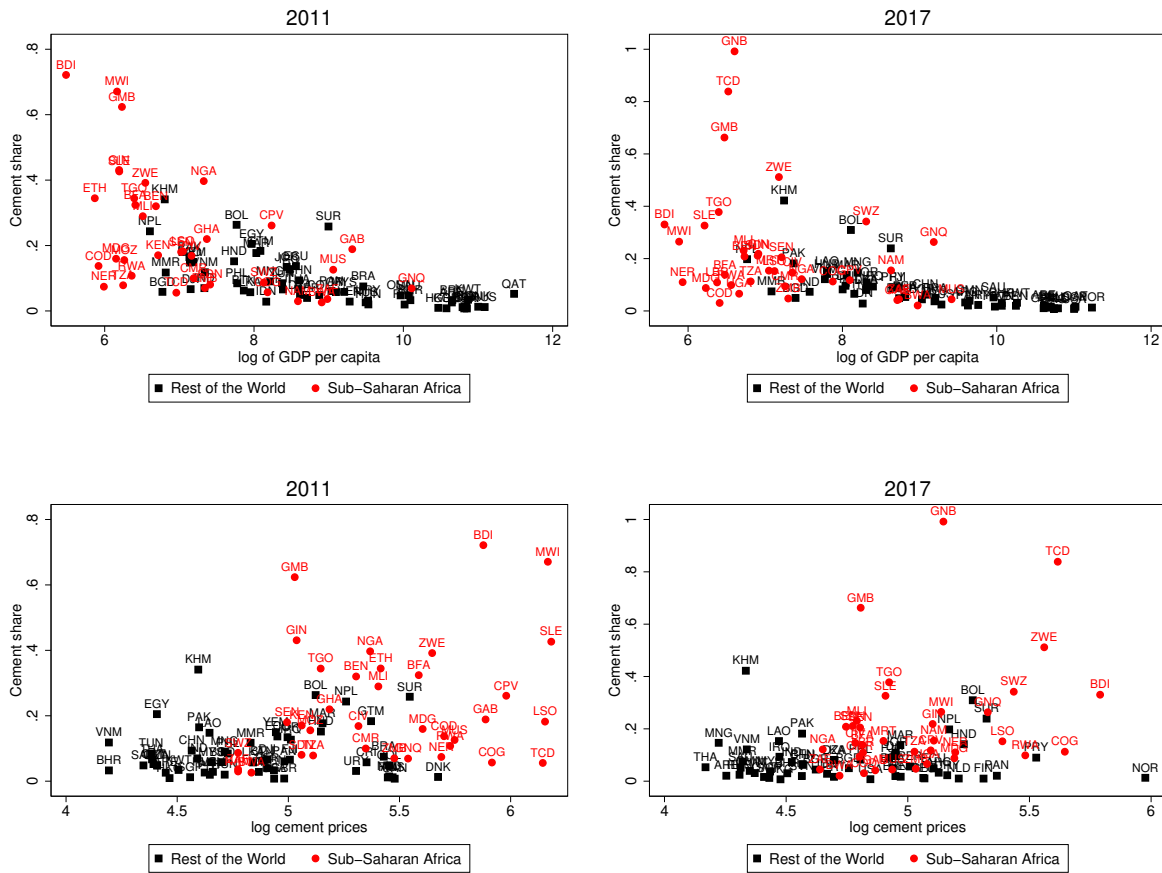
Note: The top figures show cement's share of construction expenditures and log of GDP per capita. The bottom figures show cement's share of construction expenditures and log of cement prices.

share, which is particularly striking for Sub-Saharan African countries. This is indicative of the essential nature of cement in construction, and its low elasticity of substitution. The figures thereby highlight that high prices and expenditure shares of cement are primarily, though not exclusively, an African phenomenon. While cement constitutes a negligible sector for developed countries, this is not the case for developing countries, where the industry can make up a large share of construction expenditure.

From Figure 4 alone we cannot infer the source of cement's high expenditure share in some countries. While it is tempting to conjecture that the high share is indicative of a bottleneck, it may equally be the case that cement is intensively used at earlier stages of development. As countries develop, urbanization processes and industrialisation could plausibly drive high expenditures in infrastructure and other cement-intensive structures. Regardless of their source, high expenditure shares indicate that cement is an important sector in the economy. When cement makes up a high share of construction sector expenditure, the first order impact of distortions is large. We turn to identifying such distortions in the next section.

17

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

3. The role of market power

In order to quantify the impact of market structure on cement prices, we specify a simple quantitative model of oligopoly. The goal of the model is four-fold: first, to gain an expression for markups and thus prices in the cement industry that we can take directly to the data; second, to examine the potential sources of bias in this OLS estimation. We use the model to show that the bias can reasonably be assumed to be towards zero, meaning our results are conservative estimates of the true effects. Third, the model informs our instrumental variables strategy. We show that our instrumental variable needs to be correlated with the decision to enter the market, but cannot be correlated with production costs after entry. Fourth, we use the model in the policy simulations in Section 5.

We examine the role of market structure in generating cross-country price dispersion within a simple static model, compatible with our general equilibrium framework. Our model analyses strategic production decisions while allowing for free entry with an exogenous entry cost, similar to Bekkers and Francois (2013) which is in turn similar to Melitz (2003), with a finite number of firms entering the market. An alternative model for the cement market is one in which firms form cartels. While this is the case in a number of countries, it is questionable that this applies to the majority of our countries. Further, detailed information as used in Röller and Steen (2006), for example, is not available at a global level. If firms collude even as the number of firms increases, our estimates represent lower bounds on the effects of competition.

Though the model is simple, it is also quite general, resting on two key assumptions. First, we recognise that cement is a homogeneous good and assume firms compete in standard Cournot competition, taking wider construction sector expenditure as given. Our second assumption is that demand for cement as whole has a constant elasticity of substitution, implying that it enters into the construction sector production function in a nested CES form. This assumption is not necessary to derive a firm's profit maximising behaviour, but is instead needed to allow for cross-country comparisons of market power.

For simplicity we assume that firms face constant marginal costs, though we allow for increasing returns to scale through entry costs. A fixed cost of producing in each period could be added without altering our results. We derive a log linear relationship of the marginal response of price to input costs using Shepard's Lemma. This relation becomes exact when

the cement production function has a Cobb-Douglas form. Firm-specific productivity is allowed to take any distribution over positive values.

The structure of demand also implies that spatial differences in firms are abstracted from. Syverson (2004) analyses the implications of such spatial differences in the context of ready-mix concrete, a good closely related to cement. We abstract from such spatial differences to isolate the impact of market-level competition and also model a single market price to match the available data. Transport costs can be incorporated in a slightly ad hoc manner, by assuming they are equally shared across all production by given firms, allowing for a single market price. In such an environment each firm's location would impact its firm-specific transport cost, which would be captured by its constant marginal cost.

Formally, cement firms i maximise profits in Cournot competition subject to constant marginal costs

$$\pi_i = q_i\big(p(q_i + q_{-i}) - c_i\big) \tag{1}$$

where π_i, q_i and c_i are profits, production and marginal cost for firm i, while $p(q_i + q_{-i})$ denotes the market price of cement p as a function of production by firm i, and all other firms q_{-i}.[10] Maximisation of profits given costs in each period yields the expenditure share of each firm

$$\theta_i = \frac{q_i}{Q} = \varepsilon\left(\frac{p - c_i}{p}\right) \tag{2}$$

where $\varepsilon = -\frac{d \ln Q}{d \ln p}$ is the price elasticity of demand. Summing across all n firms in the market, and defining $\bar{c} = \sum_{i=1}^{n} \frac{c_i}{n}$ as average costs, we can express log prices as a linear combination of markups and average costs

$$\ln p = \ln\left(\frac{n\varepsilon}{n\varepsilon - 1}\right) + \ln \bar{c} = \ln \mu(n) + \ln \bar{c} \tag{3}$$

where n is the number of firms in the market and ε is the elasticity of demand, or equivalently the elasticity of substitution between construction sector inputs.[11] Here we assume that $\varepsilon n > 1$ for simplicity. In Appendix C, we show that when $\varepsilon < 1$ and $n = 1$, the monopolist will engage in limit pricing.

Firms have identical production technologies using inputs x_k at price r_k but differ in their a Hicks-neutral productivities $A_i = e^{z_i + \nu}$, where z_i is the idiosyncratic portion of productivity and ν is constant within countries. We can take a first order approximation of equation (3) around some benchmark level of input prices and number of firms $\{n^*, r_1^*, ..., r_K^*\}$ in order

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[10]c includes any types of costs, including raw materials, rental of equipment, labor and transport costs.

[11]This is because firms take wider construction sector expenditure as given, so they only consider the substitution effect of price changes on demand.

to obtain a linear equation to be estimated such that

$$\ln p_j = \alpha + \gamma \ln n_j + \sum_{k=1}^{K} \beta_k \ln r_{kj} + \eta_j + \epsilon_j \tag{4}$$

for country j where n is the number of cement firms, $\eta = \mathbb{E}\big[\ln\big(\sum \frac{e^{z_i}}{n}\big)\big]$ is the unobserved component of average productivity and $\epsilon_j = \ln\big(\sum \frac{e^{z_i}}{n}\big) - \eta$ is the mean zero error. The linearisation of costs with respect to input prices appeals directly to Shepard's Lemma, meaning the coefficients β_k can be interpreted as expenditure shares. When the production technology is Cobb-Douglas, the approximation with respect to input prices is exact.

Berry, Gaynor, and Scott Morton (2019) discuss potential concerns with single-equation estimation of market power, echoed elsewhere in the empirical IO literature, including pooling across industries, product heterogeneity and attributing products to firms. Some concerns, such as pooling across different industries do not apply to studies of a single industry like ours. In fact, Berry et al. (2019) call for more industry-level studies. Other concerns, such as not observing economic markets and product heterogeneity are limited when studying a precisely defined product such as Portland cement where both the product as well as producers are well defined and identifiable. It is also worth pointing out that, while clearly there is entry and exit in the cement industry, cement markets are likely to move more slowly than other markets where opening and closing of branches occurs at much faster pace and lower costs. We explicitly recognise and address other issues they point toward. First, as they suggest, we start by providing a detailed descriptive analysis of the data. Second, we study the direction of the bias of the OLS equation theoretically and show that the nature of the bias is working against us finding an effect. Third, we motivate a plausibly valid IV from the model as a robustness check, and present a large set of further robustness tests employing restrictive sets of controls. Finally, we complement our estimates by investigating the possible sources of these markups directly using firm's financial accounts data and data on plant size distributions.

The alternative approach suggested by Berry et al. (2019) is to estimate the full demand system using cost shifters. For example, Ryan (2012) uses energy costs (natural gas, coal and electricity prices) along with skilled labor wages as instruments in estimating demand elasticities. This approach is problematic for our purposes: for instance, fuel, as defined by the ICP, is part of the construction sector basket, thus, by definition, either a substitute or complement to cement. Further, fuel is used to power virtually all machinery used on construction sites. This implies that while fuel prices are a supply shock outside the model, they also constitute part of the demand shock in our model and therefore do not satisfy the exclusion restriction. As our paper aims to understand cement's role in the network of production, rather than as a single industry, this is an important consideration.
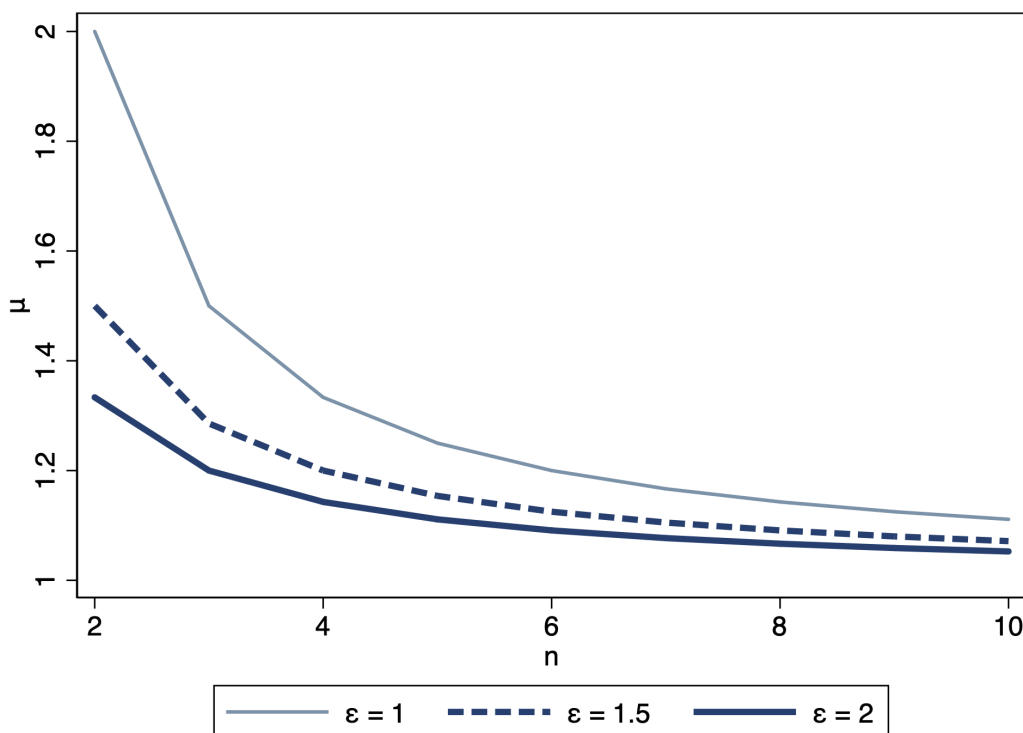
3.1. Non-linearities in $\mu(n)$

It is important to understand how non-linearities in $\mu(n)$ impact how the number of firms affect markups and the interpretation of our estimates. Markups $\mu(n)$ are a decreasing function in n ($\mu'(n) < 0$), and the effect of the number of firms in reducing markups falls as more firms enter the market ($\mu''(n) > 0$). The effect of entry on the market markup is therefore highly non-linear. To see this, note that markups over average cost can be represented as a distortion or tax τ on prices of the form

$$\tau = \frac{1}{\varepsilon n}$$

where ε is the elasticity of substitution and n is the number of firms as before. This is clearly a decreasing function of n and ε. This represents the fact that market power is determined by within market competition through the number of firms, and competition from other goods through the elasticity of substitution. Moreover, we can see that the higher the level of market power (measured by distortions), the more sensitive it is to entry of firms. Figure 5 plots the markup and the number of firms in the market for several values of ε.

Figure 5: Average markups and the number of firms

Note: This figure illustrates the non-linear effect of markups as the number of firms increases for different elasticities.

In order to estimate (4), we approximate markups $\mu(n) = \left(1 - \varepsilon n^{-1}\right)^{-1}$ as a linear function. We estimate two specifications for markups. First we express markups as a linear approxi-

mation using the log number of firms and also use the inverse number of firms. Formally, these first order approximations take the form

$$\ln\mu(n) \approx \mu(n^*) - \frac{1}{n^*\varepsilon - 1}\left(\ln n - \ln n^*\right)$$
$$\ln\mu(n) \approx \mu(n^*) + \frac{\mu(n^*)^2}{\varepsilon}\left(n^{-1} - n^{*-1}\right)$$

around some benchmark number of firms n^*. Note that the second equation implies that when $\mu(n^*) \approx 1$, which occurs when n is large, we have that $\ln\mu = 1 + (n\varepsilon)^{-1}$. In this case the coefficient on the inverse number of firms can be interpreted as the inverse of cement's elasticity of substitution. However, we can see that the interpretation of our coefficient estimates depends on the level of competition around which we approximate n^*. Given the dispersion in competition we observe across countries, it is not possible to pick a single value of n^* that is valid for all countries. Therefore, it is not feasible to recover estimates of the elasticity of substitution from our data. Still, the model shows that there is an inverse relationship between the magnitude of either coefficient estimate and ε. Our estimates should be interpreted as measuring the effect of market power on prices, which is higher the lower ε is.

3.2. Free Entry, unobserved productivity η and bias

The unobserved portion of costs η is the log harmonic average of firm-level productivity in the market. In order to understand the potential sources of bias from this unobserved parameter, we model entry as done by Bekkers and Francois (2013).

The entry process is as follows: we assume the market is in steady state, so future expected profits are constant for a given level of competition, and firms have discount factor $1 - \delta < 1$. There is an infinite pool of potential firms who can pay a fixed cost to enter the market. A number n^e enter the market and learn their idiosyncratic cost level z_i upon entry. Firms then choose whether or not to produce based on this costs level, with n firms producing in the market. Specifically, they produce whenever $p > c_i$. Let n^* be the number of firms in the market such that the expected future value of entry (before learning marginal cost) is equal to the discounted entry cost $E = \mathbb{E}\left[\sum_{t=0}^{\infty}(1 - \delta)^t \pi(n^*)\right]$. This can be simply expressed as

$$\mathbb{E}[\pi(n^*)] = \delta E = \pi^*. \tag{5}$$

Firms will enter the market as long as the discounted value of expected profits (after they enter) is greater than the fixed costs of entry. Therefore, the number of firms in the market will be the number such that profits exceed entry cost $\pi(n^e) > \delta E$, but entry of another firm

is not profitable $\pi(n^e + 1) < \delta E$. This number is given by

$$n^e = \max_{n \in Z}\{n \mid n < n^*\}. \qquad (6)$$

Finally, the n^e firms draw their cost and decide whether to produce or not. Let x_i be a random variable equal to one if $p > c_i$, with probability $G(p)$ and zero otherwise. This implies

$$n = \sum_{i=1}^{n^e} x_i = \bar{X} n^e \qquad (7)$$

where $\bar{X} = \sum_{i=1}^{n^e} \frac{x_i}{n^e}$ is the proportion of firms that produce. It is straightforward to see that this variable has expectation $\mathbb{E}[n] = G(p)n^e$, where G is the CDF of firm level costs. Equations (5), (6) and (7) determine the number of firms in the system, along with the equilibrium market production and profit levels from the previous section. We now turn to analysing bias due to unobserved costs η in this framework of entry. We prove the following result in Appendix D:

Proposition 1 *Assuming x_i is observed with certainty, OLS estimates of the parameter γ from equation (4) exhibit bias toward zero, that is,*

$$\left| \mathbb{E}\big[\hat{\gamma}_{OLS}\big] \right| \geq \left| \gamma \right|.$$

This result can be intuitively interpreted in the context of our model of entry. Imagine a random shock occurs to unobserved costs. This raises price p through lower productivity levels for firms who are already producing in the market. This higher price will raise the expected profits of firms who have yet to enter, as their costs are drawn independently of the firms already in the market. A sufficiently large price change will incentivise the entry of additional firms into the market by increasing n^e. Moreover, a given firm in the market will be more likely to produce as the price is now higher. This can be seen as a simple supply curve: higher prices will cause entry. This means our OLS estimates of market power are conservative estimates of the true effect.

Our results rely on input costs x being observed. Unobserved input costs may be a source of bias, as they can simultaneously drive up prices and reduce profits by reducing demand. As a robustness check, we control for a large basket of potential costs, including fuel, electricity and coal. Moreover, the empirical evidence suggests that demand for cement is not particularly sensitive to prices. Therefore, demand and profits would not be expected to respond much to such costs, allaying concerns of bias. One further concern is a positive covariance between production and entry costs. For example, political instability in a country deters

firms from entering but also means that the cost of inputs are high due to high expenses on security costs leading to high prices of cement. We control for political instability, rule of law and corruption using data from the World Governance Indicators to mitigate this kind of bias.

We use an instrumental variables specification to isolate the effects of market power and competition on cement prices. According to our model, the instrument needs to capture entry costs. The exclusion restriction can be reduced to $COV(E, \eta) = 0$, which means that our instrument is unrelated to unobserved cost. It is important that our instrument captures the cost of entering the market, rather than the fixed costs associated with production. Instruments for fixed costs of production F would not satisfy the exclusion restriction, as higher fixed costs cause lower productivity firms to exit the market, driving down η. We examine this case in detail in the following section.

3.3. Increasing returns to scale and fixed costs

The production of cement generally takes place in larger plants, which raises the concern that fixed costs and increasing returns to scale may be driving high prices, rather than markups. To study the implications of increasing returns, we consider the case in which firms must pay a fixed cost F in each period in order to produce. Note that these costs are distinct from the cost of entry E, which is paid only upon initial entry into the market. Profits for each firm are now given by

$$\pi_i = q_i(p - c_i) - F$$

and firms therefore produce whenever

$$c_i < p - \frac{F}{q_i}$$

while the static pricing decision of firms in the market remains unchanged. Therefore equation (4) still applies, with the caveat that unobserved productivity η is now correlated with F.

Fixed costs lead to two sources of selection: first, fixed costs increase the threshold productivity level of firms who produce after entering the market, therefore increasing η for a given level of n^e. Formally, for a given number of firms who enter the market n^e, we have that average productivity is given by

$$\eta = \mathbb{E}\left[\ln\left(\sum \frac{e^{z_i}}{n} \right) \middle| z_i > x\beta - \ln\left(p - \frac{F}{q_i} \right) \right]$$

where $x\beta$ is the log of input costs. This implies that higher values of F censor the distribu-

tion of productivity z_i at a higher value, raising the threshold value of productivity above which firms enter the market. This in turn raises the average productivity of firms who produce, essentially because some high cost firms can no longer produce profitably. Second, by reducing expected profits, fixed costs decrease the number of firms n^e who enter the market and obtain a cost draw. This may create a countervailing force reducing η, as less firms drawing from the same distribution could reduce the likelihood of any firms having a low productivity draw, thus decreasing the censored productivity η.

The above arguments make it clear that period fixed costs, like entry costs, are what generates the kind of oligopoly structure we are studying. As highlighted by De Loecker et al. (2020), the questions of whether there are large markups due to market power in cement, and whether such markups are associated with excess profits are distinct. Market power and markups may be due to inefficient entry barriers, fixed costs or indeed natural monopolies and increasing returns to scale. For example, if period fixed costs are sufficiently high, a firm may establish a position where it is the only firm in the market and therefore exercises monopoly power. An important question is whether the oligopoly structure and thus market power is upheld by entry barriers or increasing returns to scale upon entry. We address this question empirically in Section 3.5 by investigating the scale of cement plants across space and whether markups appear to be explained by high fixed costs of cement firms.

3.4. Estimating the role of market power

This section presents our empirical specification to estimate the effects of market power on the price of cement. We start by estimating equation (4) with OLS and then show the IV results, gradually adding controls in each of these specifications. As proxies for average costs we include a set of scale controls, namely the log of population, income (wages) proxied by GDP, and transport costs proxied by area, all taken from the World Development Indicators and the ICP. To take into account the institutional environment we control for corruption, political instability and rule of law, all taken from the World Governance Indicators. Our input cost controls include the price of fuel, electricity, and average equipment prices from the ICP and UN COMTRADE. We use the cost to obtain a construction permit (as percent of warehouse value) from the Doing Business Indicators as our instrument. Our instrument needs to be correlated with the number of cement firms, but uncorrelated with unobserved determinants of marginal costs in cement production.[12] We then present a number of robustness tests using alternative specifications, different measures of market structure and a restrictive set of input cost controls. Appendix Table A.1 summarizes the different data sources. Table 2 shows our baseline estimates of (4);

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[12]The enterprise surveys conducted by the World Bank are another source for data on the business environment. Unfortunately, the overlap in coverage between the enterprise surveys and our data is too small for us to be able to use them in the analysis.

columns (1)-(3) show the OLS results for different sets of controls, and columns (4)-(6) show the IV results.

Table 2: Dependent variable: ln (Price of Cement)

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln n$	-0.25***	-0.25***	-0.17***	-0.50***	-0.51***	-0.52***
	(0.050)	(0.051)	(0.049)	(0.16)	(0.17)	(0.16)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	Yes	No	Yes	Yes
Fuel	No	No	Yes	No	No	Yes
F-Stat				11.1	9.4	9.3
N	181	181	173	181	181	173
R-sq	0.322	0.337	0.430	0.180	0.192	0.199

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

The coefficient on the log of the number of firms is significant at the 1 percent level suggesting that the lower number the number of firms, the higher the price. The OLS estimate in column (1) suggests that a doubling of the number of firms is associated with a 25 percent decrease in prices. We then add further controls for governance in column (2) and fuel prices, one of the main inputs in production, in column (3). The estimated coefficient decreases in size but remains significant at the one percent level. Column (4) shows the IV results for the basic set of controls. The F-stat is around 11, suggesting that the instrument is relevant. From our previous section we know that the effect of market power is likely to be upward biased such that the OLS would be underestimating the effect of competition on prices. Indeed, the absolute value of the IV estimate is always above the OLS estimate. A ten percent increase in the number of firms decreases cement prices by about 5 percent and the effect is stable when we add additional controls.

We now show a number of robustness checks: we start by showing that our results are not driven by the particular first order approximation we took that led to an estimating equation with the log number of firms. Table 3 shows the results using the inverse of the number of firms as the main control. Again the coefficient drops as we include further controls and is likely to be underestimating the effect of market structure on prices. The instrumental variables results are again statistically significant and illustrate a stronger effect of market power on prices than what we find in the OLS, similar to the results when we use the log number of firms as the main variable capturing market power.

We then examine whether our results are consistent with different measures for market

Table 3: Dependent variable: ln (Price of Cement)

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
$1/n$	0.61***	0.59***	0.39***	1.13***	1.13**	1.13**
	(0.13)	(0.14)	(0.13)	(0.43)	(0.47)	(0.44)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	Yes	No	Yes	Yes
Fuel	No	No	Yes	No	No	Yes
F-Stat				14.4	14.1	14.0
N	181	181	173	181	181	173
R-sq	0.308	0.319	0.422	0.225	0.233	0.267

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

power, an extensive set of controls for input prices, accounting for trade, and examining the market structure of importers. Columns (1) and (2) in Table 4 shows that our results are robust to measuring market structure by the number of firms per capita or the Herfindahl-Hirschman index based using data on firm's capacities, suggesting that one more firm per 10 million people is associated with 15 percent lower prices. Column (2) shows that the more concentrated markets are, the higher are prices, in line with the bivariate correlation shown in Figure 2.

One important determinant of cement prices is input costs. In column (3) we replicate our baseline regression from column (1) in Table 2 controlling for a more extensive set of input prices including the cost of electricity, coal and machinery. The cost of electricity is directly available in the ICP data. For the cost of coal and machinery we rely on trade data from UN COMTRADE. To obtain an average price of coal we divide the total value of imports by the quantity of imports. For machinery, we construct a similar measure using data on the product category that includes machinery for crushing, grinding, mixing or kneading earth, stone, ores or mineral substances.[13] Given that measurement error is likely to be severe in this measure, we construct averages for 2007-2010 and 2013-2016. Availability of these data reduces our sample significantly. Despite the substantial reduction in sample size our results remain consistent with our previous results.

Next, while a small fraction of global production of cement is traded, some countries in our sample import significant fractions of their cement consumption. We address trade in two main ways: first, in column (4) we control for whether countries are net importers of cement or limestone. This does not seem to affect our results. Second, we compute a trade-

[13]See the appendix for the full description and product codes.

Table 4: Dependent variable: ln (Price of Cement)

	(1)	(2)	(3)	(4)	(5)
Nr firms/10 million people	-.152*** (0.058)				
Herfindahl-Hirschman index		0.603*** (0.129)			
1/n			0.419** (0.19)	0.529** (0.212)	
1/n (trade-weighted)					0.905*** (0.225)
Time FE	Yes	Yes	Yes	Yes	Yes
Scale Controls	Yes	Yes	Yes	Yes	Yes
Input costs	No	No	Yes	No	No
Importer	No	No	No	Yes	No
Obs.	189	177	100	121	117
R^2	0.271	0.288	0.489	0.261	0.243

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

weighted measure of market structure. Each country's trade-weighted market structure is a combination of their own market structure and the market structure of the main trading partner, weighted by the proportion of cement consumption that is imported. Column (5) shows that our results are robust to the trade-weighted market structure measure. Overall the data show a strong relationship between market structure and prices which is robust to different functional forms and measures of market power, an extensive set of controls for input price and accounting for trade. The instrumental variable estimates are consistent with the expected downward bias of the effect of firms on prices.

So far we assumed that each country represents a market. This is not entirely unreasonable given how little cement is traded internationally overall. However, markets might be even more local. This has been proved to be particularly relevant for the ready-mix concrete industry given the perishability of the good (Syverson, 2008). Cement is more tradable than ready-mix concrete, but also involves high transport costs. In fact, cement is typically not transported over land for more than 200-300km which might similarly give rise to local market power (CEMBUREAU, 2020). 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 common definition used (Hortaçsu and Syverson, 2007), recognizing that part of the motivation for how markets are defined is 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 firm, we compute the number of firms within a distance of 300km, counting the firm itself, and excluding plants that are either part of the same firm, or duplicate competitor plants. We can do this assuming no trade across country borders and allowing for trade across borders.[14] 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.

Table 5 shows our baseline results for the alternative 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 results are consistent with our findings so far: a higher number of firms on average leads to a lower price. Table B.3 shows that the results are consistent

Table 5: Dependent variable: ln (Price of Cement)

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
ln (n < 300km)	-0.15**	-0.15**	-0.11*	-0.32*	-0.31*	-0.25
	(0.066)	(0.068)	(0.061)	(0.17)	(0.18)	(0.18)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	Yes	No	Yes	Yes
Fuel	No	No	Yes	No	No	Yes
F-Stat				7.6	9.1	8.9
N	86	86	83	86	86	83
R-sq	0.176	0.184	0.336	0.082	0.103	0.273

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

when allowing for free trade across borders in the definition of the market variables.

A further driver of differences in prices might be the quality of transport infrastructure, particularly if cement needs to be transported over long distances. Our scale controls, particularly country size, is likely to capture part of the effect of transport costs. To examine this channel further, we also include data on the km of roads in each country and the quality of trade-related infrastructure from the Logistics Performance Index. Table B.4 shows that when we control for the quantity and quality of infrastructure our key results are unchanged, with the caveat that the F-stat is slightly lower in this specification.[15]

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[14]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.

[15]It could also be that not only the overall length of roads matters, but the length of different types of roads,

Finally, our most restrictive specification controls for both, the number of cement plants, and the number of firms in a country. This means that we only exploit variation in market structure, holding the number of plants constant. Table B.6 shows when we include the 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. What matters for cement prices is competition which is determined by the number of firms rather than the number of plants. Overall, this section suggested a strong link between market structure and cement prices.

While the results presented in this section suggest a robust and causal link between prices and market power, it could be that high prices are due to the presence of inefficiently sized plants or high fixed costs. We investigate these two alternative explanations in the following two sections relying on plant-level data from the International Cement Review (2019b) and firms' financial accounting data from Worldscope.

3.5. Minimum efficient scale

One potential explanation for differences in cement prices is economies of scale, such that small countries do not have sufficient demand for cement to achieve an efficient scale of production. Indeed, if such scale was correlated with the number of firms operating in the market, then higher prices that appear to be driven by a lack of competition may instead be driven by a lack of scale. The policy prescription of these two scenarios could hardly be more different.

In order to investigate whether there is evidence that firms operate at different scales which might be correlated with market structure, as a first step we investigate the distribution of plant capacities across countries.[16] Figure 6 plots the average capacity of cement plants for grinding and integrated plants in each country (in million tons (Mt) per year) and the number of firms operating in that country. The figures show that these are essentially random scatters, with no discernible relationship between the number of firms and average plant size. In particular, we do not see that firms are becoming increasingly larger in large countries that can sustain a high number of firms, such as the United States or India, for example. The average capacity of an integrated plant in the United States is 1.2 Mt per year, compared to 1.6 Mt in Portugal, 1.21 Mt in Belgium and 1.53 Mt in Ireland. This is likely due to the fact that high transport costs present an upward limit on the size of plants. On the other hand, the average integrated plant in Nigeria has a capacity of 4.42 Mt per year, with the largest plants having each a capacity of over 10 Mt per year. This first look at

for instance, because only primary roads are suitable to transport large quantities of cement. In Table B.5 we therefore control for the km of main, secondary and tertiary road separately. This does not affect our results.

[16]Ideally, we would have data on output for each of the firms. Unfortunately these data are not available in the plant database. Using data from the USGS minerals yearbook for 2017 that contains data on production and grinding capacity at the market level in the United States, we find that production and capacity are highly correlated (bivariate correlation of 0.95 with a p-value of 0.000).

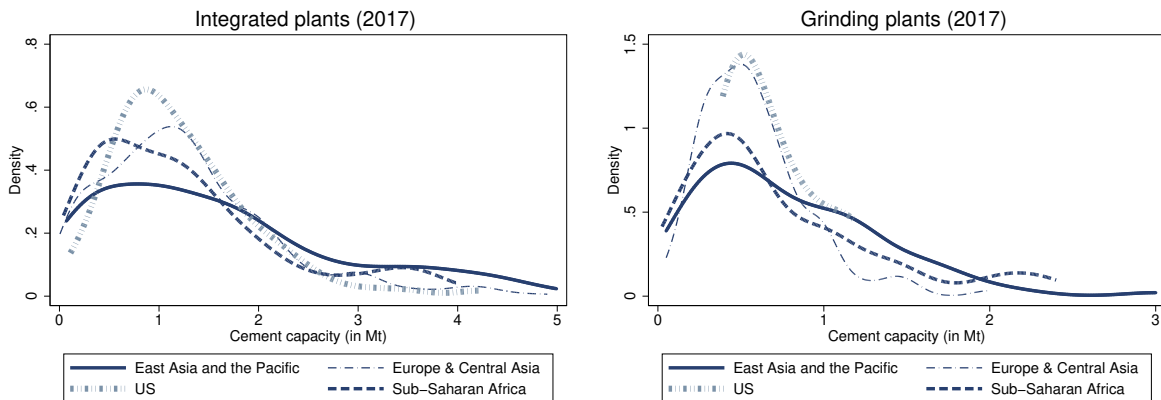Figure 6: Average plant capacity and number of firms in 2017 (in Mt per year)
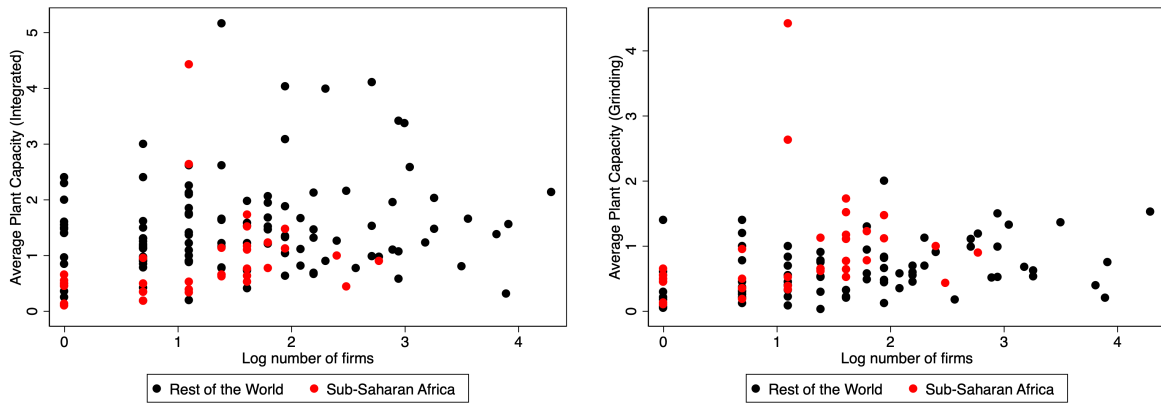
Note: This figure shows average plant capacities in 2017 for integrated and grinding plants.

the distribution of capacities does not suggest that scale economies are a key confounding factor in our main results. Still, it might be that the averages mask important differences across regions.

We therefore explore to what extent scale economies may be phenomenon specific to certain regions and particularly Africa, as several African countries in Figure 6 have both a low number of firms and relatively low capacity. Figure 7 plots the empirical density of

Figure 7: Plant size distributions across space

Note: This figure shows the distribution of plant capacities in 2017 for integrated and grinding plants, excluding 56 plants with capacity above 5 Mt (2.5 percent of the plants in our database).

plant capacity for grinding and integrated plants in Sub-Saharan Africa, alongside the corresponding distribution for Europe and Central Asia region, the East Asia and the Pacific region and the USA, distinguishing again between integrated and grinding plants. The distribution of plant sizes in Africa, Europe and East Asia is remarkably similar for both types of plants, while firms in the US tend to be slightly larger with a similarly shaped distribution.

The fact that there is little difference between the distribution of plant sizes in Sub-Saharan Africa and Europe calls into question the explanation that African countries suffer from

inefficient scale. If this were the case, such inefficiency would also apply to Europe and East Asia. We next turn to analysing whether markups in the cement industry simply pay the fixed costs of production, or are instead used to generate pure profits or rents.

3.6. Markups and profits

To measure markups and profits we primarily rely on a user-cost approach similar to Gutiér-rez and Philippon (2016). This method uses accounting measures of profits, but accounts for firm ownership of capital. It is important to note that in our framework high markups do not necessarily imply economic rent. This is because firms must use their markups to pay fixed costs of producing each period. We therefore investigate pure profits that take into account both fixed and variable costs as our main measure of rents. In line with De Loecker and Eeckhout (2018) and Gutiérrez and Philippon (2016) we assume that marginal costs consist of a labour and intermediates as well as capital owned by the firm, while fixed costs are measured by overhead costs (general selling and administrative expenses). Revenue R_{it} by firm i and time t is given by

$$R_{it} = \mu_{it} \left(r_{it} k_{it} + C_{it} \right)$$

where μ_{it} is the markup over marginal cost which consists of capital k_{it} multiplied by the user cost of capital r_{it} and the cost of goods sold C_{it}. Defining operating surplus as $OS_{it} = 1 - \frac{1}{\mu_{it}}$ and normalizing by revenue we get

$$OS_{it} = 1 - \frac{r_{it} k_{it}}{R_{it}} - \frac{C_{it}}{R_{it}}$$

which can be exploited to obtain a measure of markups μ_{it}. However, such markups are not a measure of pure profits or rents due to the presence of fixed costs. To account for fixed costs we define pure profits as

$$\pi_{it} = 1 - \frac{r_{it} k_{it}}{R_{it}} - \frac{C_{it}}{R_{it}} - \frac{F_{it}}{R_{it}} \tag{8}$$

where F_{it} is expenditure on overhead costs, analogous to F in our theoretical framework. This measure of pure profits is a measure of excess profits, accounting for the costs of any overhead or return to capital held by the firm. In practice it may be the case that some of the fixed costs of cement production are associated with installing physical capital such as factories and other infrastructure and therefore be part of k. Even though the structure of costs impacts our calculations of markups (the higher the fraction of fixed costs that are related to capital, the more sensitive our results are to what user cost of capital we use), it is largely irrelevant for pure profits which is our central metric of rents.

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 (SIC code: 3241).[17] In line with De Loecker et al. (2020) we measure costs C_{it} as "Cost of goods sold", overhead costs F with "General selling and administrative expense", while capital k_{it} is given by "Net property, plant and equipment".

The only variable determining profits which is not directly available in Worldscope is the user cost of capital r_{it}. We utilise several approaches. As our benchmark we let the user cost of capital equal to a firm's borrowing cost, defined as a firm's interest payment divided by the total debt D_{it} held by the firm so that $r_{it} = \frac{interest_{it}}{D_{it}} = x_i$. This measure captures firm-specific risk premia, reflecting the cost of borrowing for new capital a particular firm faces.[18] We also construct a variant of this measure that is constant across firms within a given country and year, such that $r_i = \sum_i \frac{x_i}{n} = \bar{x}$. Third, we use an alternative definition $r_t = r_t^f + \Delta$ where r^f is the country-specific risk-free real rate of interest from the World Bank and Δ is depreciation and a risk premium, which we set to 12% following De Loecker et al. (2020). While this strategy may be reasonable for developed economies, for many countries this measure leads to possibly implausibly large estimates of the user cost of capital, as firms located in developing countries may be able to borrow at a lower rate than governments who face high risk premia. To address this concern, we follow De Loecker and Eeckhout (2018) and impose the user cost of the USA on all countries as a fourth measure. We exclude observations which have capital shares of expenditure which are greater than total revenue, and observations with negative capital costs. Our main results use the firm-specific user cost of capital and we show robustness using our alternative measures. Figure A.1 plots the empirical density of capital expenditure's share of value added, computed under each measure of the user cost.

3.6.1. Expenditure shares

Having constructed our measure of the user cost of capital, we can now analyse firms' expenditures on different factors of production. We start by considering the respective factors' share of value added, where value added is defined as revenue less intermediates.[19] We assume that cost of goods sold is comprised solely of intermediates and labor costs. Intermediates make up a large share of costs, yet they are not likely to be subject to any constraints. For example, while hiring extra workers of building new factory capacity may take time and involve significant fixed costs, buying more limestone or using more energy should be relatively straightforward.

Figure 8 plots the empirical density of value added shares for our sample. The density of

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

[18]We winsorise this measure, excluding the top and bottom two percent of the distribution for each year.

[19]We chose value added as the denominator simply for expositional clarity.

the pure profit rate is calculated using the entire sample, however we restrict the graph to non-negative values. We can see that both overhead costs and profits tend to account for a larger share of value added than capital or labour. While high overhead costs suggest that fixed costs play an important role, the high levels of profits in excess of such costs are evidence that markups are not solely paying for high fixed costs of production. The figure shows that firms in the cement industry tend to earn high excess profits which cannot be explained by fixed costs.

Figure 8: Labour, capital and overhead share of value added
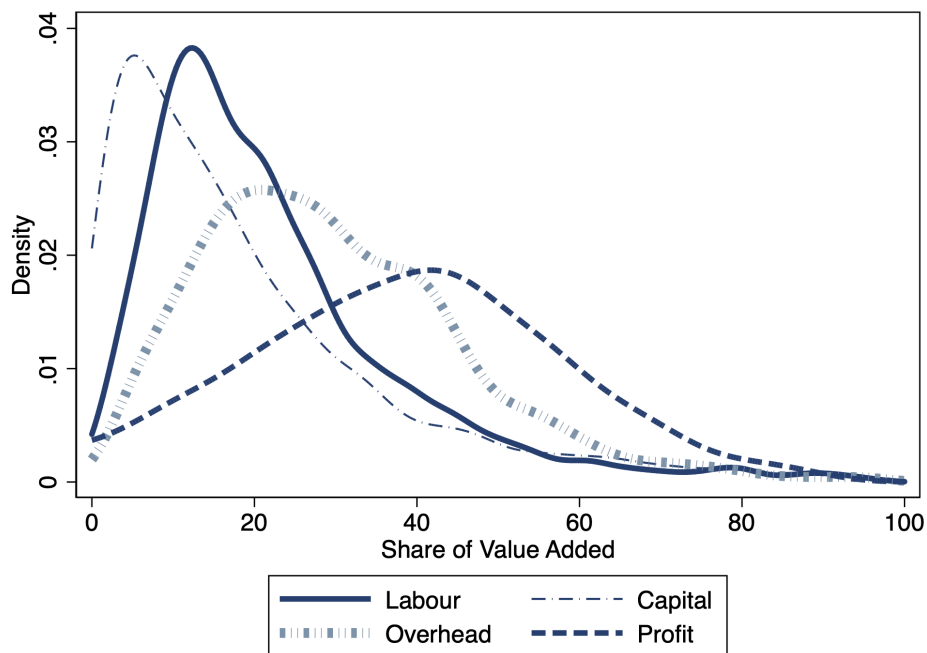
Note: This figure shows the distribution of labor, capital, and overhead expenditures as well as pure profits as a share of value added.

3.6.2. Profitability of cement firms

We next examine the profitability of cement firms, and the co-variation with the number of firms operating in each market. To do this, we link our measure of pure profits with data on the number of cement firms operating in a country using data for 2011 and 2017. Figure 9 shows that almost all firms operating in a monopoly or duopoly market make positive pure profits, with a tendency to earn higher profits that firms operating in more competitive markets. While some firms operating in markets with three to five firms make losses, the majority make significant profits. Firms operating in countries with six or more firms have a lower density of high profits, with a high density of lower but positive profits.

To provide a more formal investigation of this correlation for 2011 and 2017 we estimate

Figure 9: Profits and competition
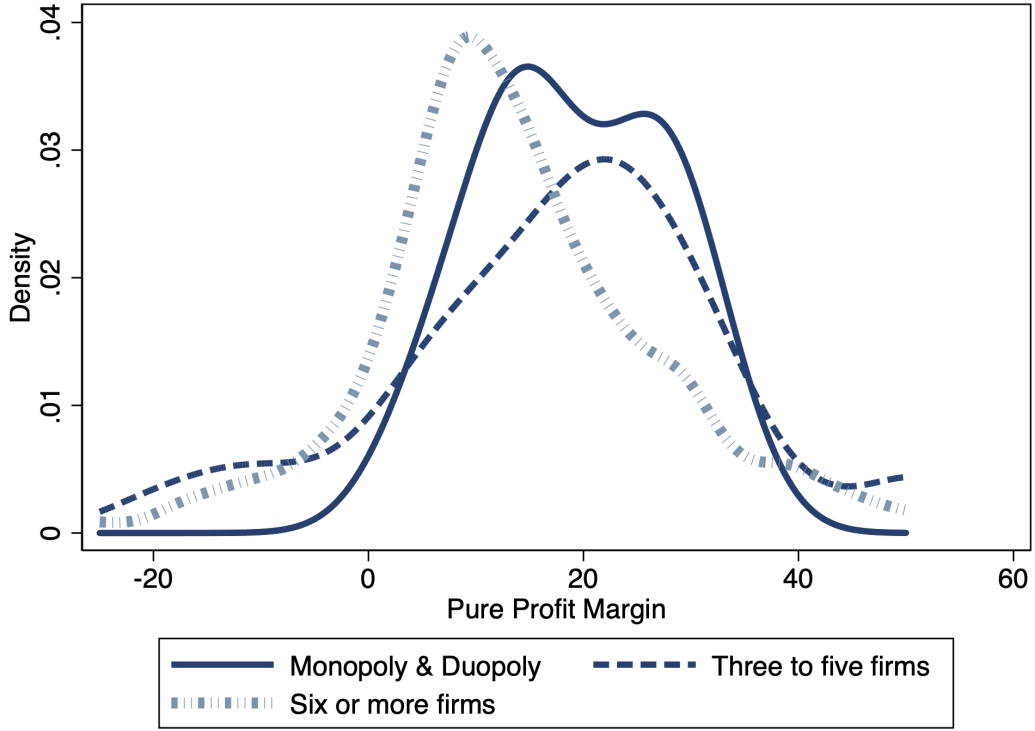
Note: This figure shows the distribution of the profit rate for different levels of competition.

the following equation

$$\pi_{ijt} = \alpha_r + \phi_t + \gamma \ln n_{jt} + \delta \ln k_{ijt} + \beta Z_{jt} + \varepsilon_{ijt} \qquad (9)$$

where π_{ijt} is the excess profit of firm i operating in country j at time t, k is the firm's capital stock, n is the number of firms in country j, Z is a vector of country-specific controls (log GDP, area and population) and α_r are region fixed effects. It is important to note that our goal is to understand how competition and profits covary in the data. We do not attempt to obtain causal estimates, as markups and the level of competition and firm size are endogenously determined.

We also include a firm's capital stock as a proxy for firm size, to investigate whether there are significant economies of scale which allow larger firms to earn higher profits. It should be noted that we would expect the coefficient δ to be positive, as our model predicts that large firms are also high productivity firms, who charge higher markups. We estimate equation (9) for profits calculated under each of our four measures of user cost of capital. Our baseline specification restricts the sample to firms which we could match to an observation in Global Cement Review database.[20]

Table 6 reports the results for each specification. We see that across all specifications, there

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[20]We also used the entire sample of firms and the results are qualitatively similar.

Table 6: Profits and competition - Global Cement Review firms

	$r_{i,j} = r_j^f + 12\%$	$r_i = r_{US}^f + 12\%$	$r_{i,j} = x_{i,j}$	$r_{i,j} = \bar{x}_j$
	(1)	(2)	(3)	(4)
$\log n_k$	-4.61*	-6.84*	-4.51	-5.61
	(2.65)	(3.52)	(3.30)	(3.81)
$\log k_i$	-0.79	-0.99*	0.38	0.49
	(0.57)	(0.56)	(0.84)	(0.71)
Agg controls	Yes	Yes	Yes	Yes
Countries	33	42	41	41
N	191	274	225	274
R-sq	0.086	0.090	0.125	0.178

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

is a negative estimated relationship between the level of competition and the number of firms. The relationship is significantly different from zero at the ten percent level in columns (1) and (2) which use the country-specific risk-free rate plus 12 percent or the US risk-free rate plus 12 percent. In columns (3) and (4) we use the firm-specific borrowing costs and the country-specific average of the firm-specific borrowing costs. The coefficients are very similar but our standard errors are larger in these two specifications. The coefficient on capital is only significant in column (2) with a negative sign, providing further evidence that economies of scale are not the key driver behind high profit rates.

3.6.3. Trends in profit rates

We now turn to quantifying the trends in our metric of excess profitability over the sample. As a starting point, Figure 10 plots the evolution of excess profit rates over time for a selection of firms. The selection of firms include Dangote cement and PPC Ltd, two large African producers, alongside Cemex, CRH and LafargeHolcim which are among the leading firms in the industry globally. We can see that over time, the profit rates of the two African firms have fallen, but from extremely high initial levels. The profit rate of Dangote is particularly striking. Despite the fact that it has halved in the last ten years, it is still far larger than that of any of the industry leaders. This fact is even more striking when one considers that the profit rates of industry leaders have been steadily rising over the past ten years.

This section used a model of oligopoly to estimate the relationship between market structure and prices, showing a robust negative relationship between the number of firms and cement prices in both the OLS and the IV estimates. We also used alternative functional forms, measures of competition and used geo-coordinates of plants to compute a local mea-

Figure 10: Profit rate for selected firms over time
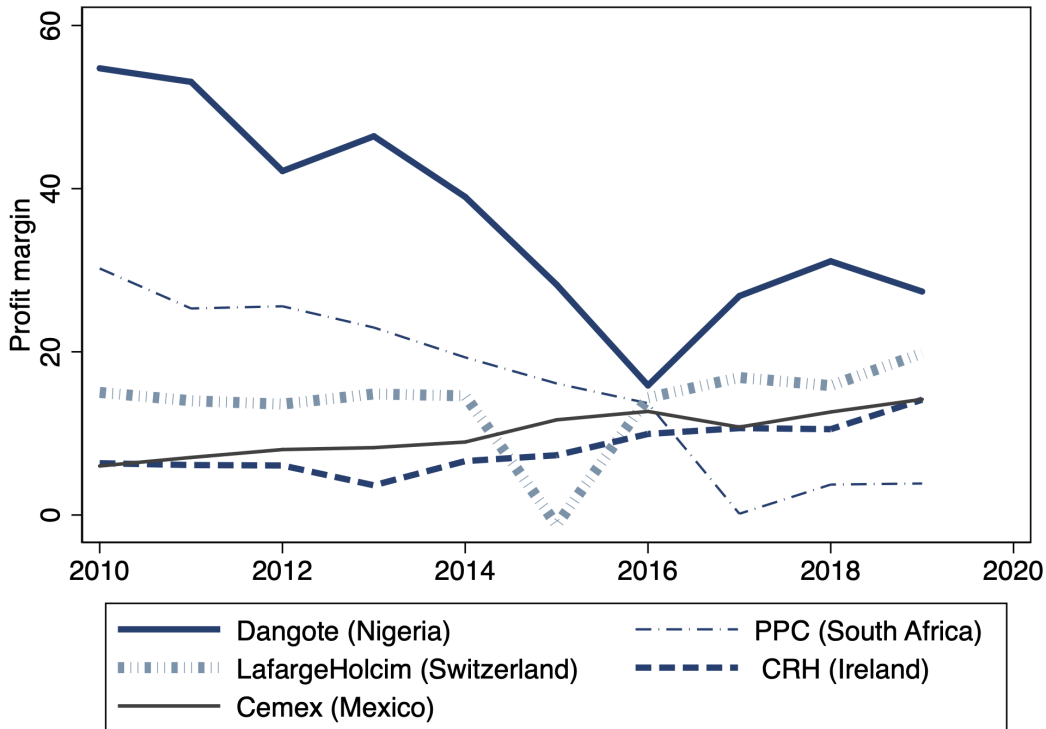
Note: This figure shows profits over time for selected firms.

sure of competition. We showed that neither scale nor fixed costs seem to be driving this relationship: there is little difference in firm sizes across space and firm accounting data suggests at firms in this industry have significant excess profits after paying for fixed costs. Leone et al. (2021) also find large markups in the cement industry that declined over time, and that minimum efficient scale is unlikely to account for these. We differ in our treatment of fixed costs. They assume that fixed costs and entry costs are the same, while we find profits in excess of total costs in the data. We interpret this as evidence for the existence of significant entry costs that go beyond plant installation costs. The next section addresses to what extent competition policies in cement can affect steady-state output.

4. Cement in the network of production

Thus far we have established that cement firms have been making substantial excess profits, particularly in developing countries. We now explore the consequences of this for macroeconomic development. To do this, we embed a production network into a two-sector neoclassical growth model that we take to the data. The model also incorporates the oligopoly market structure presented in Section 3. We briefly outline the model here and provide a full derivation in Appendix E.

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.[21] We let the price of the consumption index be the numeraire, such that $p_c = 1$. Consumer optimisation results in the usual Euler equation

$$\frac{\dot{c}}{c} = \frac{r^k}{p_I} + \frac{\dot{p}_I}{p_I} - \delta - \rho \tag{10}$$

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 $\tau_i = 1 - \mu_i^{-1}$. Part of firms' profits are paid to cover fixed costs F_i and the remainder is rebated lump-sum to consumers. For clarity of exposition, we assume that entry costs sustain excess profits, but are only faced by prospective entrants. Further, we assume that entry costs are deadweight losses that are paid in annuities at the risk free rate.

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 gross of fixed costs as

$$Y^G = wL + rK + \tau Y^G$$

where τ is the aggregate profit rate gross of fixed costs. We can therefore define net nominal output as

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

where $Y^F = wL + rK$ is factor income and $P_y F = \sum_{i=1}^{N} P_y F_i$ are total fixed costs in the economy. We index fixed costs to the output price deflator for simplicity.

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

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[21]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 $u''(c) < 0$.

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 Σ is given by

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

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 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 equilibirum quantities.

I. Output

Following Lehn and Winberry (forthcoming) 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 2 *Starting from a base period output deflator $P_{y,t_0} = s_{t_0} p_I + (1 - s_{t_0}) p_c$, nominal output in the Cobb-Douglas network economy is given by*

$$Y_t = D_t^y A k_t^\alpha - F \tag{11}$$
$$D_t^y = \frac{\prod_{i=1}^N (1 - \tau_i)^{\psi_i}}{1 - \tau_t}$$

where $\psi^{C\prime} = \beta'(I - \Sigma)^{-1}$, $\psi^{I\prime} = \lambda'(I - \Sigma)^{-1}$ and $\psi = s_{t_0} \psi^I + (1 - s_{t_0}) \psi^C$ defines the sensitivity vectors in consumption, investment and output respectively. $A = \prod_{i=1}^N A_i^{\psi_i}$ is aggregate productivity, while $\tau_t = \sum_{i=1}^N \gamma_{i,t} \tau_i$ is the aggregate profit rate.

The proposition shows that we can express output using a simple aggregate production function, but crucially including a misallocation term D^y. For a constant capital stock micro distortions impact aggregate efficiency through their relative level. If, for example, $\prod_{i=1}^{N}(1-\tau_i)^{\psi_i} = 1-\tau_t$, there is no efficiency loss from distortions with a constant capital stock. The network structure ensures that even with uniform distortions this will not be the case, as distortions propagate more to upstream sectors (Liu, 2019).

II. Steady state

Proposition 2 holds in all periods. The difference between short- and long-run impacts of distortions occurs through steady-state capital stock k^*.

Proposition 3 *The steady-state capital stock is given by*

$$k^* = \left(\frac{\alpha D_I A_I}{\delta + \rho} \right)^{\frac{1}{1-\alpha}} \tag{12}$$

where $D_I = \prod_{i=1}^{N}(1-\tau_i)^{\psi_i^I}$ is the total distortion in investment production while $A_I = \prod_{i=1}^{N} A_i^{\psi_i^I}$ is the total productivity in investment. Moreover, the steady-state savings rate is given by

$$s^* = (1-\tilde{\tau}^*)\chi \tag{13}$$

where $\chi = \frac{\alpha\delta}{\delta+\rho}$ is the savings rate in perfect competition and $\tilde{\tau} = \tau - F/Y$ is the pure profit rate.

Expression (12) shows that the absolute level of markups reduces investment and the long-run capital stock. This is in contrast to a static model, which only implies efficiency losses through dispersion in marginal revenue products, determined by dispersion in distortions (Hsieh and Klenow, 2009). Therefore equation (12) implies that the output losses from markups will be larger in the long run. Combining equations (11) and (12) we can obtain an expression for long-run output as a function of technology $\{A_i\}_{i=1}^{N}$, markups $\{\tau_i\}_{i=1}^{N}$ and fixed costs F.

III. Efficient size of cement sector

We can measure the distortion in cement by measuring its size in perfect competition, relative to its size in the data.

Proposition 4 *Let $i = cem$ denote the cement sector. In the perfectly competitive benchmark with zero distortions in all sectors, steady-state cement expenditure as a share of output is given*

by

$$\gamma_{cem}^{PC} = \psi_{cem}^{I}\chi + \psi_{cem}^{C}(1-\chi) \tag{14}$$

where $\chi = \frac{s^*}{1-\tau^*}$ is the savings rate in the perfectly competitive economy.

This proposition tells us that expenditure shares depart from their ideal value for two reasons; first, due to differences between marginal sensitivities ψ^j in consumption and investment. Second, expenditure shares can also be distorted since pure profits reduce the savings rate in the economy, and therefore expenditure shares for investment-intensive goods.

We can use this proposition to understand how distortions in cement and other sectors impact the aggregate expenditures on cement relative to its value in perfect competition. This allows us to define a centrality measure $\xi_{cem} = \frac{\gamma_{cem}^{PC}}{\gamma_{cem}}$ in the spirit of Liu (2019). However, rather than defining the marginal impact of subsidies in cement, this centrality measure is informative about the size of the cement sector relative to the efficient benchmark.[22] It should be noted that γ measures cement expenditures as a share of output, not total expenditure. Markups reduce expenditure on intermediate inputs in general, thereby reducing overall expenditure as a share of output (the intermediate input multiplier). The value of ξ alone is therefore not enough to infer the marginal benefit of reducing markups in cement.

5. Quantification

Through the lens of this model, we can understand how excessive profits in the cement industry impact macroeconomic development. We first quantify the reduction in cement expenditure implied by the network structure of production. Next, we turn to examining the effect of competition policy on output, considering both entry subsidies and anti-trust. In our model, anti-trust amounts to forcing plants which are part of a multi-plant firm to operate independently. We consider anti-trust applied to one plant, adding one firm to the market, and also anti-trust forcing all plants to operate independently. The benefits of these policies depend crucially on the potential gains from reducing markups in cement compared to the costs due to reduced scale economies.

5.1. Data

We combine data on the input-output structure of countries with firm-level estimates of markups to parameterize the model. We assume markups are the only form of distortion in the economy. Due to data constraints we apply our results to four countries: the USA, Brazil, India and Indonesia. To obtain the expenditure matrix Ω we use input-output data

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[22]Fixed costs alter the notion of efficiency. The first best policy in this economy is one in which one firm operates in cement to maximise scale economies, but also produces at marginal costs to maximise allocative efficiency. In this case, fixed costs would be paid lump sum by the social planner.

from the World Input-Output Database (WIOT) compiled by Timmer, Dietzenbacher, Los, Stehrer, and De Vries (2015) which provides input-output data at a 55-industry-level across countries between 2000 and 2014. As our model is of a closed economy, we must allocate imports. We follow Liu (2019) in modelling trade as a fictitious sector which transform exports to imports in a one to one fashion. Any trade surplus or deficit is interpreted as a lump-sum transfer.

The industry classified as "Manufacture of other non-metallic mineral products" in the WIOT encompasses cement production.[23] To identify the cement sector in more detail, we assume the following: cement output is used exclusively as an intermediate input in the construction sector, and cement uses the same basket of intermediate inputs as the wider non-metallic minerals sector.[24] We measure cement production (and trade) by combining data in quantities q_{cem} from Cemnet with price data from the ICP p_{cem}. This information alongside our assumptions allows us to extract cement from the non-metallic mineral industry, creating a distinct industry in 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.

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 3.6, based on Gutiérrez and Philippon (2016).[25] We use the average borrowing cost in the country as a measure of the user cost of capital in the baseline. 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, such as (a) alternative measures of user costs, (b) pure accounting profits and (c) markups measured by a production function approach following De Loecker and Eeckhout (2018).

We apply Worldscope firms to WIOT industries using the primary SIC code reported in the data. 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

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

[24]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.

[25]In Section 3.6, we defined operating surplus as operating income less capital expense, with operating income measured by revenue less COGS (cost of goods sold) to ensure all sources of costs add up to revenue. Here we define operating income as OIBD (Operating income before depreciation) following Baqaee and Farhi (2020), which yields more conservative estimates of aggregate markups. The distinction is small, and the results of Section 3.6 are unchanged using this alternative measure.

to a Hicks-neutral productivity shifter. This allows us to express each sector in terms of a representative firm. We can then define industry-level markups as the revenue-weighted harmonic average of firm-level markups, assuming the firms in Worldscope are representative of their sector. We therefore assume that all goods produced in a sector have identical markups. This in turn allows us to recover the cost-based input-output matrix Σ from the data.[26]

As we have artificially constructed a cement industry, we must also construct markups in cement. For simplicity, we assume all firms in the cement sector face the same marginal costs in this section. According to our assumptions of unitary elasticity of substitution in cement and constant marginal costs across firms, the profit rate in cement is given by $\frac{1}{n}$. We therefore let markups in cement equal to this value, assuming that entry costs are such that the expected profits from entering the market are zero or less. Given the level of markups observed in other sectors these are conservative assumptions for the countries in question, with implied markups over marginal cost in cement ranging from 12% in Indonesia to just 2% in India.[27]

For our calibration, we assume the standard value of $\alpha = \frac{1}{3}$, and that $\rho + \delta = 10\%$. The latter assumption ensures that steady-state income differences are determined solely by technology and distortions. We allow δ and ρ to vary across countries in order to reconcile the savings rates we see in the data.[28] For our anti-trust policy evaluations, we must also specify the structure of fixed costs. When a firm is broken up into constituent plants, no entry costs is paid. However, whatever overheads are present at a plant-level must now be paid by each plant. This adds a cost of anti-trust equal to the lost scale economies from firm-level fixed costs or overheads. We assume that overhead constitute 40% of total fixed costs. This figure corresponds to the split seen between overhead (selling, general and administrative expenses) and entry or plant specific fixed costs (pure profits and return on property, plant and equipment) in the accounting data analysed in Section 3.6.[29] We also assume overhead is the only fixed cost facing existing firms, and that other fixed costs relate to entering the market. Finally, we assume that markups in sectors other than cement pay for pure profits. That is, all fixed costs in other sectors are encapsulated by capital costs, which are accounted for in the calculation of markups.

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[26]Following Liu (2019), we take the average markup of a country for sectors with missing markup data.

[27]We compute markups from observed market structure, rather than estimating them from Worldscope, so that we can simulate competition policies.

[28]The savings rates seen in the data imply negative discount rates for India and Indonesia. To allow for this in the model, we introduce idiosyncratic risk following Benigno and Fornaro (2018) in appendix Section E.3.

[29]Whether or not capital costs in the form of property, plant and equipment are fixed or variable costs is unclear. While plant installation costs are generally interpreted as a source of fixed costs, capital is seen as a variable cost in steady-state. When capital costs are excluded from fixed costs, overhead's share rises to just under 50%. The results are qualitatively unchanged.

5.2. Evaluating competition policies

In this section, we use our calibrated model to evaluate the impacts of competition policies in cement on aggregate output. This allows us to measure the size of the cement sector relative to the efficient benchmark, and to examine how entry subsidies and anti-trust in the cement industry affect steady-state output. Our analysis focuses on three developing countries; Brazil, India and Indonesia, alongside the USA. Cement markets in these countries range in their levels of competition, with 9 firms in Indonesia, 15 in Brazil, 17 in the USA and 45 in India.

We start by considering the scenario in which there is a 10% profit rate in all sectors in the economy. As the profit rate and thus markups are equal across sectors, this will help to isolate how cement's network position impacts the size of the distortion.[30] Figure 11a plots expenditure in cement as a share of GDP in the efficient economy relative to its observed value in the data ξ_{cem}, which tells us the size of the cement sector relative to its ideal value. We see that across all four countries, in the efficient benchmark cement would be about

Figure 11: Efficient size of cement relative to observed size $\xi_{cem} = \frac{\gamma_{cem}^{PC}}{\gamma_{cem}}$

(a) Uniform markup with $\tau_i = 10\%$ (b) Markups from Worldscope
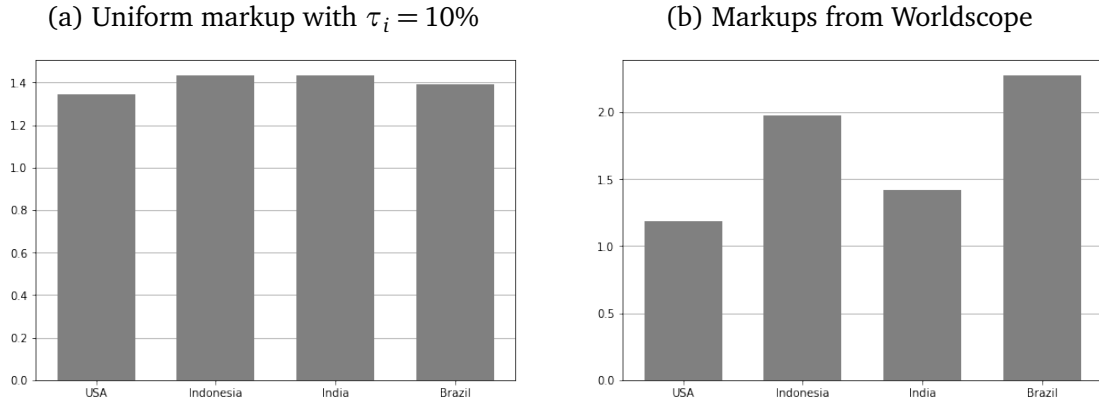
Note: This figure shows the efficient size of cement as a share of GDP relative to the observed size for a uniform markup of 10 percent (figure on the left) and markups estimated using Worldscope data (figure on the right).

30% larger than it is in the data with a uniform profit rate. This figure is very similar across countries, despite the stark differences in their development levels.

In terms of ξ, we see that cement ranks first in terms of ξ amongst the 55 sectors in Brazil, second in the USA and Indonesia, and fifth in India. In short, this evidence implies that the cement sector is an "upstream" sector, supplying intermediate inputs to many downstream sectors in the supply chain. The evidence suggests that the network position of cement is similar across countries, with a large reduction in cement's size due to its consistent upstream network position.

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[30]A similar strategy is employed by Liu (2019) to demonstrate the hierarchical nature of production networks.

Figure 11b plots the equivalent measure ξ_{cem} using our baseline measure of markups in the accounting data. We see that differences in markups across sectors create differences in the reduction of cement's size. The high level of markups in Brazil contribute to the large reduction in size, as the profit rate in the economy directly reduces the savings rate and therefore cement's expenditure as a share of output. When we use the markups data, the reduction in size of cement relative to perfect competition is the largest amongst all sectors in India and Indonesia, second in Brazil and 14th in the USA. These large differences are generated by markups in the aggregate economy, rather than the cement sector alone. Even if the cement sector was perfectly competitive, the observed value of ξ_{cem} would change only slightly. This is because ξ_{cem} is determined by distortions in all sectors and not just cement itself, which is small in size. Reducing markups in cement can nonetheless have positive welfare effects, though these effects can be expected to be small relative to the aggregate economy.

We next turn to evaluating the effects of competition polices aimed at reducing markups. We consider three policy choices: (i) a lump-sum subsidy to promote the entry of one firm, (ii) breaking up one multi-plant firm and (iii) breaking up all possible multi-plant firms.[31] When plants are broken up, the market may not generate enough profits to pay the ongoing fixed costs of each plant independently. Therefore, policy choice (iii) involves breaking up the maximum number of multi-plant firms possible without causing existing firms to exit the market. If all plants are forced to operate independently in the model, firms would exit if necessary until all firms can pay their ongoing fixed costs delivering the same result. In practice, we see that not all plants can operate independently with the level of fixed costs in our calibrated model. However breaking up of firms can significantly increase the number of firms operating in the market. The number of firms operating increases to 23, 14, 71 and 26 in Brazil, Indonesia, India and the USA respectively. Entry subsidies that would generate an equivalent change in the number of firms cause large decreases in output, so are not considered in the subsequent analysis.

Figure 12 reports the percentage change in steady-state output from each policy in the four countries. In all countries, the benefit of an entry subsidy is quite small. The largest benefit is seen in Indonesia, with a 0.003% rise in output resulting from the subsidy. We also see that anti-trust has very small positive impacts in the USA and India. These countries have the lowest measured markups and have relatively competitive cement markets. However anti-trust is a relatively powerful tool in Brazil and particularly in Indonesia. The breaking up of a single firm results in a 0.01% rise in steady-state output in Brazil, and a 0.02% rise in Indonesia. The effect becomes much larger when all possible firms are broken up, with

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[31]The entry condition may not hold with equality due to the integer problem. The entry subsidy we consider is the minimum subsidy such that a single extra firm is guaranteed to enter the market, even if the precise level of entry costs are unobserved. This is obtained by assuming entry costs are such that profits in the market are equal to discounted entry costs.
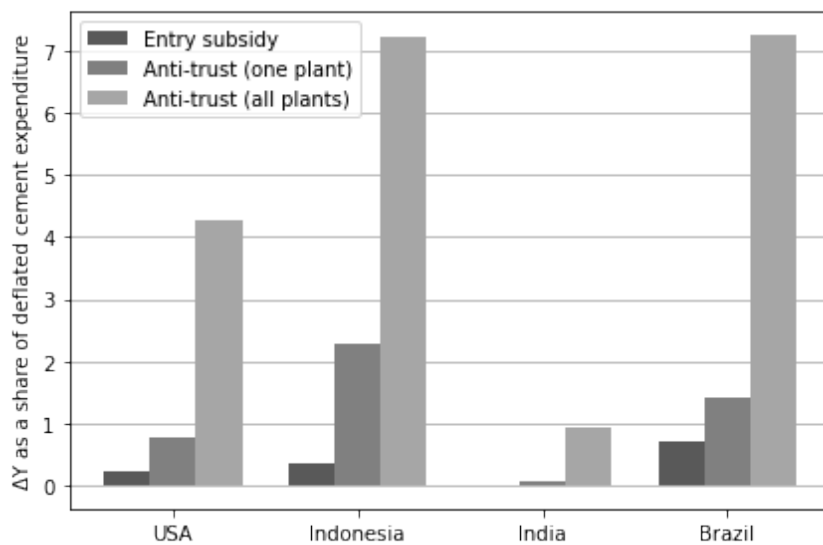
Figure 12: Impact of competition policies on steady-state output
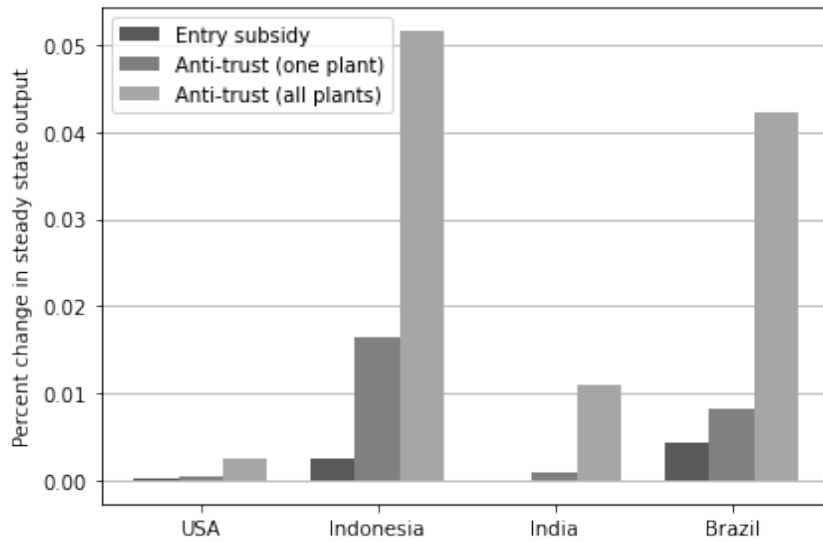
Note: This figure shows the impacts of competition policies on steady-state output.

the change in steady-state output rising to 0.04% in Brazil and 0.05% in Indonesia.[32]

Figure 13: Impact of competition policies on steady-state output as share of cement output

Note: This figure shows the impacts of competition policies on steady-state output as a share of cement expenditure.

While the changes in output induced by competition policies in cement are small in nominal terms, we next consider the scale at which cement operates. Figure 13 plots the same changes as Figure 12, instead normalised by deflated output in cement rather than aggregate output. When we consider the small size of the cement industry and indeed single cement firms relative to the aggregate economy, these figures are substantial. The bene-

[32]Appendix Figure A.2 shows the results using alternative markup estimates.

fit of the maximal anti-trust policy in terms of steady-state output is over 7% of cement expenditure, a large benefit. Indeed much of the variation across countries is due to differences in cement's share of output. As a share of cement expenditure, the impact in the USA is much closer to that of Indonesia and Brazil. Impacts in India remain small due to the large number of firms operating there. These figures are particularly striking when taking into account that the net change inside the cement industry is negative, as the increased fixed costs are larger than the increase in cement output. However, the positive effects of increased cement production through the network more than compensate for these costs.

These policy choices have very different implications for the distribution of income that are outside the scope of the model. Entry subsidies involve lump-sum taxation funding increased aggregate profits for firms, so that the market can support more firms. Anti-trust, in contrast, reduces firms' profits by increasing competition at the costs of reduced scale efficiency. In our simple framework, lump-sum taxes and lump-sum profits are equivalent. This is likely not the case in practice. Anti-trust is both more potent and likely to be more equitable than entry subsidies, increasing output while moving resources away from firms with excess profits.

Unfortunately, due to data constraints in requiring both sector-level markups and input-output data, we can not carry out these simulations for Sub-Saharan African countries in the same way. In order to better understand how our results may apply to these countries, we study the potential benefits of maximal antitrust policies for different market structures. As a benchmark, we use the Tanzanian input-output table for 2015 and apply a ten percent uniform profit rate in all non-cement sectors (Tanzania National Bureau of Statistics, 2021). Figure 14 plots the predicted benefits of antitrust in this setting for various combinations of number of firms and plants. The figure also indicates the market structure of countries in Sub-Saharan Africa in 2017 for comparison. Countries located at xy-plane of the graph are those without any scope for anti-trust since the number of firms equals the number of plants.

The figure shows much stronger effects as the level of competition (measured by the number of firms) declines, with effect sizes ranging from 0.025 to about 1% of steady-state output for different levels of observed market concentration. We also see that the marginal benefit of antitrust is decreasing in the number of plants and becomes flat when an extra firm would be unprofitable and forced to exit. Most of the potential gains arise from breaking up the first few firms. This suggests that the potential benefits estimated in our simulations would be larger for countries with low levels of competition, even if there are only a few plants that could be forced to operate independently.

The aim of these simulations is to highlight the key forces that determine the size of the effects rather than predict the impact of competition policy in these contexts. The simula-

Figure 14: Effects of antitrust by market structure based on Tanzanian I-O data
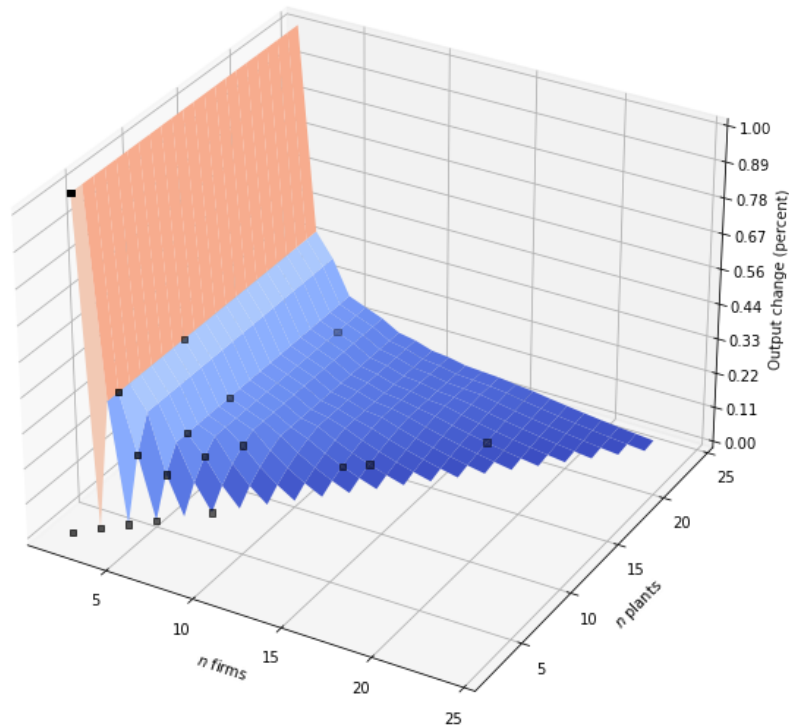
Note: This figure shows the impacts of breaking up of multi-plant firms, assuming a uniform 10% profit rate in non-cement sectors, and using Tanzanian Input-Output data. The squares indicate combinations of number of firms and plants found in Sub-Saharan Africa.

tions suggest that the effects of improved competition are likely to be large in Sub-Saharan African countries due to highly concentrated markets and the fact that expenditure shares of cement in many of the Sub-Saharan African countries are large as shown in Figure 4. Even in countries which have only a single plant, we can appeal to the theoretical findings of our model. We argued in Section 3 and proved in Appendix C that when $\varepsilon \leq 1$ and there is a single firm in the market, the monopolist will engage in limit pricing. Therefore, policies which reduce this limit price can increase production in cement with no costs in terms of scale economies. In practice, import prices are likely to represent a limit price to monopolists. Salvo (2010) examines the case of threatened import competition for oligopolists in Brazil. Therefore, removing tariffs and other barriers to trade in cement also has the potential to yield pro-competitive benefits.

6. Pass-through of cement to building costs

One key assumption of our model is that cement prices affect investment prices. 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 for a 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, 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.

With these caveats in mind, we can provide suggestive evidence on the link between cement prices and construction costs in two ways. First, 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, namely: 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. 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: skilled and unskilled labor, a vibratory plate compactor and an aggregate base.

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 7. We also use the 2011 ICP cement prices to examine the correlation in Columns (3) and (4). Column (1) in Table 7 shows that a one percent increase in the price of cement is associated with a 0.36 percent increase in costs of the composite component, 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.

To further explore these patterns, Figure A.3 shows the distribution of coefficients from a regression that uses each component separately. Given the data constraints, each regression 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

Table 7: 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)
Log(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.

plate compactor and aggregate base - show little correlation again.

A second way we can explore the relationship between cement prices and building cost is by extracting data collected by a leading global construction consultancy firm as part of their Africa construction handbook, which lists data on different residential (i.e. average multi-unit high-rise, luxury unit high-rise, individual 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) for 2011 and 2017. 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.

Table 8 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 one percent increase in the price of cement is associated with a 0.8 percent 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

Table 8: Dependent variable: Log of cost per square meter

	(1)	(2)	(3)	(4)	(5)
Log(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.

but the elasticity is close to 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 robust and shows a tight link between building costs and cement prices.

We also explore the correlations for each of the categories in Figure A.4. Again, our sample size is small (between 26 and 46 locations in 14 to 24 countries). The table 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.

7. 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 and show empirically that market power plays an important role in generating price dispersion in cement across countries: the higher the number of firms in a country, the lower prices. We theoretically show that the OLS estimates of the effects of market power are downward biased, which our empirical estimates confirm. We show that our results are robust to a different functional forms, extensive controls for input prices, alternative definitions of market power and controlling for trade in limestone and cement. We use plant-level data and firm's financial accounts data to show that it is unlikely that firms are operating below efficient scale and that markups are used to cover high fixed costs.

Third, we show that markups in intermediate inputs used for investment goods can have an impact on the long-run productive capacity of the economy which outweighs their share in aggregate production. This result follows from recognizing investment and consumption goods as distinct, and the fact that construction plays a crucial role in producing investment. Moreover, this assumption leads to different effects due to distortions in the production of both goods. Specifically, as distortions in investment change both prices and the return on investment, they act like a tax on capital, with resources being reallocated towards consumption. To highlight our main channel, our model only allows for a single produced factor, physical capital. If other produced factors, such as technology or human capital relied on physical capital to be produced, their long-run levels would also be reduced. Indirect effects from markups in intermediate inputs used for investment goods might therefore be large for long-run development.

Our model shows that the long-run output is disproportionately sensitive to bottlenecks in essential sectors such as cement. Our analysis highlights the role of market power and competition in generating such bottlenecks. While cement is a small sector on average in terms of expenditure, for certain countries expenditure shares of cement in investment are large.

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. Our analysis still provides compelling evidence for significant effects of market power in raising the price of cement and that this has important effects for the steady-state capital stock. A second limitation of our quantitative exercise is our focus on the effect of competition policy on steady-state output, rather than differences in incomes due to distortions in cement. Therefore our results highlight the large consequences of the type of market power we show empirical evidence for, but do not

estimate the potential income differences resultant from differences in market power in cement. Nonetheless, the evidence presented highlights that a lack of competition in crucial sectors can have severe impacts on the efficiency of investment production in low-income countries.

So why do not more firms enter certain markets in light of the significant markups documented which in turn would bring down prices? While explaining the origins of a country's market structure is beyond this paper, we can offer a tentative answer. First, firms have started entering certain Sub-Saharan African markets and we can see that cement prices have come down between 2011 and 2017.[33] Still, there appear significant barriers to entry, possibly difficult to measure or even observe. World Bank (2016) discusses several of these, including the granting of temporary or geographic rights to limestone resources (e.g., Nigeria, Botswana, Kenya), import restrictions (e.g., Angola, Cameroon, Ethiopia, Nigeria, Liberia) and product standards (e.g., Liberia, Nigeria).

What do our results suggest for policy makers concerned with high cement prices? We have illustrated the impact of two specific policies: subsidizing entry costs and breaking up of firms. Our results suggest that breaking up multi-plant firms has significant effects on long-run output while subsidizing entry has more limited effects. Our overall findings therefore reinforce a stronger role for competition policy in low-income countries. Second, by showing how markups have differential effects depending on where they occur, our results carry a clear message on which areas should deserve focus in competition policy for governments scaling up investment. Governments keen on ensuring that investment in physical structures yields the highest benefits possible will want to pay particular attention to markups in the sectors involved in the production of investment goods.

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[33]Some markets have become more concentrated during this time: for example, Nigeria moved from five to three firms.

References

ACEMOGLU, D., V. M. CARVALHO, A. OZDAGLAR, AND A. TAHBAZ-SALEHI (2012): "The Network Origins of Aggregate Fluctuations," *Econometrica*, 80, 1977–2016.

ALFARO, L. AND F. Z. AHMED (2010): "The Price of Capital: Evidence From Trade Data," *Harvard Business School BGIE Unit Working Paper*.

ATKIN, D. AND D. DONALDSON (2015): "Who's Getting Globalized? The Size and Implications of Intra-national Trade Costs," Working Paper 21439, National Bureau of Economic Research.

BACCHINI, F., P. GENNARI, AND R. IANNACCONE (2003): "A New Index of Production for the Construction Sector Based on Input Data," *Roma, Italy, Dipartimento delle Satitistiche Economiche, Instituto Nazional di Staitistica, Italy*.

BAQAEE, D. R. (2018): "Cascading Failures in Production Networks," *Econometrica*, 86, 1819–1838.

BAQAEE, D. R. AND E. FARHI (2019): "JEEA-FBBVA Lecture 2018: The Microeconomic Foundations of Aggregate Production Functions," *Journal of the European Economic Association*, 17, 1337–1392.

——— (2020): "Productivity and Misallocation in General Equilibrium," *The Quarterly Journal of Economics*, 135, 105–163.

BARTELSMAN, E., J. HALTIWANGER, AND S. SCARPETTA (2013): "Cross-Country Differences in Productivity: The Role of Allocation and Selection," *American Economic Review*, 103, 305–34.

BEKKERS, E. AND J. FRANCOIS (2013): "Trade and Industrial Structure with Large Firms and Heterogeneity," *European Economic Review*, 60, 69–90.

BENIGNO, G. AND L. FORNARO (2018): "Stagnation traps," *The Review of Economic Studies*, 85, 1425–1470.

BERGQUIST, L. F. AND M. DINERSTEIN (2020): "Competition and Entry in Agricultural Markets: Experimental Evidence from Kenya," *American Economic Review*, 110, 3705–47.

BERRY, S., M. GAYNOR, AND F. SCOTT MORTON (2019): "Do Increasing Markups Matter? Lessons From Empirical Industrial Organization," *Journal of Economic Perspectives*, 33, 44–68.

BESLEY, T., N. FONTANA, AND N. LIMODIO (forthcoming): "Antitrust policies and profitability in non-tradable sectors," *American Economic Review*.

BIGIO, S. AND J. LA'O (2020): "Distortions in Production Networks," *The Quarterly Journal of Economics*, 135, 2187–2253.

BOEHM, J. AND E. OBERFIELD (2020): "Misallocation in the Market for Inputs: Enforcement and the Organization of Production," *The Quarterly Journal of Economics*, 135, 2007–2058.

BUERA, F. J., J. P. KABOSKI, AND Y. SHIN (2011): "Finance and Development: A Tale of Two Sectors," *American Economic Review*, 101, 1964–2002.

BUREAU OF ECONOMIC ANALYSIS (2021): "Input-Output Accounts Data: Use Tables," .

BURSTEIN, A. T., J. C. NEVES, AND S. REBELO (2004): "Investment Prices and Exchange Rates: Some Basic Facts," *Journal of the European Economic Association*, 2, 302–309.

CARVALHO, V. M. (2014): "From Micro to Macro via Production Networks," *Journal of Economic Perspectives*, 28, 23–48.

CARVALHO, V. M., M. NIREI, Y. SAITO, AND A. TAHBAZ-SALEHI (2020): "Supply Chain Disruptions: Evidence from the Great East Japan Earthquake," *Columbia Business School Research Paper*.

CASELLI, F. AND J. FEYRER (2007): "The Marginal Product of Capital," *The Quarterly Journal of Economics*, 122, 535–568.

CAUNEDO, J. AND E. KELLER (2021): "Capital Obsolescence and Agricultural Productivity," *The Quarterly Journal of Economics*, 136, 505–561.

CEMBUREAU (2020): "Key Facts Figures," https://cembureau.eu/about-our-industry/key-facts-figures/, accessed: 2020-11-03.

COLLARD-WEXLER, A. (2013): "Demand Fluctuations in the Ready-mix Concrete Industry," *Econometrica*, 81, 1003–1037.

COLLIER, P., M. KIRCHBERGER, AND M. SÖDERBOM (2016): "The Cost of Road Infrastructure in Low-and Middle-Income Countries," *World Bank Economic Review*, 30, 522–548.

DE LOECKER, J. AND J. EECKHOUT (2018): "Global Market Power," Working Paper 24768, National Bureau of Economic Research.

DE LOECKER, J., J. EECKHOUT, AND G. UNGER (2020): "The Rise of Market Power and the Macroeconomic Implications," *The Quarterly Journal of Economics*, 135, 561–644.

DE LOECKER, J., P. K. GOLDBERG, A. K. KHANDELWAL, AND N. PAVCNIK (2016): "Prices, Markups, and Trade Reform," *Econometrica*, 84, 445–510.

DEMIR, B., A. C. FIELER, D. Y. XU, AND K. K. YANG (2021): "O-Ring Production Networks," Centre for Economic Policy Research Working Paper DP15741.

EATON, J. AND S. KORTUM (2001): "Trade in Capital Goods," *European Economic Review*, 45, 1195–1235.

EDMOND, C., V. MIDRIGAN, AND D. Y. XU (2019): "How Costly are Markups?" Unpublished Manuscript.

FORBES (2020): "Africa's Billionaires," https://www.forbes.com/africa-billionaires/list/#tab:overall, accessed: 2020-02-21.

GLOBAL COMPETITION REVIEW (2020): "Indian Tribunal Confirms 784 million Cement Cartel Fines," https://globalcompetitionreview.com/article/1172272/indian-tribunal-confirms-eur784-million-cement-cartel-fines, accessed: 2020-03-17.

GRASSI, B. (2018): "IO in IO: Size, Industrial Organization, and the Input-Output Network-Make a Firm Structurally Important," Working Paper 691, Innocenzo Gasparini Institute for Economic Research, Bocconi University.

GUTIÉRREZ, G. AND T. PHILIPPON (2016): "Investment-less Growth: An Empirical Investigation," Working Paper 22897, National Bureau of Economic Research.

HERCZEG, M., D. MCKINNON, L. MILIOS, I. BAKAS, E. KLAASSENS, K. SVATIKOVA, AND O. WIDERBERG (2014): "Resource Efficiency in the Building Sector," *Final report. Prepared for European Commission by ECORYS and Copenhagen Resource Institute, Rotterdam, the Netherlands*.

HORTAÇSU, A. AND C. SYVERSON (2007): "Cementing Relationships: Vertical Integration, Foreclosure, Productivity, and Prices," *Journal of Political Economy*, 115, 250–301.

HSIEH, C.-T. AND P. J. KLENOW (2007): "Relative Prices and Relative Prosperity," *American Economic Review*, 97, 562–585.

——— (2009): "Misallocation and Manufacturing TFP in China and India," *The Quarterly Journal of Economics*, 124, 1403–1448.

INTERNATIONAL CEMENT REVIEW (2013): "Global Cement Report 10," Tradeship Publications Ltd.

——— (2019a): "Global Cement Report 13," Tradeship Publications Ltd.

——— (2019b): "Plant Database," www.cemnet.com, accessed: 2019-11-12.

JONES, C. I. (1994): "Economic Growth and the Relative Price of Capital," *Journal of Monetary Economics*, 34, 359–382.

——— (2011): "Intermediate Goods and Weak Links in the Theory of Economic Development," *American Economic Journal: Macroeconomics*, 3, 1–28.

KREMER, M. (1993): "The O-Ring Theory of Economic Development," *The Quarterly Journal of Economics*, 108, 551–575.

LEHN, C. V. AND T. WINBERRY (forthcoming): "The Investment Network, Sectoral Comovement, and the Changing US Business Cycle," *The Quarterly Journal of Economics*.

LEONE, F., R. MACCHIAVELLO, AND T. REED (2021): "The Falling Price of Cement in Africa," Policy Research Working Paper No WPS9706, World Bank Washington, DC.

LIU, E. (2019): "Industrial Policies in Production Networks," *The Quarterly Journal of Economics*, 134, 1883–1948.

LIU, E., A. MIAN, AND A. SUFI (2021): "Low interest rates, market power, and productivity growth," Tech. rep.

MCBRIDE, M. E. (1983): "Spatial Competition and Vertical Integration: Cement and Concrete Revisited," *The American Economic Review*, 73, 1011–1022.

MEHTA, P. K. AND P. J. M. MONTEIRO (2012): *Structural Concrete: Theory and Design*, McGraw-Hill Education.

MEIJER, J. R., M. A. HUIJBREGTS, K. C. SCHOTTEN, AND A. M. SCHIPPER (2018): "Global Patterns of Current and Future Road Infrastructure," *Environmental Research Letters*, 13, 064006.

MELITZ, M. J. (2003): "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71, 1695–1725.

MILLER, N. H. AND M. OSBORNE (2014): "Spatial Differentiation and Price Discrimination in the Cement Industry: Evidence from a Structural Model," *The RAND Journal of Economics*, 45, 221–247.

MONGEY, S. (2019): "Market Structure and Monetary Non-neutrality," Unpublished Manuscript.

PETERS, M. (2020): "Heterogeneous Markups, Growth, and Endogenous Misallocation," *Econometrica*, 88, 2037–2073.

QUARTZ AFRICA (2017): "Africa's Richest Man has a Built-in Advantage with Nigeria's Government," https://qz.com/africa/1098137/africas-richest-man-has-a-built-in-advantage-with-nigerias-government, accessed: 2020-02-21.

RESTUCCIA, D. AND R. ROGERSON (2008): "Policy Distortions and Aggregate Productivity with Heterogeneous Establishments," *Review of Economic Dynamics*, 11, 707–720.

RESTUCCIA, D. AND C. URRUTIA (2001): "Relative Prices and Investment Rates," *Journal of Monetary Economics*, 47, 93–121.

RÖLLER, L.-H. AND F. STEEN (2006): "On the Workings of a Cartel: Evidence from the Norwegian Cement Industry," *American Economic Review*, 96, 321–338.

RYAN, S. P. (2012): "The Costs of Environmental Regulation in a Concentrated Industry," *Econometrica*, 80, 1019–1061.

SALVO, A. (2010): "Inferring market power under the threat of entry: the case of the Brazilian cement industry," *The RAND Journal of Economics*, 41, 326–350.

SCHMITZ JR, J. A. (2001): "Government Production of Investment Goods and Aggregate Labor Productivity," *Journal of Monetary Economics*, 47, 163–187.

SYVERSON, C. (2004): "Market Structure and Productivity: A Concrete Example," *Journal of Political Economy*, 112, 1181–1222.

——— (2008): "Markets: Ready-mixed Concrete," *Journal of Economic Perspectives*, 22, 217–234.

TANZANIA NATIONAL BUREAU OF STATISTICS (2021): "Input-Output Accounts Data: Use Tables," .

TIMMER, M. P., E. DIETZENBACHER, B. LOS, R. STEHRER, AND G. J. DE VRIES (2015): "An Illustrated User Guide to the World Input–Output Database: The Case of Global Automotive Production," *Review of International Economics*, 23, 575–605.

UNECE (2012): *Forest Products Annual Market Review 2011-2012*, United Nations Economic Commission for Europe.

UZAWA, H. (1963): "On a Two-sector Model of Economic Growth II," *The Review of Economic Studies*, 30, 105–118.

WORLD BANK (2015a): "Operational Guidelines and Procedures for Measuring the Real Size of the World Economy: 2011 International Comparision Program," Washington, DC: World Bank.

——— (2015b): "Purchasing Power Parities and the Real Size of World Economies: A Comprehensive Report of the 2011 International Comparison Program," Washington, DC: World Bank.

——— (2016): "Breaking Down Barriers : Unlocking Africa's Potential through Vigorous Competition Policy," World Bank Washington, DC.

——— (2020): "Purchasing Power Parities and the Size of World Economies: A Comprehensive Report of the 2017 International Comparison Program," Washington, DC: World Bank.

WORLD STEEL ASSOCIATION (2018): https://www.worldsteel.org/steel-by-topic/steel-markets/buildings-and-infrastructure.html, accessed September 2018.

YOUNG, J. (2001): "Portland Cements," in *Encyclopedia of Materials: Science and Technology*, ed. by K. J. Buschow, R. W. Cahn, M. C. Flemings, B. Ilschner, E. J. Kramer, S. Mahajan, and P. Veyssière, Oxford: Elsevier, 7768 – 7773.

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.

A.1. ICP

We use price data collected in the context of the 2011 and 2017 International Comparison Project. The price surveys contain detailed instructions and guidelines for those reporting prices, and aims 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 if labour, including "off the books" payments etc. 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 percent, although this may not hold for civil engineering works (World Bank, 2015a). We base our choice on inputs on Bacchini, Gennari, and Iannaccone (2003), Herczeg, McKinnon, Milios, Bakas, Klaassens, Svatikova, and Widerberg (2014), World Steel Association (2018), and UNECE (2012).

Bacchini et al. (2003) attempt to construct an alternative index of construction sector production and find that the most important category of intermediate goods is the production of concrete, cement and plaster and products made from these materials, followed by the manufacture of structural metal products. Bricks, tiles and construction products, ceramic tiles and flags and builder's carpentry and joinery are also included.

As mentioned above, the evidence suggests concrete, cement and plaster are the most important raw material inputs in the construction sector. Due to constraints regarding the data available, we use prices for ready-mix concrete and ordinary Portland cement to proxy for all cement-based material inputs. The fact that cement prices are strongly correlated with sand prices in the ICP dataset, with a correlation coefficient of .54, indicates that cement prices should give a decent approximation of plaster/mortar based inputs (sand is the other

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)
Plant-level data	
Plant capacity	Global Cement Report 13, online database
Firm-level data	
Cost of goods sold	Worldscope
Revenue	Worldscope
General selling and administrative costs	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 onwards 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.

major constituent of plaster and mortar).

A report by ECORYS, a consultancy, and the Copenhagen Resource Institute finds that steel,

copper and aluminium dominate metal use in the construction industry (Herczeg et al., 2014). The ICP dataset contains prices for several types of steel, as well as copper pipes. However, there are only 19 observations for the price of copper pipes. Therefore, we include structural steel and mild steel reinforcement in the selection of key material inputs. A report by OECD researchers finds that steel is one of societies most used materials, with the construction sector taking up more than half of all steel consumption. Moreover, according to the World Steel Association, and industry group, 25 percent of steel used in buildings is structural steel sections, with 44 percent being reinforcement bars, while 60 percent of steel used in transport infrastructure construction is reinforcement bars, with the rest primarily made up of structural sections and rail tracks (World Steel Association, 2018). Clearly, structural steel sections and reinforcement bars make up the majority of steel used in construction, and therefore they are included in the selection of core inputs.

According to the UN's data regarding forestry output for 2015, softwood timber made up 52.5 percent of industrial roundwood consumption for construction in Europe (softwood, hardwood and wood based panels), and 55 percent in North America (UNECE, 2012). This indicates softwood is the most widely used wood-based input in construction, and is thus included in the selection of core inputs. ECORY's report also estimates that bricks are the third largest material input by weight in the construction sector making up 6.7 percent of all input, behind only concrete(42 percent) and aggregates (25 percent). Therefore, we include common bricks. Table A.2 lists all inputs used in this paper.

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.

A.2. 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 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 im million tons per year.

To match the 2017 ICP prices with market structure we use the global plant database (International Cement Review, 2019b). The database contains information on group ownership, company name, facility name and location of the plant as well as capacity at a plant 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.[34]

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.

A.3. UN COMTRADE

Cement

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.

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".

Market structure of 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

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

than 1500 tons of Portland cement, equalling the amount of cement needed for about 100 single-family homes.[35] We exclude countries that are mainly importing from China due to lack of data on the market structure in China.

Other data from 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).

A.4. Transport Infrastructure

We use two different sources of data to measure the quality of transport infrastructure: first, we use data from the Global Roads Inventory Dataset on the km of roads from Meijer, Huijbregts, Schotten, and Schipper (2018). Second, from the Logistics Performance Index we use information on the quality of trade-related infrastructure.

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

B. Additional Tables and Figures

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

	concrete (m^3)	cement (ton)	aggregate (m^3)	sand (m^3)
Panel A: ICP 2011				
East Asia and Pacific	176.0	237.5	44.4	33.3
Europe and Central Asia	113.2	170.3	26.8	21.8
Latin America and Caribbean	262.8	324.2	44.5	38.1
Middle East and North Africa	188.5	232.2	31.1	29.7
North America	131.3	165.0	51.6	49.0
South Asia	305.6	367.1	61.0	51.3
Sub-Saharan Africa	419.7	544.5	85.1	43.5
Panel B: ICP 2017				
East Asia and Pacific	170.2	229.6	49.0	35.1
Europe and Central Asia	130.0	203.8	43.9	35.8
Latin America and Caribbean	266.8	351.0	55.1	38.8
Middle East and North Africa	177.8	212.1	39.6	36.9
North America	148.3	127.3	23.0	17.3
South Asia	282.2	346.1	94.8	61.5
Sub-Saharan Africa	296.7	410.7	75.1	57.2

	softwood (m^3)	bricks (m^3)	mild steel (ton)	struc. steel (ton)
Panel C: ICP 2011				
East Asia and Pacific	820.1	158.3	1858.7	1057.9
Europe and Central Asia	417.2	269.1	1122.1	1611.5
Latin America and Caribbean		167.7	2489.0	2591.0
Middle East and North Africa	797.9	302.4	1914.0	2293.3
North America	124.6	425.7	964.2	1185.4
South Asia	1389.0	200.1	2774.7	
Sub-Saharan Africa	762.5	444.8	3050.3	3491.8
Panel D: ICP 2017				
East Asia and Pacific	1132.1	185.0	1594.2	1978.6
Europe and Central Asia	769.0	432.0	1150.3	1536.3
Latin America and Caribbean	1047.4	265.5	2114.7	2651.3
Middle East and North Africa	924.3	225.9	1930.9	2493.7
North America	1394.3	466.1	1125.1	1167.5
South Asia	2282.3	259.0	2401.8	2709.7
Sub-Saharan Africa	1385.3	354.6	2899.6	7957.5

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: 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.

66

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

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
ln (n < 300km) FT	-0.15***	-0.15***	-0.12**	-0.32*	-0.31*	-0.25
	(0.054)	(0.054)	(0.049)	(0.17)	(0.18)	(0.18)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	Yes	No	Yes	Yes
Fuel	No	No	Yes	No	No	Yes
F-Stat				7.9	7.8	7.4
N	86	86	83	86	86	83
R-sq	0.212	0.220	0.365	0.074	0.095	0.285

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

Table B.4: Dependent variable: ln (Price of Cement)

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln n$	-0.25***	-0.25***	-0.19***	-0.46***	-0.48***	-0.49***
	(0.048)	(0.048)	(0.048)	(0.15)	(0.15)	(0.14)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Infrastructure	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	Yes	No	Yes	Yes
Fuel	No	No	Yes	No	No	Yes
F-Stat				6.9	7.1	9.6
N	164	164	157	164	164	157
R-sq	0.370	0.377	0.436	0.259	0.261	0.239

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

Table B.5: Dependent variable: ln (Price of Cement)

|	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
ln n	-0.25***	-0.24***	-0.17***	-0.54***	-0.55***	-0.57***
	(0.051)	(0.051)	(0.052)	(0.19)	(0.19)	(0.19)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Scale	Yes	Yes	Yes	Yes	Yes	Yes
Infrastructure	Yes	Yes	Yes	Yes	Yes	Yes
Governance	No	Yes	Yes	No	Yes	Yes
Fuel	No	No	Yes	No	No	Yes
F-Stat				5.3	4.9	7.4
N	149	149	142	149	149	142
R-sq	0.374	0.383	0.436	0.188	0.190	0.132

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

Table B.6: Dependent variable: ln (Price of Cement)

	OLS		
	(1)	(2)	(3)
ln (Number of firms)	-0.27***	-0.26***	-0.13**
	(0.074)	(0.072)	(0.055)
ln (Number of plants)	0.023	0.017	-0.037
	(0.069)	(0.070)	(0.059)
Time FE	Yes	Yes	Yes
Scale	Yes	Yes	Yes
Governance	No	Yes	Yes
Fuel	No	No	Yes
N	176	176	168
R-sq	0.316	0.331	0.431

Note: Reported standard errors are clustered at the country level. *, **, *** denote significance at 10%, 5% and 1% levels.
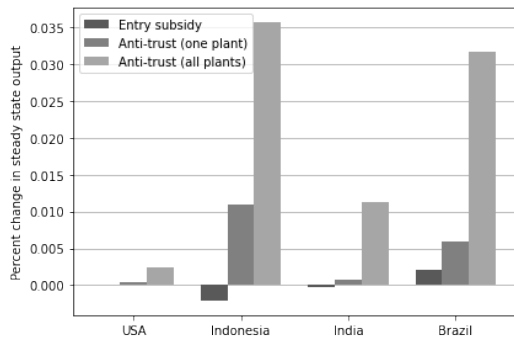
Figure A.1: Capital share for different measures of user cost
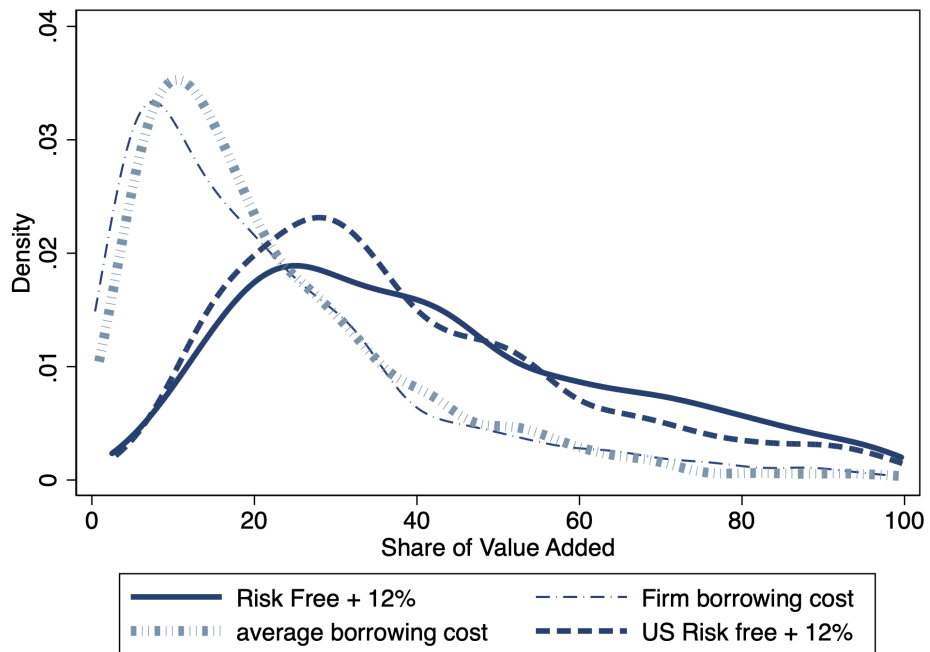
Note: This figure shows the distribution of capital's share of value added for three different measures of the user cost of capital.

Figure A.2: Impact of competition policies on steady-state output using alternative markup estimates
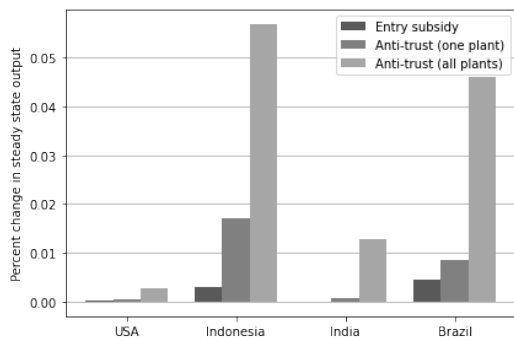
(a) User cost: risk free rate plus premium
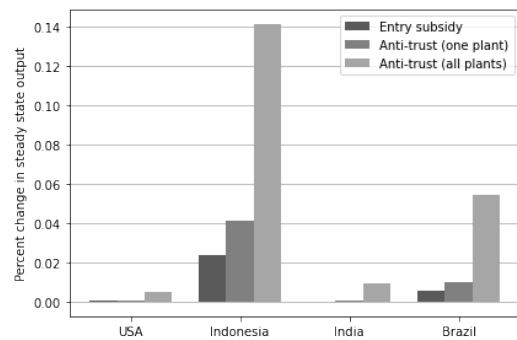

(b) User cost: US risk free rate plus premium
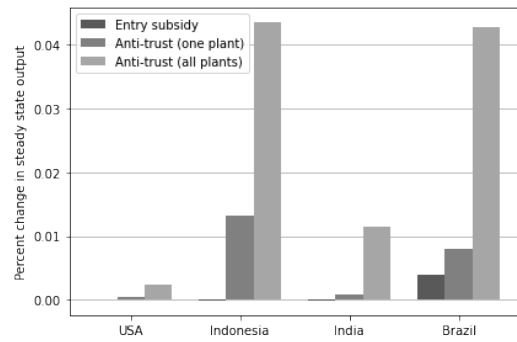
(c) User cost: firm borrowing cost

(d) Production function approach

Note: This figure shows the impacts of competition policies on steady-state output using different markup estimates.

Figure A.3: Cement prices and construction costs: 2005 ICP data
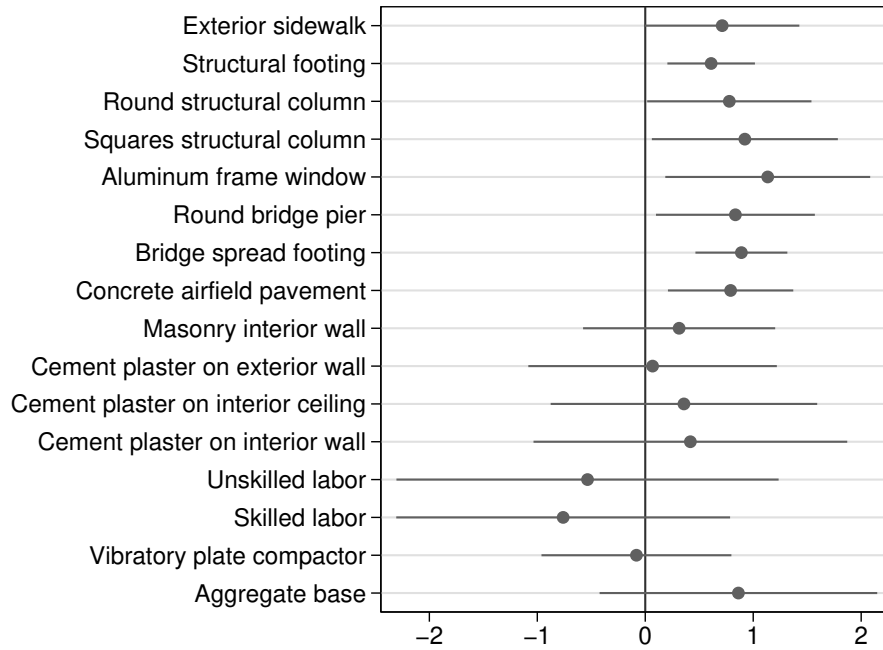
Note: This figure shows the coefficients from a regression of log cement prices on construction composites using 2005 ICP data.

Figure A.4: Cement prices and construction costs per square meter
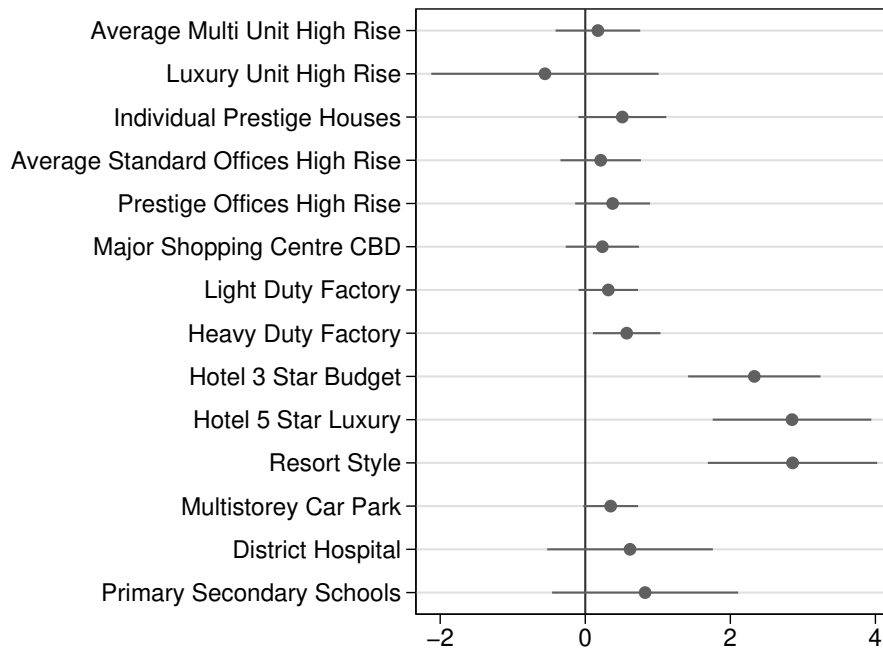
Note: This figure shows the coefficients from a regression of log cement prices on construction costs per square meter.

C. Limit pricing and monopoly outcomes

In standard models of monopolistic competition, $\varepsilon > 1$ is assumed to obtain a sensible result. This is because when $\varepsilon \leq 1$, the monopolist's profits are strictly decreasing in the quantity produced. This is because expenditure is non-decreasing in price. Therefore a monopolist's optimal strategy is to produce the minimum possible amount, which yields the highest possible price and thus profits. This scenario is clearly counterfactual. Allowing for entry and subsequent oligopoly can resolve this issue.

This section presents an explanation for the assumption of limit pricing for monopolists. Throughout, we assume that if $\varepsilon \leq 1$, then

$$\lim_{Q \to 0} X^c(Q) > r^* E + F$$

where $X^c(Q) = p(Q)Q$ is the expenditure on cement as a function of quantity produced Q.[36] That is, when the elasticity of demand is less than or equal to unity, expenditure in the market will eventually surpass the annualised entry cost as the quantity produced goes to zero. This means that there is some level of price such that the entrant can profitably enter. To simplify the exposition, we consider the case in which costs are homogeneous across firms $c_i = c$. We assume that when $n = 1$ incumbents consider the strategy of potential entrants when setting prices, while when $n > 1$ firms only consider the strategy of other firms in the market. To keep the exposition tractable, assume that incumbents choose quantity to produce, which the entrant can respond to by either paying the entry costs and producing, or staying out of the market.

Proposition 5 *Consider the case where the market can only support a single entrant $n = 1$, but $\frac{1}{2} < \varepsilon \leq 1$. Define $\tilde{\pi}^E(q^I)$ as an entrant's optimal production upon entry, given the incumbent's production q^I. In Nash equilibrium, the incumbent will produce a limiting quantity, given by*

$$q^* = \min\{q : \tilde{\pi}^E(q) \leq r^* E + F\}$$

where the entrant's strategy is to enter the market (competing a la Cournot) when $q^I < q^*$ and remain outside the market otherwise.

Proof

For ease of notation, we define total annualised entry costs as $r^* E + F = \bar{E}$ while $\pi^i(q^i, q^{-1}$ denotes the profits of firm I as a function of their own production q^i and other firms' production q^{-1}. We start in part 1 by assuming the cutoff value q^* exits and show that if this

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[36]This ensures that when $\varepsilon = 1$, the constant expenditure on cement is larger than the entry cost. Whereas when < 1, its share of its CES bundle will go to one, and we require that this bundles expenditure share be greater than entry cost. In general equilibrium, this condition will depend on the network structure.

is the case, we have the limiting Nash equilibrium. We then proceed to show in part 2 that the cutoff value q^* does indeed exist.

Part 1 First assume there exists some cutoff value q^* such that $\tilde{\pi}^E(q^*) = \bar{E}$. Assume that the entrant and incumbent are employing strategies s^i as outlined in Proposition 5, such that

$$s^I = q^*$$

$$s^E = \begin{cases} 0 & \text{if } q^I \geq q^* \\ q^{cournot}(q^I) & \text{if } q^I < q^* \end{cases}$$

where $q^{cournot}(q^I)$ is the best response to q^I in cournot competition. We will now show that neither party has an incentive to deviate from their strategy.

Firstly, consider the entrant. We know from the definition of q^*, the maximum profit the entrant can earn given $q^I = q^*$ is zero. Therefore the entrant naturally has no incentive to change their strategy.

Next consider the incumbent. Given that $\varepsilon < 1$, we know that profits are decreasing in the quantity produced in the market. The incumbent therefore has an incentive to produce the minimum quantity possible. However, she must also consider the possibility of entry and competition by the entrant. Formally, suppose $q^I = q^*$, and take the entrant's strategy s^E as given. We know that for any $q^I \leq q^*$, $q^E = 0$. Therefore, for all $q^I \leq q^*$ profits are given by

$$\pi(q^I|s^E) = q^I \left(\left(\frac{q^I}{Q} P \right)^{-\frac{1}{\varepsilon}} - c \right), \quad \text{for all } q^I \leq q^*$$

It follows from $\varepsilon \leq 1$ that this is decreasing in q^I, which implies

$$\pi(q^*|s^E) > \pi(q^I|s^E) \quad \text{for all } q^I \leq q^*.$$

Therefore q^* dominates any strategy $q^I < q^*$, taking s^E as given. Now consider any $q^I > q^*$. We know in this case, the entrant will compete in Cournot competition. Therefore, the incumbent's best response will also be the response in Cournot competition. Given $\varepsilon < \frac{1}{2}$ the equilibrium will be as described in Section 3, and profits in this case will be

$$\max_{q^E > q^*} \pi(q^I|s^E) = \frac{pQ(2)}{\varepsilon 4}$$

where $pQ(2)$ is the expenditure on cement when $n = 2$, given in Section 3. The fact that

the market can support one firm $n = 1$ is equivalent to stating

$$\bar{E} > \frac{pQ(2)}{\varepsilon 4} = \max_{q^E > q^*} \pi(q^I | s^E) \tag{C.1}$$

which provides an upper bound on profits in Cournot competition. Now consider prospective profits for entrants given q^*. In order to make a profit, entrants will produce a positive quantity upon entry $q^E > 0$. From before we know that $\varepsilon < 1$ implies aggregate profits are decreasing in the quantity produced $Q = q^E + q^I$. Therefore given q^*, aggregate profits will be less when the entrant produces, that is

$$(q^E + q^*)(p(q^E + q^*) - c) < \pi(q^* | s^E) \quad \text{for all } q^E > 0$$

which in turn implies

$$\pi(q^* | s^E) > \tilde{\pi}^E(q^*) = \bar{E}$$

from the fact that the entrants profits are bounded from above by total profits in the market. From equation (C.1) we therefore have that $\pi(q^* | s^E) > \pi(q^I | s^E)$ for all $q^I > q^*$, while we have already shown the result for $q^I \leq^*$. Thus, q^* is the incumbents best response to the entrants strategy s^I. This implies that conditional on the existence of q^*, this is a Nash equilibrium.

Part 2 We now prove the existence of the cutoff value q^*. Suppose it does not exist. Then we have

$$\tilde{\pi}^E(q^I) < \bar{E} \quad \text{for all } q^I > 0 \tag{C.2}$$

which implies the entrant will never enter the market. We can then pick an arbitrarily small $q^I = \delta$ such that the above condition holds for all q^E. Suppose in turn the entrant chooses to produce $\kappa\delta$, so that the entrant's share of production upon entry is given by $\frac{\kappa}{\kappa+1}$. This implies profits are given by

$$\pi^E(\kappa\delta, \delta) = \frac{\kappa}{\kappa+1}\left(X^c((\kappa+1)\delta)\right) - \kappa\delta c$$

where $X^c(Q) = p(Q)Q$ is the expenditure on cement as a function of quantity produced Q. Now consider this profit as δ tends to zero. By assumption we know that $\lim_{Q \to 0} X^c(Q) > \bar{E}$, which implies

$$\lim_{\delta \to 0} \pi^E(\kappa\delta, \delta) > \frac{\kappa}{\kappa+1}\bar{E}$$

Given that this condition holds for any constant κ, that implies that the entrant can choose κ^* such that $\lim_{\delta \to 0} \pi^E(\kappa^*\delta, \delta) > \bar{E}$. This contradicts equation (C.2). Therefore the cutoff value q^* exists. $\lim_{Q \to 0} X^c(Q) > \bar{E}$. Q.E.D.

D. Proof of proposition 1

Proof The exogeneity of market-wide costs x in the price equation

$$\ln p^c = \gamma \ln n + x\beta + \eta$$

implies the statement is equivalent to stating $COV(n, \eta) > 0$. Therefore, we wish to prove that the unobserved component of prices is positively correlated with the number of firms producing in the market. That is, when prices rise but costs do not, more firms will enter the market.

We start by showing the result for the cutoff value $n^*(\eta)$, which is a continuous function of η. The result then easily extends to the integer valued $n(\eta)$. First we show n^* is an increasing function of η. Totally differentiating unconditional expected profits $\mathbb{E}[\pi(n^*(\eta), p(\eta))] = \bar{\pi}(n^*(\eta), p(\eta))$ with respect to η yields

$$\frac{d\bar{\pi}}{d\eta} = \frac{\partial \bar{\pi}}{\partial p}\frac{dp}{d\eta} + \frac{\partial \bar{\pi}}{\partial n^*}\frac{dn^*}{d\eta}$$

by the chain rule, as all other variables in the system are exogenous. Equation (5) implies that the equilibrium level of unconditional expected profits $\bar{\pi}$ is constant, and therefore $\frac{d\bar{\pi}}{d\eta} = 0$. This implies

$$\frac{\partial \bar{\pi}}{\partial p}\frac{dp}{d\eta} = -\frac{\partial \bar{\pi}}{\partial n^*}\frac{dn^*}{d\eta}.$$

Bekkers and Francois (2013) show that unconditional expected profits are an increasing function of prices, that is, $\frac{d\pi}{dp} > 0$. Moreover, equation (3) naturally implies $\frac{dp}{d\eta} > 0$, meaning price increases as unobserved cost increases. Therefore,

$$\frac{\partial \bar{\pi}}{\partial p}\frac{dp}{d\eta} > 0$$

$$\Rightarrow \frac{\partial \bar{\pi}}{\partial n^*}\frac{dn^*}{d\eta} < 0$$

Furthermore, Bekkers and Francois (2013) show that profits and the number of entrant firms are inversely related, that is $\frac{\partial \bar{\pi}}{\partial n^*} < 0$. This, combined with the above expression,

75

implies

$$\frac{dn^*}{d\eta} > 0$$

which means $n^*(\eta)$ is an increasing function of η. Now we have that

$$COV(n^*,\eta) = \mathbb{E}\left[\left(\eta - \mathbb{E}[\eta]\right)\left(n^*(\eta) - \mathbb{E}[n^*(\eta)]\right)\right]$$
$$= \mathbb{E}\left[\left(\eta - \mathbb{E}[\eta]\right)\left(n^*(\eta) - n^*(\mathbb{E}[\eta])\right)\right] > 0$$

which is greater than zero from the fact that $\frac{dn^*}{d\eta} > 0$, by the mean value theorem.
The number of firms that enter the market is given by

$$n^e(\eta) = x \quad \text{if} \quad n^*(\eta) \in [x, x+1)$$

while the number of firms that actually produce is the fraction of these which receive a cost draw greater than the prevailing price $p(\eta)$, which is itself increasing in η. Therefore we have that

$$COV(n^*,\eta) = \mathbb{E}\left[\left(\eta - \mathbb{E}[\eta]\right)\left(n(\eta) - n(\mathbb{E}[\eta])\right)\right] > 0$$

which gives the desired result. Q.E.D.

E. General equilibrium 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.

E.1. Economic Environment

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

$$C = \prod_{i=1}^{N} c_i^{\beta_i} \tag{E.1}$$

$$I = \prod_{i=1}^{N} x_i^{\lambda_i} \tag{E.2}$$

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

$$q_i = A_i (k_i^{\alpha} \ell_i^{1-\alpha})^{1-\sum_{i=1}^{N} \sigma_{i,j}} \prod m_{i,j}^{\sigma_{i,j}} \tag{E.3}$$

where $m_{j,i}$ denotes industry i's use of intermediate input j. The assumption that the production function is Cobb-Douglas, and of constant α implies capital labour ratios are constant across all sectors, which simplifies the analysis. Capital evolves according to

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

where δ is a constant depreciation rate.

E.2. Producers

We model producers at an industry level. We assume that firms change markup μ_i over marginal costs, while choosing inputs to minimize marginal costs (E.3). Markups are microfounded from the two stage entry game considered in Section 3, and are made up of fixed cost payments and pure profits $\mu_i = \chi_i + \pi_i$. Pure profits are rebated lump sum to households, while we model fixed costs simply as deadweight losses. The producers budget constraint takes the form

$$\Pi_i = p_i q_i - \left(\sum_{i=1}^{N} p_j m_{j,i} + r k_i + w \ell_i + F_i \right) \tag{E.4}$$

where p_i denotes the price of good i, F_i are fixed costs and Π_i are profits rebated to households.

E.3. Households

In the main text, we stated the Euler equation for a representative household in a standard neoclassical model with discount rate ρ. Such an economy is only defined when $\rho > 0$. The derivation of this Euler equation is a textbook result, which we exclude for brevity. Instead we focus on a household block that can sustain negative effective discount rates in the model.

Here we describe a model with idosyncratic unemployment risk following Benigno and Fornaro (2018), which features an effective discount rate $\tilde{\rho}$ which can be less than zero. We do this in order to allow our model to match the high savings rates seen in Indonesia and India in our data.

Following Liu, Mian, and Sufi (2021), we first derive the aggregate Euler equation in discrete time, then take the continuous time limit to economy consists of a unit measure of households, each with preferences given by

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

where C_t is the composite consumption good and ρ is the discount rate. Households supply labour inelastically earning wages w_t and hold one period risk free bonds b_t, earning returns R_t. Households also face constant probability v of being unemployed at any instant. There is also a lump sum transfer T_t from employed to unemployed households. This transfer is chosen such that unemployed income is a constant fraction $q < 1$ of employed income. Finally we assume that unemployed households cannot borrow and that trade in firm shares is impossible, so each household receives the same profit stream. The household's budget constraint is given by

$$p_{c,t}C_t + \frac{b_{t+1}}{1+R_t} = \zeta_t w_t L_t + d_t + T_t + b_t$$

where ζ_t is an indicator equal to one when the household is employed while d_t is the total dividend stream to households from firms, which includes profits and capital payments, net of investment costs. As shown by Benigno and Fornaro (2018), the Euler equation of the employed implies the aggregate relation between consumption and real interest rates given by

$$\frac{c_{t+1}}{c_t} = e^{-\rho t}(1+R_t)(1-v+v/q)$$

using the fact that $p_{c,t} \equiv 1$ to exclude a term for inflation. We can take the limit of this

expression as the time period shrinks to zero to obtain

$$\frac{\dot{c}(t)}{c(t)} = R(t) - \tilde{\rho}$$

where $\tilde{\rho} = \rho + v - v/q$ is the discount rate modified to account for the risk of future unemployment, which induces precautionary savings. It is clear that $\tilde{\rho} < \rho$, implying that this model can sustain negative effective discount rates.

To close the model we assume that firms invest in capital, which they can trade freely at each instant. Arbitrage implies that the return on investing in bonds R is equal to the return on investing in capital (dropping time dependence)

$$R = \frac{r^k}{p_I} + \frac{\dot{p}_I}{P_I} - \delta$$

from which we can derive the aggregate consumption path, given by

$$\frac{\dot{c}}{c} = \frac{r^k}{p_I} + \frac{\dot{p}_I}{P_I} - \delta - \tilde{\rho}$$

which is simply equation (10) with a modified discount rate $\tilde{\rho}$.

E.4. Aggregation

We define nominal output gross of fixed costs as

$$Y^G = wL + rK + \tau Y^G$$

where τ is the aggregate profit rate gross of fixed costs. We can therefore define net nominal output as

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

where $Y^F = wL + rK$ is factor income and $P_y F = \sum_{i=1}^{N} P_y F_i$ are total fixed costs in the economy. Market clearing implies that

$$P_Y Y = wL + rK + \Pi - P_Y F = p_I I + p_c C \qquad \text{(E.5)}$$

which is simply the sum of households' expenditures. Letting $\tau = \frac{\Pi}{Y}$, it is straightforward to show that $\frac{rK}{Y} = \alpha(1-\tau)$. Fixed costs are modelled as deadweight losses, priced according to the aggregate output deflator.

E.5. Input-output definitions

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

$$\mathbf{\Omega} = [\omega_{i,j}] = \left[\frac{p_j m_{j,i}}{p_i q_i} \right] \tag{E.6}$$

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

$$\tau = \sum_{i=1}^{N} \gamma_i \left(1 - \frac{1}{\mu_i} \right). \tag{E.7}$$

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 $\tau_c = \sum_{i=1}^{N} \gamma_i^c \left(1 - \frac{1}{\mu_i} \right)$. We similarly define the cost-based input-output matrix $\mathbf{\Sigma}$, or production elasticity matrix, as

$$\mathbf{\Sigma} = \left[\mu_i \omega_{i,j} \right] \tag{E.8}$$

noting that

$$\mu_i p_i = q_i w \ell_i + r k_i + \sum_{k=1}^{N} p_k m_{k,i}.$$

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

$$\psi^{C\prime} = \beta'(I - \mathbf{\Sigma})^{-1}, \quad \psi^{I\prime} = \lambda'(I - \mathbf{\Sigma})^{-1}$$

while we define the influence vector for total output with respect to a base year t_0 as follows

$$\xi = s_{t_0} \psi^I + (1 - s_{t_0}) \psi^C$$

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

We now turn to proving the main propositions in the text.

E.6. Proofs of general equilibrium model

Lemma 1 *The equilibrium price vector is given by*

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

where $\boldsymbol{\kappa}$ is a vector of constants 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 $A_j = \prod_{i=1}^N (\kappa_i A_i)^{\gamma_i^j}$ for $j \in \{c, I\}$, where κ_i are constants dependent on the shares of production.

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

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

where $\kappa_i = \prod_{j=1}^N \sigma_{i,j} \ln \sigma_{i,j}$ is a constant dependent on the shares of production in the model and $C = \alpha^\alpha (1 - \alpha)^{1-\alpha}$. This can be written in matrix form as

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

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

$$\ln \mathbf{P} = -(I - \mathbf{\Sigma})^{-1}(\ln \mathbf{A} - \ln \boldsymbol{\mu} - \boldsymbol{\kappa}) + \mathbb{1}_N (\alpha \ln r + (1 - \alpha)\ln w + \ln C) \tag{E.10}$$

From Lemma 1 and equation (E.12), the price of investment goods can be written as

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

or equivalently in levels using $\psi^{C\prime} = \beta'(I-\Sigma)^{-1}$ and $\psi^{I\prime} = \lambda'(I-\Sigma)^{-1}$ we have

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

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

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

<div align="right">Q.E.D.</div>

In the main text, we ignore the constant κ_i as we can always normalise technology to remove these terms.

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*

$$P_{y,t} = p_I^{s_{t_0}} \tag{E.11}$$

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

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

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

Proof of Proposition 2 Now by our choice of numeraire, $\ln P_c = 0$. We can use Lemma 1 to obtain

$$\ln p_c = \beta'\ln \mathbf{P} = 0$$
$$\alpha\ln r + (1-\alpha)\ln w = \gamma^{C\prime}(\ln \mathbf{A} - \ln \boldsymbol{\mu} - \boldsymbol{\kappa}) + \ln C \tag{E.12}$$

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

We now use this to obtain an expression for deflated aggregate output. Equal factor intensities across sectors implies 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

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

where $\ln C = \alpha\ln\alpha + (1-\alpha)\ln(1-\alpha)$. Using equation (E.12), we can therefore define factor income in logs as

$$\ln Y^F = \gamma^{C\prime}(\ln A - \ln\mu - \kappa) + \alpha\ln K + (1-\alpha)\ln L$$

or equivalently in per capita levels

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

where $D_c = \prod_{i=1}^N \mu_i^{-\gamma_i^C}$, $A_c = \prod_{i=1}^N (\kappa_i A_i)^{\gamma_i^C}$ while $C = \alpha^\alpha(1-\alpha)^{1-\alpha}$. From this we can obtain nominal net output from its definition. Dividing nominal output by the output deflator (E.11), we have

$$Y = \frac{D_c A_c}{p_I^{s_{t_0}}(1-\tau)}k^\alpha - F$$

Now from the definition of p_I given in Lemma 1, we have that

$$Y = \frac{(D_c A_c)^{1-s_{t_0}}(D_I A_I)^{s_{t_0}}}{1-\tau}k^\alpha - F$$

Now defining $\psi = s_{t_0}\psi^I + (1-s_{t_0})\psi^C$ alongside $A_y = \prod_{i=1}^N (\kappa_i A_i)^{-\gamma_i}$ we have

$$Y = D_y A_y k^\alpha - F$$

$$\text{where} \quad D_y = \frac{\prod_{i=1}^N (1-\tau_i)^{-\gamma_i}}{1-\tau}$$

which completes the proof.

Proof of Proposition 3 Constant capital labour ratios imply that

$$Y^F = \frac{rK}{\alpha}$$ (E.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 (10) implies

$$\frac{r^*}{p_I^*} = \delta + \rho$$ (E.14)

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

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

which gives the first result.

Now we obtain an expression for steady-state savings rate. The definition of steady state implies that $\dot{k} = 0$, which implies that in steady state

$$I^* = \delta k^*$$

while we know from equation (E.14) that $p_I^* = \frac{r^*}{\delta+\rho}$ which together with the above relation implies

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

This relation can be combined with (E.13) to obtain

$$p_I^* I^* = \chi Y^F$$

where $\chi = \frac{\alpha\delta}{\delta+\rho}$. This tells us that steady-state investment is a constant fraction of factor income. Therefore, differences in the steady-state savings rate are due to discrepancies between factor income and actual income, due to markups. Therefore defining the pure

profit rate as $\tilde{\tau} = \tau - F/Y$, we have that the savings rate out of net income is given by

$$\frac{p_I^* I^*}{P_Y Y^*} = s^* = (1 - \tilde{\tau}^*)\chi$$

which completes the proof.

Proof of Proposition 4 In any state, expenditure shares are given by

$$\gamma' = (s\lambda + (1-s)\beta)(I - \mathbf{\Omega})^{-1}$$

in the efficient economy the input-output matrix $\mathbf{\Omega}$ will equal to the elasticity matrix $\mathbf{\Sigma}$. Therefore, expenditure shares in the efficient economy are given by

$$\gamma' = (s\lambda + (1-s)\beta)'(I - \mathbf{\Sigma})^{-1}$$
$$\gamma = s\psi^I + (1-s)\psi^C$$

The previous argument has shown that the steady-state investment rate is a constant fraction of factor income. In the efficient economy with zero distortions, factor income and actual output coincide. Therefore the steady-state savings rate will be equal to χ. Combining this with the above expression implies that in steady state

$$\gamma^{PC} = \chi\psi^I + (1-\chi)\psi^C.$$

Taking the entry in this vector for sector $i = cem$ gives the result.