Concrete thinking about development*

Keelan Beirne

Princeton University

Martina Kirchberger

Trinity College Dublin

October 2020

Abstract

Low efficiency in the production of capital goods is often proposed as an explanation for the large differences in the investment rate across countries. We use new micro-data on key input prices and market structure to understand the reasons for these differences and their implications for capital accumulation. We start by presenting three key motivating facts. First, we document a large dispersion in prices of eight key inputs used in the construction of structures and show that cement prices are particularly high in Sub-Saharan Africa compared to the rest of the world. Second, using data on the market structure of the cement industry at a global level we find that cement prices are highest in countries with few firms. Third, we show that the construction sector constitutes about half of gross fixed capital formation and cement plays a significant role in construction sector expenditures, particularly in the poorest countries. We then estimate a simple model of oligopoly that allows for free entry using data on prices, market structure and a rich set of controls. Our estimates suggest that the market structure of the cement industry leads to significantly higher prices, and are robust to the inclusion of a restrictive set of controls. Finally, we embed our oligopoly model into a simple general equilibrium model that distinguishes between investment and consumption goods and focuses on the construction sector's role in producing investment. We show that when we allow for the production of distinct investment goods in a neoclassical model, distortions in investment producing sectors have a disproportionate impact on productive capacity. Our quantification exercises illustrates that the steady-state capital stock in the poorest countries is most sensitive to changes in markups in cement.

*For helpful comments we thank Timo Boppart, Paco Buera, Pascaline Dupas, Ed Glaeser, Doug Gollin, Matt Kahn, Joe Kaboski, Hannes Malmberg, Tommaso Porzio, Morten Ravn, Howard Smith, and Chris Woodruff as well as seminar participants at TCD, UCD, the STEG Workshop on Firms, frictions and spillovers, and industrial policy, and the NoEG Winter workshop. Many thanks to Juan Duran, Harry Humes, Alice Luraghi and Sameer Shaikh for excellent research assistance. We are grateful to the ICP Global Office at the World Bank for sharing the average price data for the global core lists for construction and machinery and equipment and support with many questions on the data. Many thanks to Thomas Armstrong for answering questions on the cement plant database, conversations about the industry, and making available historical data. We gratefully acknowledge funding from the Arts and Social Sciences Benefaction Fund. All potential errors are our own.

Corresponding author: Martina Kirchberger, Department of Economics, Trinity College Dublin, Dublin 2, Ireland; email: martina.kirchberger@tcd.ie, website: https://sites.google.com/site/mkirchberger.

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, 2019a; Baqaee, 2018; Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi, 2012; Jones, 2011). 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, 2014a; 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 of 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, 2014, 2020). We also collect and hand-code current and historical data from industry reports on market structure in the cement industry, such the name and number of firms operating in each country in a given year and each firm's capacity. 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 at a global level. Third, we build a simple model of capital accumulation to examine the impact of distortions that occur in sectors producing investment on capital. We use our model to examine the effects of changes in the market structure and markups on the steady-state capital stock.

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 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, capital consists of (i) machinery and equipment and (ii) construction, each of which accounts for about 50 percent on average. 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 is 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 costs 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 Sub-Saharan African countries. In other words, the region with the lowest level of infrastructure also faces the highest prices of a complementary 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. Both, using exchange rates and PPPs, the price of cement in Sub-Saharan Africa is 1.5-3.6 times the price of cement in the United States. 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.[1] 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

[1] 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).

distortions as they are unlikely to reflect differences in quality, which has been proven to be important in the market for agricultural equipment (Keller and Caunedo, 2019). 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, 2019). 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 country's capacity. The remaining 20 percent of capacity are produced by plants owned by LafargeHolcim, the second largest cement producer world-wide.

Using data our data on the number of firms active in each of the countries as well as firm capacities for both time periods, we show a strong bivariate relationship between cement prices and market structure that goes beyond anecdotes: cement prices are decreasing in the number of firms and increasing in market concentration, as measured by the Herfindhal-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 for cement.

In light of the large differences in cement prices and the key role cement plays in the production of concrete (for which there are few, if any, substitutes), 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 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 specification 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.

We then formulate a simple neoclassical model of capital accumulation which distinguishes between investment and consumption goods, and accounts for the construction sector's role in producing investment. 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 suggests the long run capital multiplier, as discussed by Jones (2011), is determined by the capital intensity of the investment sector, rather than the economy at large. Further, it implies that the effect of distortions in construction intermediates is determined by resultant changes in the efficiency of investment production, rather than changes in the efficiency of aggregate production, of which they make up a much smaller share. It is important to clarify that we focus on the effect of construction sector intermediates rather than intermediate goods in other sectors. If construction sector intermediate goods are used in other sectors, the effect would naturally be greater, as demonstrated by Jones (2011).

Given our analysis focuses on the effects of markups rather than non-rebated distortions,[2]

[2]As indicated by Baqaee and Farhi (2019b), distortions that are not rebated are isomorphic to changes in productivity, whereas markups allow for the transfer of resources to another industry.

our concern is the effect of allocative efficiency on the capital stock. A clear benchmark to such effects in the literature is given by Baqaee and Farhi (2019b), who develop an aggregation theorem for inefficient economies. More specifically, they decompose the first order elasticity of output to markups in a given sector into a direct effect, equal to the sector's share of output, and a reallocation effect. That is, the reduction in output in the sector due to the distortion, plus the effect of the reallocation of those resources to other sectors. Our model applies the intuition of Baqaee and Farhi (2019b) to a specific context, that of construction sector intermediates.

However, our model is not strictly subject to the results of Baqaee and Farhi (2019b), as we allow for non-homothetic demand in the form of distinct investment and consumption. In terms of determining long run capital, whether distortions in construction cause resources to be substituted to another part of investment or allocated to consumption is important. Due to the fact that distortions in capital production lead to a change in rates of return as well as prices, resources are reallocated toward consumption as a result of distortions in the investment sector.[3] This implies that in terms of investment and capital stock, markups behave like productivity distortions, as resources leave the sector rather than being reallocated. This also implies that consumption is initially higher due to the reallocation of resources, but ultimately declines due to lower capital stock in the economy. Moreover, while this reallocation may cause the initial effect on output to be small, this may mask much larger changes in the long run capital stock.

We use the model to quantify the predicted effects of market power and prices in the cement sector on the steady state capital stock. Our model shows that distortions in cement production can lead to disproportionate effects relative to the sector's expenditure as a percent of GDP. This is due to two factors: first, cement's share of construction sector expenditures is significant even though its share of GDP may be negligible; second, cement is a relatively non-substitutable input. We conduct two counterfactual experiments: the effects of entry of one firm and a 10 percent decrease in prices on the steady-state capital stock. This is a modest increase in price in comparison to the price differences observed in the data.

For our range of parameterisations, the effects on capital are large for countries which are relatively poor and predominantly in Africa. While the average increase in the capital stock due to a ten percent price decrease is around one percent, the maximum increase is around four times the mean, approximately four percent. The effects of entry are dependent on our parameter of the elasticity of substitution and thus market power. However, the distribution of effects displays the same skewness, with some countries displaying remarkably large effects despite average effects across countries being relatively low. For our median value

[3] Also, unequal factor shares implies that there is an additional effect: distortions in intermediates affect labour allocated to construction through a complementary effect. Plausible estimates of capital intensities imply this leads to further reallocation away from investment.

of the elasticity of substitution, the predicted increase in the capital stock due to the entry of a single firm is greater than half a percent for seven countries in 2011, despite the average increase being just 0.19 percent. Six of these seven countries are located in Sub-Saharan Africa, and five have a per capita GDP of less than $3200 a year in PPP terms (Namibia being the other). In 2011, differences by region and income is even starker: twelve of the fifteen countries showing a sensitivity greater than half a percent were located in Sub-Saharan Africa and had a per capita GDP under $3000. This highlights that while the macroeconomic effects might be negligible for advanced economies, they can be large for many low-income countries.

Our paper sits 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; Keller and Caunedo, 2019; Collier, Kirchberger, and Söderbom, 2016; Hsieh and Klenow, 2007; Jones, 1994; Restuccia and Urrutia, 2001), input-output linkages in production networks (Baqaee and Farhi, 2019a; Kremer, 1993; Jones, 2011; Demir, Fieler, Xu, and Yang, 2020; Grassi, 2018; Carvalho, 2014), the role of firm-level markups in general equilibrium (De Loecker, Eeckhout, and Unger, 2020; Edmond, Midrigan, and Xu, 2019; Mongey et al., 2017) and misallocation in developing countries (Boehm and Oberfield, 2020; Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008; Schmitz Jr, 2001). Our theoretical model is embedded in this literature. Our key contribution is to bring new micro-data to understand distortions in a specific sector that is key for 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 (2004a), Hortaçsu and Syverson (2007), Miller and Osborne (2014b) 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.

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 model of capital accumulation. Section 5 presents a quantification exercise of the macroeconomic impact of market structure and prices in cement. Section 6 concludes.

2. Motivating Facts

This section presents key motivating facts on the dispersion of input prices, the global cement industry, the construction sector's role in gross fixed capital formation and cement's role in construction. 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, 2014, 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.[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, 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

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

[5]Prices recorded for the ICP are intended to be national averages.

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

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 8 key inputs across space. Precise definitions of the inputs are listed in the Appendix.

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. 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 30 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). Taking into account the local price level makes the price differences even starker. In PPP terms, in 2011 concrete costs 3.2 times the price in Sub-Saharan Africa that it costs in the United States and this factor 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.

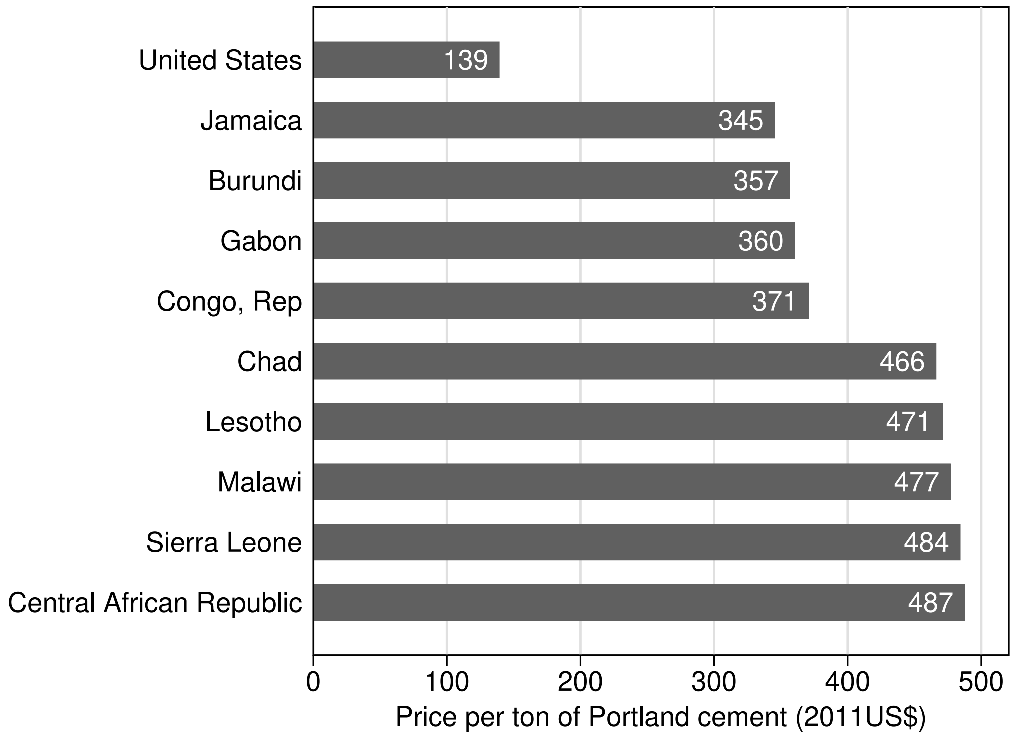
Panels C and D show the prices of softwood, bricks, mild steel reinforcement and structural steel. Coverage of countries is somewhat lower for these inputs (between 63 countries for structural steel and 78-89 countries for mild steel reinforcement). Panel C shows that for softwood, price differences 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 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, as lower wages in Sub Saharan Africa mean such 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 indexes.

In light of the stark 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 that the price per ton of Portland cement in the most expensive countries in the world is at least 2.5 times as expensive as in the United States. Cement is most expensive in the Central African Republic and Sierra Leone, where the av-

Figure 1: Ordinary Portland cement in the US and the 10 most expensive countries in 2011



Notes: 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.

erage 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 in Sierra Leone and in the Central African Republic increases to 9.7 and 6.5, 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. This explanation does not square with the high profit margins that we observe for firms operating in these countries. 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. Finally, it might be that market structure leads to higher prices; 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 focus on market structure as a key channel to drive higher prices, while controlling for the cost of input prices, scale and the institutional environment.

2.2. The global cement industry

This section shows key facts on market structure of the cement industryat a global level. To measure market structure, we use data on the 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.[7] The data is based on surveys and correspondence with plants and corporate offices, reports, and company disclosures. To define the number of firms, we use the group name if it is provided and otherwise the company name. For example, in Mexico there are 39 plants, owned by 9 companies which are in turn owned by 6 groups. Since price-setting is likely to take place at the level of the group, we are most interested in this variable.

The cement industry is characterized by high market concentration at a global level: 40 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.

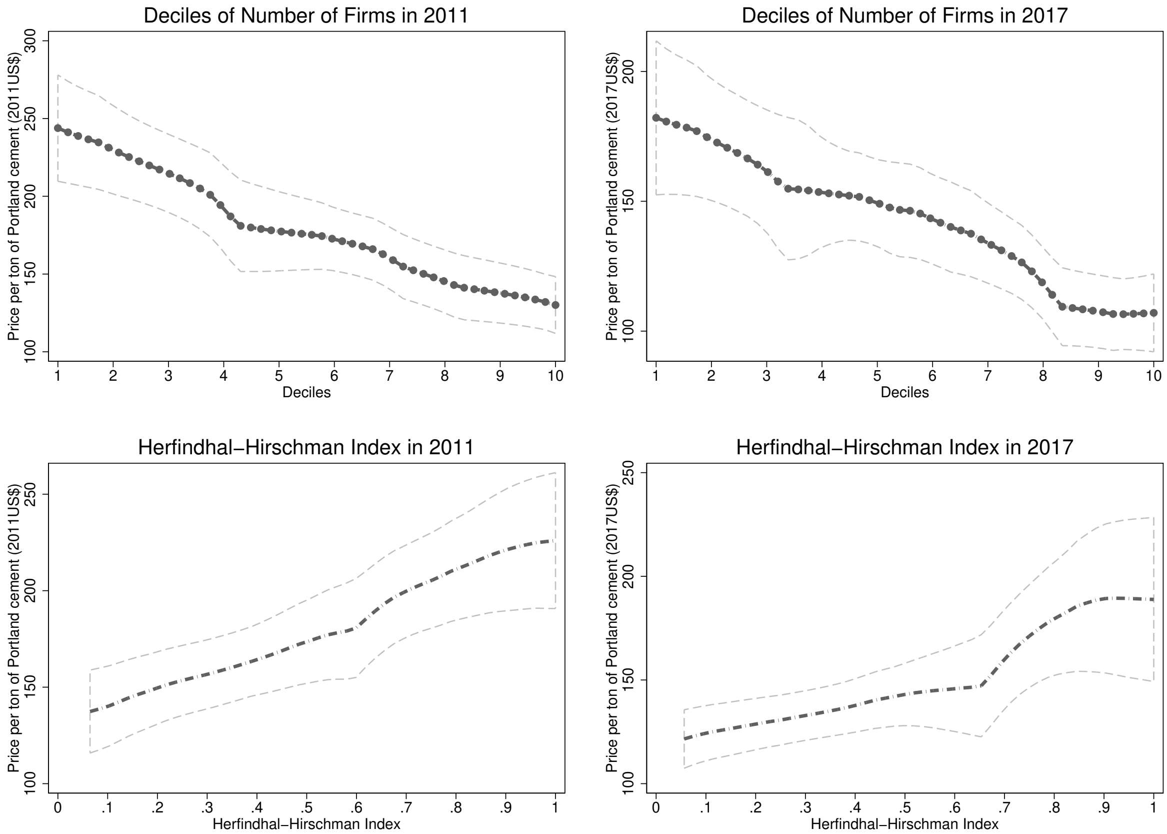
Global cement consumption in 2018 was almost 4000 million tons (Mt), out of which China consumed more than half, followed by India, the United States and Indonesia which account for another 500Mt. Trade is negligible at an aggregate level, and exports and imports account for five percent of total consumption. This is 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-

[7] We do not distinguish between grinding and integrated plants for the purpose of this paper as they both produce the final product cement.

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

Figure 2: Market structure and cement prices, all countries



Notes: 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 Herfindhal-Hirschman index. All figures plot a 95 percent confidence interval.

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 3.4 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.

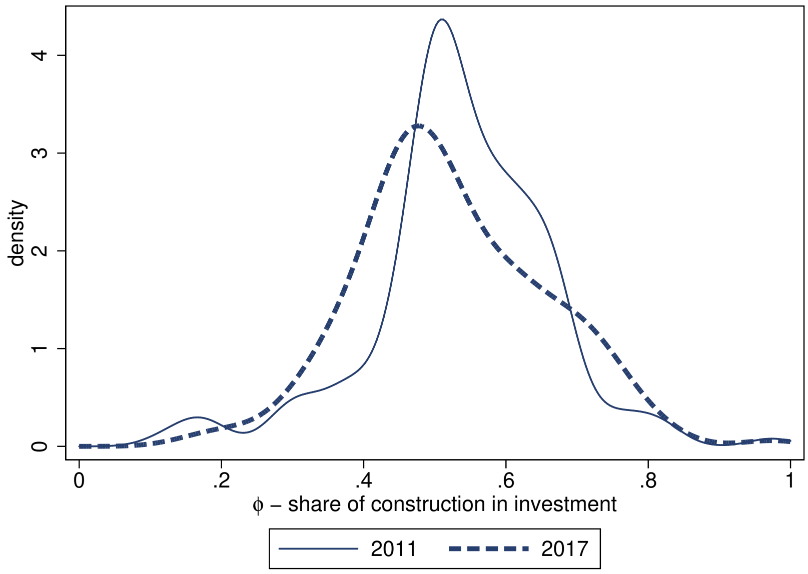
2.3. Cement consumption

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

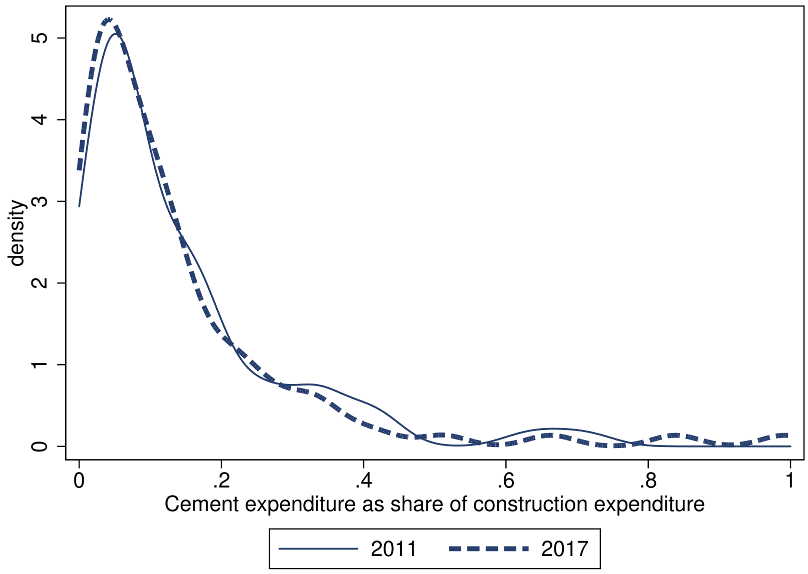
0.5 in both years, in line with earlier results by Burstein, Neves, and Rebelo (2004) who also find a share of roughly one half.

Figure 3: Construction and cement expenditure shares

(a) Construction share of investment expenditures



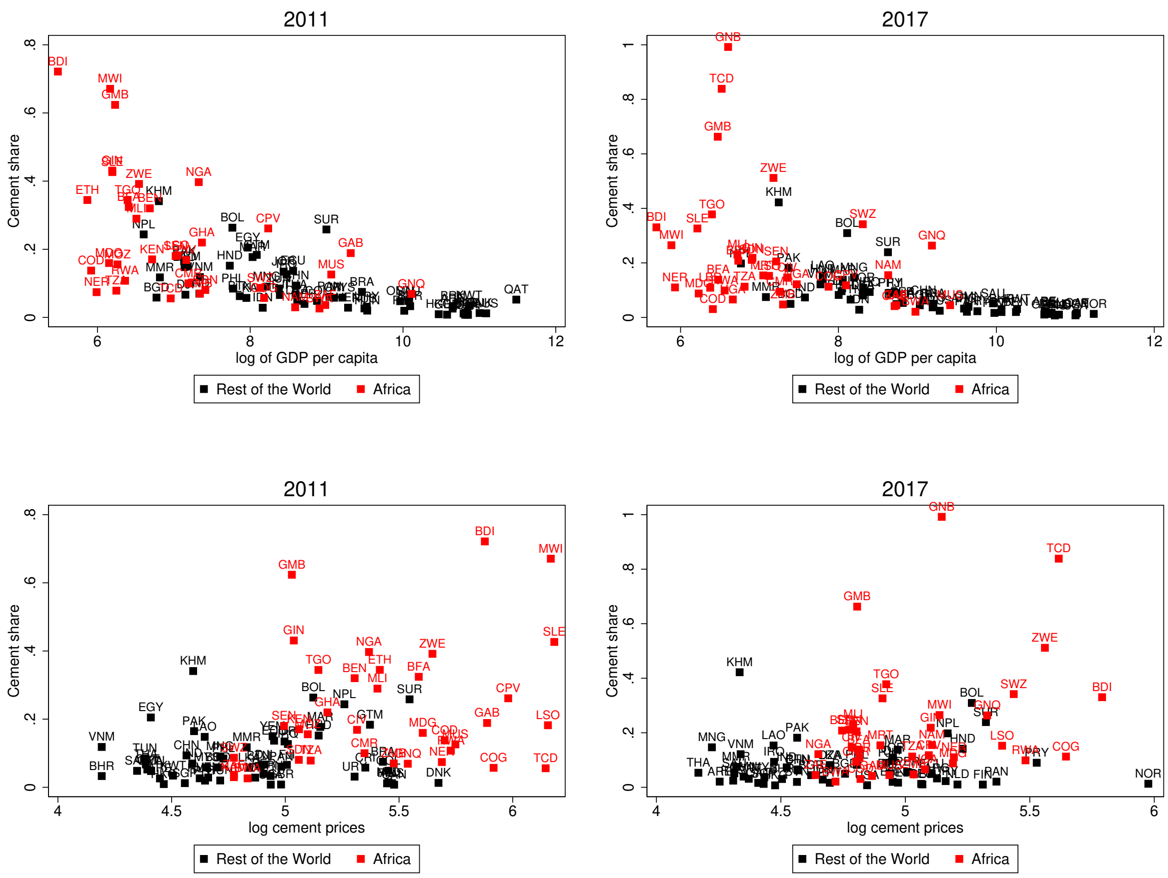
(b) Cement share of construction expenditures



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 the construction sector expenditure 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.[8] 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 spend more than 17 percent of construction 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

Figure 4: Cement's share of construction expenditures



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

[8] We exclude data from Liberia and Comoros for which cement's share of construction sector expenditures exceeds one.

expenditure 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 these figures 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. Moreover, the positive relationship between expenditure shares and the price of cement suggests that demand is inelastic. Therefore, distortions in cement have the potential to cause bottlenecks for two reasons. First, cement makes up a high share of construction sector expenditure in these countries, so this first order impact is large. Second, inelastic demand suggests that firms cannot readily substitute away from cement as prices rise. We turn to identifying such distortions in the next section.

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 Herfindhal-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 three-fold: first, to gain an expression for markups and thus prices in the cement industry that we can take directly to the data; second, it allows us 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 as the variability of costs across firms becomes smaller, our IV estimation yields consistent estimates.

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 similar to Melitz (2003) with a finite number of firms entering the market.

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. Our second assumption is that demand for cement as whole has a constant elasticity of substitution, implying it enters into the construction sector production function in a nested CES form. This assumption is not necessary to derive 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 (2004b) 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, which is an essential assumption in order to incorporate the model into a general equilibrium framework and model the market with a single price of supply. 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}. 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 $\varepsilon = \frac{d\log Q}{d\log p}$ 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

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

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.[9]

Firm have identical production technology using inputs x_k at price r_k but differ in their a Hicks-neutral productivity $A_i = e^{z_i + \nu}$, 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 to obtain a linear equation to be estimated such that

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

for country j where n is the number of cement firms, $\eta = \mathbb{E}\left[\log\left(\sum \frac{e^{z_i}}{n}\right)\right]$ is the unobserved component of average productivity and $\epsilon_j = \log\left(\sum \frac{e^{z_i}}{n}\right) - \eta$ 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. We now turn to evaluating the consequences of non-linearities in $\mu(n)$ and potential sources of bias within this framework.

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

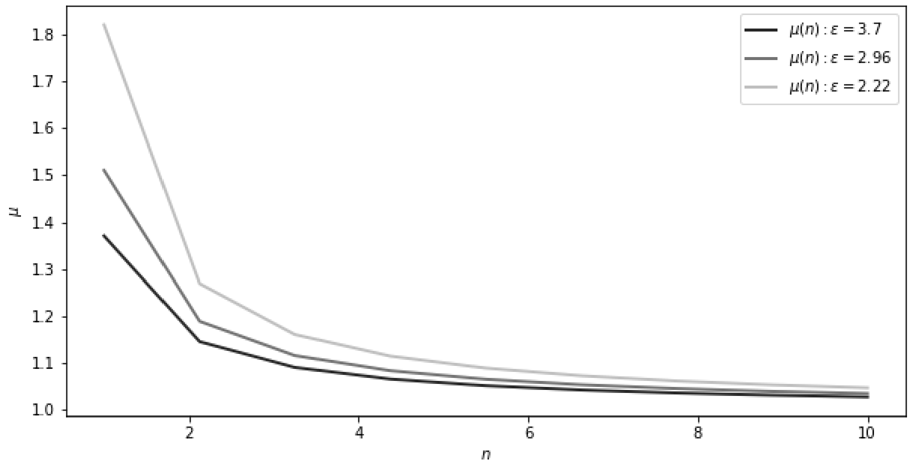
$$\tau = \frac{1}{\varepsilon n}$$

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

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

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 from Ryan (2012) which we use in the counterfactual experiment in Section 4.

Figure 5: Average markups and the number of firms



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 approximation using the inverse number of firms. We repeat using the log number of firms. Formally, these first order approximations take the form

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

around some benchmark number of firms n^*. Note that the first equation implies that when $\mu(n^*) \approx 1$, which occurs when n is large, we have that $\log \mu = 1 + (n\varepsilon)^{-1}$. 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) which is similar to Melitz (2003) with a finite number of firms entering the market.

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 $E = \mathbb{E}\big[\sum_{t=0}^{\infty}(1-\delta)^t \pi(n^*)\big]$. 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

$$n^e = \max_{n \in Z}\{n \,|\, n < n^*\} \tag{6}$$

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

$$n = \sum_{i=1}^{n^e} x_i = \bar{X}\, n^e \tag{7}$$

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 the appendix:

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

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

This result can be intuitively interpreted in the context of our model of entry. Imagine a random shock to unobserved costs occurs. 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. We use the cost to obtain a construction permit (as percent of warehouse value) from the Doing Business Indicators as our instrument. 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 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 E.

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

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

where $x\beta$ is the log of input costs. This implies that higher values of F censor the distribution 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 more firms drawing from the same distribution could lead to more low cost firms entering the market, excluding high cost firms and increasing 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 separate. 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.

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. Next, we present a number of robustness tests using alternative specifications, different measures of market structure and a restrictive set of input cost controls. As proxies for average costs we include a set of scale controls, namely P population, income (wages) I proxied by GDP, and transport costs A proxied by area, all taken from the World Development Indicators and the ICP. In the robustness section we include a larger set of input cost controls including fuel, electricity, and average equipment prices.

Panel A in Table 2 shows the OLS regression. The table shows that the inverse of the

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

	(1)	(2)	(3)
Panel A: OLS			
$1/n$	0.611^{***}	0.593^{***}	0.393^{***}
	(0.122)	(0.127)	(0.123)
Time FE	YES	YES	YES
Scale Controls	YES	YES	YES
Governance	NO	YES	YES
Fuel	NO	NO	YES
Obs.	181	181	173
R^2	0.308	0.318	0.42
Panel B: IV			
$1/n$	1.135^{***}	1.137^{**}	1.141^{**}
	(0.434)	(0.479)	(0.451)
Time FE	YES	YES	YES
Scale Controls	YES	YES	YES
Governance	NO	YES	YES
Fuel	NO	NO	YES
F-stat	14.193	13.861	13.799
Obs.	181	181	173
R^2	0.221	0.228	0.262

number of firms is significant at the 1 percent level and suggests that the lower number the number of firms, the higher the price. 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 is decreasing in size but remains significant at the one percent level.

Panel B shows the IV results. The F-stat is around 10, 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 coefficient on the inverse of the number of firms is likely to be downward biased. Indeed, the IV estimate is always above the OLS estimate. The inclusion of further controls again decreases the coefficient slightly, but it remains significant.

We next show a number of robustness checks: we start by showing that our results are not driven by the particular functional form implied in the model in which we control for market structure using the inverse of the number of firms. Table 3 shows the results using the log of the number of firms as the main control. The instrumental variables results are statistically significant and illustrate a higher effect of market power on prices than what we find in the OLS, similar to the results when we use the inverse of the number of firms as the main variable capturing market power. The table shows that in all cases the number

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

	(1)	(2)	(3)
Panel A: OLS			
Ln(Number of Firms)	-.247***	-.247***	-.166***
	(0.047)	(0.048)	(0.047)
Time FE	YES	YES	YES
Scale Controls	YES	YES	YES
Governance	NO	YES	YES
Fuel	NO	NO	YES
Obs.	181	181	173
R^2	0.321	0.336	0.429
Panel B: IV			
Log(Number of Firms)	-.514***	-.526***	-.530***
	(0.164)	(0.178)	(0.168)
Time FE	YES	YES	YES
Scale Controls	YES	YES	YES
Governance	NO	YES	YES
Fuel	NO	NO	YES
F-stat	11.007	9.268	9.258
Obs.	181	181	173
R^2	0.168	0.177	0.181

of firms is highly significant, indicating that a doubling of the number of firms leads to a 25 percent decrease in prices. Again the coefficient drops as we include further controls and is likely to be underestimating the effect of market structure on prices.

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

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

	firms/cap	herf	inputs	importer	weighted
	(1)	(2)	(3)	(4)	(5)
Nr firms/10 million people	-.172***				
	(0.049)				
Herfindhal-Hirschman index		0.613***			
		(0.13)			
1/n			0.577***	0.437**	
			(0.162)	(0.188)	
1/n (trade-weighted)					0.863***
					(0.162)
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.	181	175	134	100	128
R^2	0.248	0.293	0.356	0.479	0.275

robust to measuring market structure by the number of firms per capita or the Herfindhal-Hirschman index based using data on firm's capacities, suggesting that one more firm per 10 million people reduces prices by 17 percent. 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 data on the cost of coal and machinery we rely on trade data from UN COMTRADE. To get average prices of coal we divide the total value of imports by the quantity of imports. For machinery, we construct a similar measure of the cost of machinery using data on the product category that includes "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".[10] Availability of these data reduces our sample significantly. Given that measurement error is likely to be severe in this measure, we construct averages for 2007-2010 and 2013-2016. Despite the substantial reduction in sample size our results remain consistent with our previous results.

Finally, a small fraction of global production of cement is traded and some countries in our sample are importing 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

[10] This corresponds to product code 7283 SITC Revision 4.

cement or limestone. This does not seem to affect our results. Second, we compute a trade-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.

Overall, this section suggested a strong link between market structure and cement prices. The next section asks what the effects of markups are on capital accumulation.

4. General equilibrium model

In this section we present a simple general equilibrium framework to quantify the impact of distortions in intermediate inputs in the investment sector on capital accumulation. A derivation of these results can be found in Appendix C.

Our model displays a general result: distortions have a disproportionate impact when they occur in sectors which produce investment. We treat the investment production as representative sector to simplify the analysis. Given our focus on distortions in a key input in investment we abstract from the production structure within the investment sector. Below we discuss an alternative parametric version of our model where we specify that investment is produced using construction and machinery, in line with how national accounts treat gross fixed capital accumulation. In the model we continue to assume that cement faces a single elasticity of demand, an assumption made plausible by cement's nature as a largely construction sector-specific input.

Time is continuous. There are two factors, capital and labour. New capital is produced in an investment sector, purchased by consumers and invested in the capital stock, which depreciates at rate δ. Consumers' choose investment and consumption in order to maximise infinite lifetime utility. We assume that the economy admits a representative agent, and that utility takes the standard form (with $u'(c) > 0$ and $u''(c) < 0$)

$$\int_t^\infty e^{-\rho t} u(c(t)) dt$$

where c is a composite consumption good and ρ is the discount rate. We let the price index of consumption equal to one in all periods. The optimal path of consumption is given by the usual Euler equation

$$\frac{\dot{c}}{c} = \frac{1}{\epsilon_u(c)}\left(\frac{r^k}{p} + \frac{\dot{p}}{p} - \delta - \rho\right) \tag{8}$$

where $\epsilon_u(c) = -\frac{u'(c)}{cu''(c)}$ and p is the price of new capital goods. We consider a representative investment firm who produces investment goods y_I with a constant returns to scale production function

$$y_I = f(\{x_{Ij}\}, k_I, L_I)$$

using a set of intermediate inputs x_I indexed by j alongside capital k_I and labour L_I. For simplicity, we assume that each intermediate good is produced using capital and labour, and production is homogeneous of degree one. The investment producer minimises cost, charging an exogenous markup μ_I.

We focus on the steady state of the economy, in which the capital stock and consumption are constant. Constant factor supplies imply that the price of investment is static in the steady state, meaning that $\dot{p} = 0$, so that in the steady state we have

$$\frac{r^k}{p} = \delta + \rho$$

which is a slight modification on the usual steady state condition. Taking the log differential of this expression yields

$$d\log r^k = d\log p$$

which implies that in the steady state, changes in the marginal return of capital are equal to the replacement cost of capital. Define

$$\lambda_j = \frac{p_j x_{Ij}}{\sum_i p_i x_{Ii}}$$

as the cost share of intermediate good j in investment, and let $\lambda_k = \alpha_k$. Define α_j as capital's share of costs in the production of good j, implying $1 - \alpha_j$ is labour's share. Next, we let the capital share of total investment be defined as $\alpha_I = \sum_j \lambda_j \alpha_j + \alpha_k$, while we denote the aggregate expenditure on capital in the wider economy by $r^k k = \Lambda_k$, and similarly for labour $wl = \Lambda_L$.

Proposition 2 *The marginal response of the steady state capital stock to markups in interme-*

diate sector j is given by

$$\frac{d\log k^*}{d\log\mu_j} = \frac{d\log(\Lambda_k - \Lambda_L)}{d\log\mu_j} - (1-\alpha_I)^{-1}\lambda_{Ij}. \tag{9}$$

In expression (9), the first term gives the percentage change in expenditure on capital, less the equivalent change for labour. This represents the fact that by reducing material inputs in the affected firms, the distortion reallocates resources which may change the economy-wide demand for factors. For example, in the Cobb-Douglas case with uniform capital share α, this term would be equal to zero and markups behave like a tax on capital. In order to apply equation (9) to cement industry, we assume that this term is approximately equal to zero when $j = c$, where c denotes the cement industry. Essentially, we assume that distortions in cement have a negligible effect on the relative expenditure shares of factors in the economy.[11]

We also consider second order changes, given by

$$\frac{d^2\log k^*}{d\log\mu_c^2} = -(1-\alpha_I)^{-1}(1-\varepsilon)\lambda_{Ic}(1-\lambda_{Ic}) \tag{10}$$

where $\varepsilon = \frac{d\log q_c}{d\log p_c}$ and c denotes the cement industry. The second order term accounts for changes in the expenditure share of cement in investment. This share rises when $\epsilon < 1$ (when cement is a complement), amplifying the negative effects of increasing markups and dampening the positive effects of reductions in markups. The converse is true when cement is a substitute $\varepsilon > 1$. Using this expression, we approximate changes to the capital stock to the second order according to the equation

$$\Delta\log k^* = -(1-\alpha_I)^{-1}\lambda_{Ic}\Big(\Delta\log\mu_c + (1-\varepsilon)(1-\lambda_{Ic})\Delta\log\mu_c^2\Big) \tag{11}$$

This relation highlights that cements' share of investment λ_{Ic} rather than it's overall share of output determines it's effects on capital stock. In order to map this expression to cross country data, we assume that ε is constant, which implies that cement enters investment in a nested CES form.

Relation 9 shows the important difference between distortions in the consumption sector. With inelastically supplied labour, a distortion in the consumption sector only has an impact through changes in allocative efficiency (Baqaee and Farhi, 2019b) and has no effect on the resources devoted to consumption in aggregate. Distortions in the investment sector, however, change both prices and rental rates, leading to a reduced rate of long-run investment. This shows that the location of distortions is of fundamental importance to their long-run

[11]The expenditure share of both labour and capital will decline with a rise in markups in cement. We only assume the impact on the cost share of labour and capital is negligible.

impact.

5. Counterfactual Exercise

In this section, we apply the results of our model to the data to study the marginal impact of changes in the market structure and markups for cement on long-run capital accumulation.[12] We do this by calculating the predicted change in steady-state capital resulting from the entry of a single firm into the market, and a 10 percent price decrease in markups. It should be noted the predicted changes are in terms of long-run values and manifest themselves over time rather than in a discrete adjustment.

Our goal is to apply the predictions of the model, namely equation (11)

$$\Delta \log k^* = -(1-\alpha_I)^{-1} \lambda_{Ic} \Big(\Delta \log \mu_c + (1-\varepsilon)(1-\lambda_{Ic}) \Delta \log \mu_c^2 \Big)$$

to the available data in order to quantify the impact of distortions in the production of cement on the wider economy.

5.1. Data for Quantification Exercise

In order to compute counterfactual estimates of equation (11), we require data on three parameters: cement's share of investment expenditure λ_{Ic}, the capital intensity of aggregate investment α_I and the elasticity of substitution of cement ε. Together, these parameters determine the response of steady-state capital stock to changes in markups in the cement industry. The expenditure share of cement defines cement's size within aggregate investment production, while the elasticity of substitution determines how cement's share changes when markups change. The aggregate intensity of capital in investment defines how changes in the price of producing construction sector goods and thus investment compound over time into changes in the steady state capital stock. We use the model in Section 3 to estimate changes in markups.

The most important parameter defining cement's impact is its share in investment expenditures. As in Section 2.3, we use a combination of ICP and global cement report data to construct this measure. Section 2.3 provides evidence to suggest that this parameter is large for many countries, particularly poorer ones.

As discussed in earlier sections, the elasticity of substitution affects both the sensitivity of price to market power and the sensitivity of expenditure to prices. We let ε take three values, the baseline parameter estimate from Ryan (2012), and the bounds of a 95 percent confidence interval around this estimate.

[12] We exclude countries with one firm only in line with our oligopoly framing.

Table 5: Parameters

Parameter	Value	Source
λ_{Ic}	varies	ICP expenditure shares and Cemnet
α_I	.33	Standard value
ε	$\varepsilon \in \{2.22, 2.96, 3.7\}$	Baseline estimates from Ryan (2012)

The final parameter which defines cement's impact on long-run capital is the capital intensity of investment, which determines the capital multiplier. While this parameter is clearly the most important for long run dynamics in a general setting, it is not our main focus here. Therefore, we carry out our baseline analysis letting $\alpha_I = .33$, which is the standard value for a single sector economy. Table 5 summarises our baseline parameter choices.

5.2. Results

In this section, we implement equations (3) and (11) using the data and parameter choices provided above, to study the effect of shocks to the market structure and price of cement. This gives a second order approximation of the change in capital stock resulting from these shocks for a sample of 68 countries, based on the number of firms in their cement market and cement's share of expenditure. We present results for 2017 here, and report the same results using 2011 data in appendix tables B.2, B.3 and figure A.2. We also exclude countries with a single cement firm, to be consistent with our oligopoly framework. We report results including all countries in appendix tables B.4, B.5 and figure A.3.

We consider two shocks, the entry of a single firm with cost $c_i = \bar{c}$ (due to removal of some exogenous barrier to entry) and a 10 percent increase in price. The effect of entry is dependent on the elasticity of substitution in two ways: first, in the response of prices to entry, and second, in the second order effect of prices on capital. The former of these is naturally absent when we fix the change in prices. Moreover, cross-country differences in the effects of entry and exit are driven by both the existing market structure and in turn the expenditure share of cement, however market structure is irrelevant when we fix the change in price. Therefore, the effect of fixed changes in prices measures the pass-through from cement prices to the capital stock, while the effect of entry also depends on how sensitive the price is to market structure. Mathematically speaking, this can be seen in the expression of the marginal effect of changes in the number of firms n on prices

$$\frac{dlogk^*}{dn} = \overbrace{\left(\frac{dlogk^*}{dlogp}\right)}^{\text{Effect of p on } k^*} \underbrace{\left(\frac{dlogp}{dn}\right)}_{\text{Effect of n on prices}}$$

The comparison of these effects highlights the role substitutability and market structure play, both in generating markups and compounding distortions.

Table 6: Percentage change in k^* from entry of one firm

	Elasticity	Mean	Std. Dev.	Min.	Max.	N
$\frac{\Delta k^*}{k^*}$	$\varepsilon = 3.7$	0.15	0.24	0	1.44	68
	$\varepsilon = 2.96$	0.19	0.31	0	1.85	68
	$\varepsilon = 2.22$	0.27	0.43	0	2.58	68

Table 7: Percentage change in k^* from 10 percent decrease in price

	Elasticity	Mean	Std. Dev.	Min.	Max.	N
$\frac{\Delta k^*}{k^*}$	$\varepsilon = 3.7$	1.05	0.88	0.06	4.32	68
	$\varepsilon = 2.96$	0.99	0.84	0.06	4.11	68
	$\varepsilon = 2.22$	0.93	0.79	0.06	3.89	68

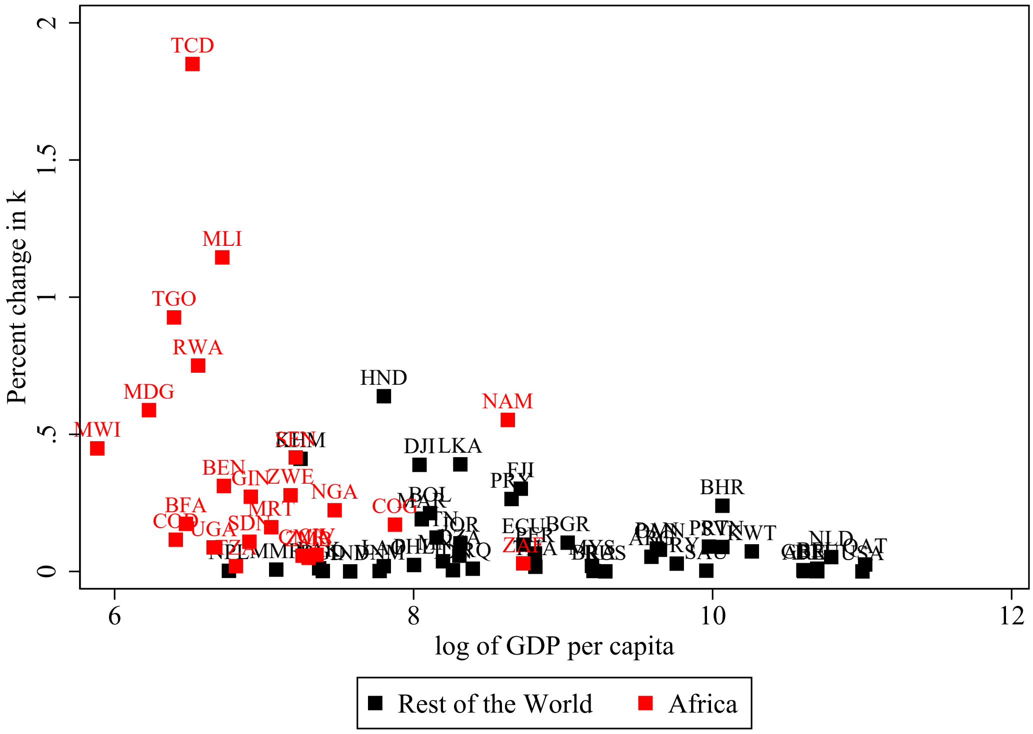
Summary statistics of the effect of the entry of one firm are given in Table 6, for each of our choices of ε. Equivalent statistics for a ten percent increase in price are given in Table 7. The values reported are in percentages. Both tables highlight the skewness towards zero in the distribution of changes, meaning that there are a number of countries who display large effects. We can see that in all cases, the average effect is low and less than one percent in all cases, yet the maximum effect for countries is much higher, ranging from two to almost four percent. Figure 6 gives the distribution of these effects along with log of GDP for each of the cases presented in Table 6. We can see that there is a particular set of countries for whom these effects are large, and that these countries are relatively poor and predominantly in Sub-Saharan Africa. This highlights a crucial point: while industries like cement may have a negligible macroeconomic effect for advanced economies, for certain developing countries the macroeconomic effect can be large.

The results shown in Table 6 along with Figures 6a-6c clearly show that the magnitude of the effects can vary substantially for different elasticities of substitution in quite a small range. We can see from these figures that while the shape of the distribution remains roughly constant for each of these values of ε, the scale varies significantly, with the maximum effect approximately doubling when we move from the lower to the upper bound of ε. This, along with the similar effects given by Table 7, suggests that the elasticity of substitution primarily affects the market power of firms, and therefore by extension the magnitude of price changes when competition increases. Moreover, the impact of low levels of substitutability is much higher for countries with uncompetitive markets due to the multiplicative effect.

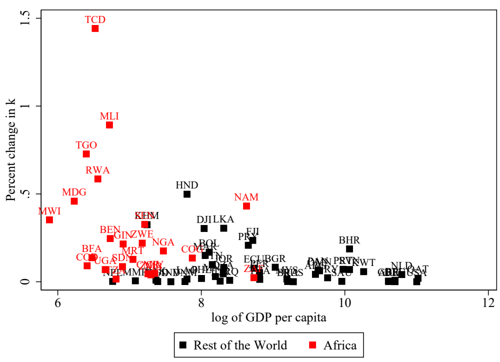
Table 7 shows remarkably similar effects from a fixed price change across our choices of ε, with just a 0.03 percent difference in average effects. This is due to the fact that as we specify the price change endogenously, the effects of ε on markups are not present. Figure 7 displays the distribution of effects for the case $\varepsilon = 2.96$. We can see again that the countries

Figure 6: Long run effect Entry of one firm

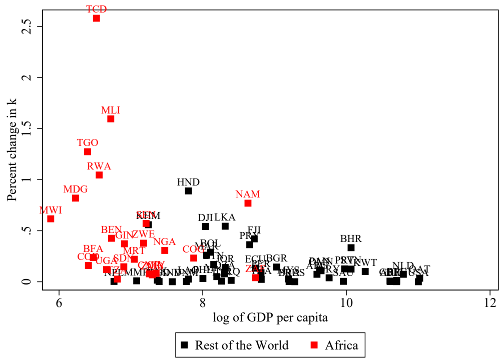
(a) $\varepsilon = 2.96$



(b) $\varepsilon = 3.7$



(c) $\varepsilon = 2.22$

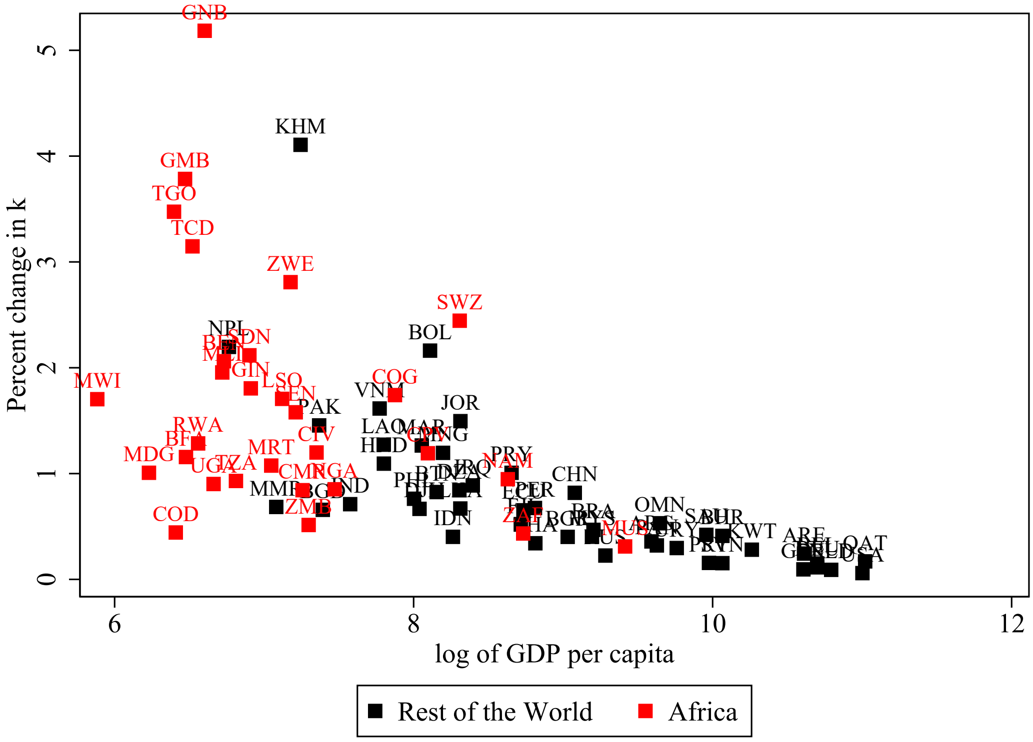


for whom the impact is large tend to be both poor and African. The large effects for some countries as shown in Figures 6 and 7 are due in part to the large expenditure shares of cement, along with the tendency of these countries to have low levels of competition.

We also carry out the analysis letting α_I be a weighted average of the capital share of machinery and construction, which we assume are constant across countries. For this case we take the capital intensity of construction from Acemoglu and Guerrieri (2008), while we use the Manufacturing Industry Database for the USA compiled by Becker, Gray, and Marvakov (2013) to find the capital share of machinery.[13] We take the weighting between

[13]Following Acemoglu and Guerrieri (2008) we define the capital share to be the share of value-added

Figure 7: Long run effect to 10 percent price decrease $\varepsilon = 2.96$



construction and machinery from the ICP expenditure shares data, meaning for this case α_I varies across countries. Appendix Figure A.4 shows that the patterns are very similar.

Our counterfactual experiments suggests that the impact of market structure in cement on the productive capacity of the economy can far outweigh its share of aggregate production. The exercise illustrates how distortions in cement can cause the quantity of investment and capital stock of a country to be significantly lower for low-income countries, while the effects for the majority of countries are quite small. Entry of an additional firm and price changes have therefore disproportionate effects on a small set of low-income countries, due to a low number of firms causing high sensitivity of prices to competition and high expenditure shares on cement.

5.3. Pass-through of cement to building costs

One assumption of our model is that cement prices affect investment prices.[14] 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

[14]In our model the investment sector directly uses intermediate goods, capital and labor. We could have also modelled the investment sector as using construction goods and equipment and machinery. This set-up, while closer to the national accounts view of the investment sector, leads to a number of further parameters in our model without providing further insights. We therefore opted to keep the model as parsimonious as possible.

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 notoriously known for 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 an approach known as Basket of Construction Components (BOCC) 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 constructions 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 8. We also use the 2011 ICP cement prices to examine the correlation in Columns (3) and (4). Column (1) in Table 8 shows that a one percent

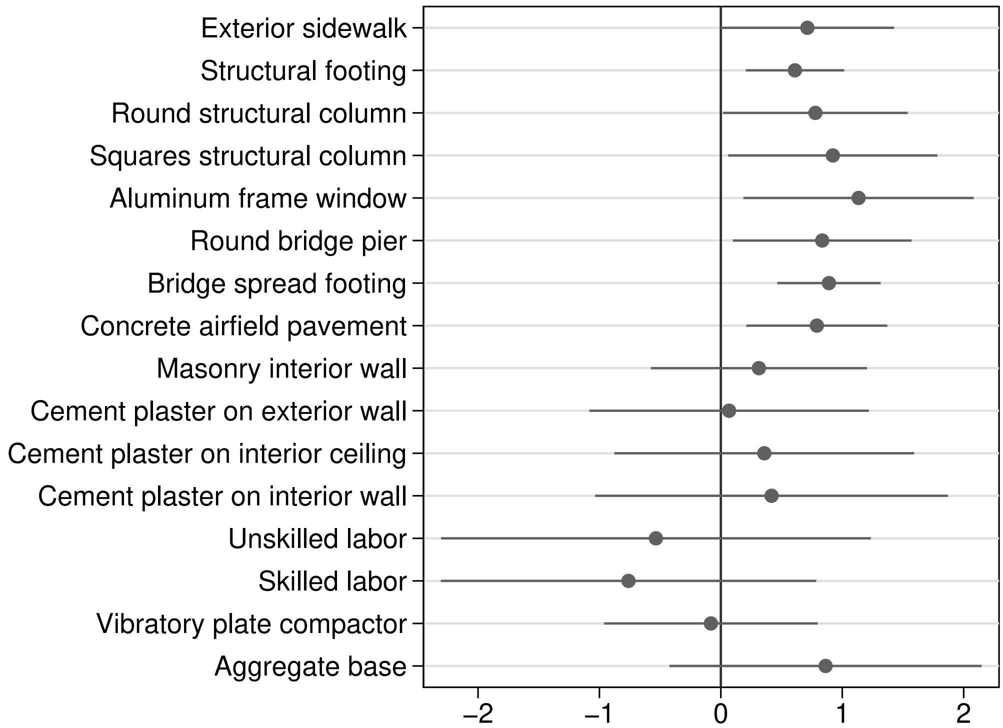
Table 8: Dependent variable: Log of cost of component

	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	14	10	14
R^2	0.841	0.951	0.791	0.915

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 8 shows the distribution of coefficients from a regression that uses each component separately. Given the data constraints, each regres-

Figure 8: Cement prices and construction costs



Notes: This figure shows the coefficients from a regression of log cement prices on construction composites.

sion has between 12 and 14 observations. Still, several of these composite construction costs correlate significantly with cement prices, in particular the goods for which we would expect cement to account for a significant fraction such as sidewalks, structural footings, columns, bridge piers and a concrete air field. Prices for other inputs - labor, a vibratory plate compactor and aggregate base - show little correlation again.

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 9 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

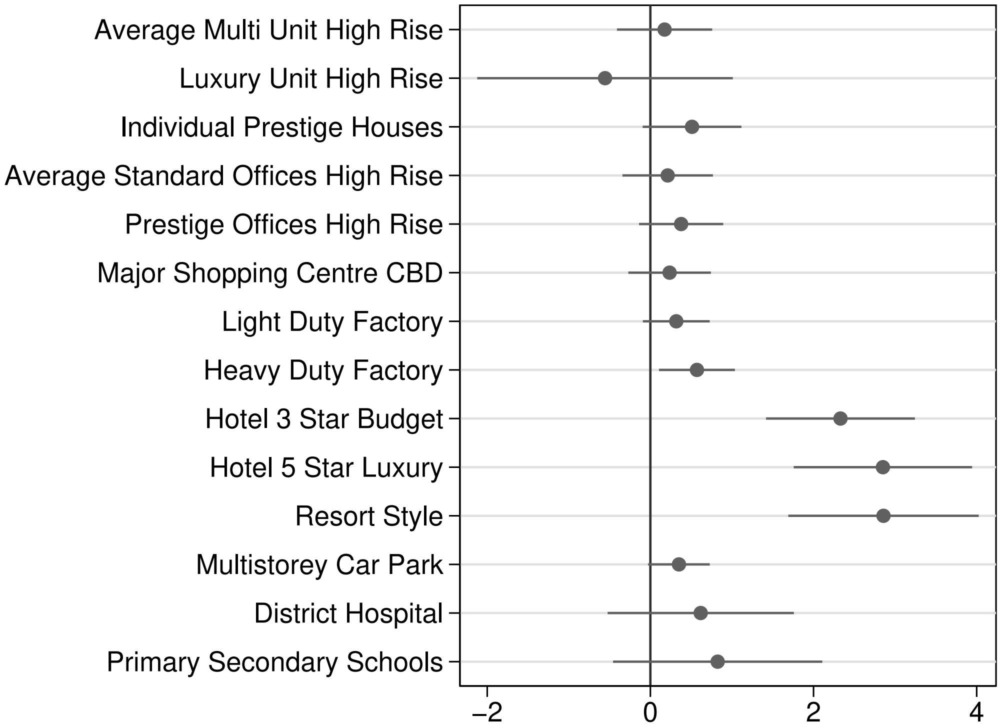
Table 9: Dependent variable: Log of cost per square meter

	(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
R^2	0.706	0.717	0.72	0.804	0.757

(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 but the elasticity is high 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 9. 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 is higher when cement prices are high. While more research is needed to pin down the relationship between particular input prices, such as cement, and output prices, the evidence presented

Figure 9: Cement prices and construction costs



Notes: This figure shows the coefficients from a regression of log cement prices on construction costs per square meter.

here suggests that there is a significant link.

6. Conclusion

This paper makes three contributions. First, we establish a novel set of motivating facts, highlighting that there is a large dispersion of construction sector input prices across countries, with Sub-Saharan African countries having the highest prices for most goods. Such stark differences are not seen in the aggregate construction sector PPP prices, as lower wages in Sub Saharan Africa likely mean such 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 bottlenecks and barriers to trade. We show that cement prices are highest in countries with a small number of firms. 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.

Second, we show empirically that market power plays an important role in generating price dispersion in cement across countries. We theoretically show that the OLS estimates of the effects of market power are downward biased, and also verify this empirically by estimating the equation using an instrumental variables strategy. We show that our results are robust to a different functional form, extensive controls for input prices, alternative definitions of market power and controlling for trade in limestone and cement. The key limitation of our estimation is our low sample size, which limits the power of our analysis and the lack of data on prices within countries. Although we find significant and remarkably robust results despite both a small sample and downward bias in the OLS, our estimates are subject to fairly wide confidence intervals. The analysis still provides compelling evidence for significant effects of market power in raising the price of cement.

Third, we show how high prices in such inputs can have an impact on the long run productive capacity of the economy which outweighs their share of aggregate production, due to their role in the production of investment. 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. More specifically, as distortions in investment change both prices and the return on investment, they act similarly to a productivity shock, with resources being reallocated towards consumption. However, 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.

Finally, the model suggests that the long-run capital stock is disproportionately sensitive to bottlenecks in essential sectors such as cement. Our analysis has highlighted the role of market power and competition in generating such bottlenecks. While cement is a small insignificant sector on average, for certain countries it can have large effects. The sensitivity of long-run capital to changes in market structure has a similar, albeit starker, trend across countries, with certain countries having effects much larger than the average rate, and these countries are poor and largely African. The source of these large effects are low levels of competition and thus high sensitivity of prices to entry, and large shares of cement in construction sector expenditure. These effects are positively related if cement is a complementary good.

One limitation of our quantitative exercise is our focus on the marginal sensitivity of the capital stock across countries, rather than differences in its level due to distortions in cement. Therefore our results highlight the large consequences of the kind of market power we find 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 low-income countries.

Our analysis provides evidence that large price differences exist in construction sector intermediates and that such differences, due to distortions, result in important effects on the wider economy. Moreover, we show that market structure in the form of oligopoly is a strong driver of price differences in cement, and that the macroeconomic effects predicted by our model are large for many low-income countries. Markups have therefore differential effects depending on the sector and stage of development at which they occur.

References

ACEMOGLU, D., V. M. CARVALHO, A. OZDAGLAR, AND A. TAHBAZ-SALEHI (2012): "The network origins of aggregate fluctuations," *Econometrica*, 80, 1977–2016.

ACEMOGLU, D. AND V. GUERRIERI (2008): "Capital deepening and nonbalanced economic growth," *Journal of political Economy*, 116, 467–498.

ALFARO, L. AND F. Z. AHMED (2010): "The price of capital: Evidence from trade data," *Harvard Business School BGIE Unit Working Paper*.

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. AND E. FARHI (2019a): "The microfoundations of aggregate production functions," Tech. rep.

BAQAEE, D. R. (2018): "Cascading failures in production networks," *Econometrica*, 86, 1819–1838.

BAQAEE, D. R. AND E. FARHI (2019b): "Productivity and misallocation in general equilibrium," *The Quarterly Journal of Economics*, 135, 105–163.

BECKER, R., W. GRAY, AND J. MARVAKOV (2013): "NBER-CES manufacturing industry database," *Technical Notes*.

BEKKERS, E. AND J. FRANCOIS (2013): "Trade and industrial structure with large firms and heterogeneity," *European Economic Review*, 60, 69–90.

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.

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.

CASELLI, F. AND J. FEYRER (2007): "The marginal product of capital," *The quarterly journal of economics*, 122, 535–568.

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., J. EECKHOUT, AND G. UNGER (2020): "The rise of market power and the macroeconomic implications," *The Quarterly Journal of Economics*, 135, 561–644.

DEMIR, B., A. C. FIELER, D. Y. XU, AND K. K. YANG (2020): "O-Ring Production Networks," .

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?" Working paper.

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," Tech. rep., IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University.

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

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.

KELLER, E. AND J. CAUNEDO (2019): "Capital Obsolescence and Agricultural Productivity," Working paper.

KREMER, M. (1993): "The O-ring theory of economic development," *The Quarterly Journal of Economics*, 108, 551–575.

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.

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 (2014a): "Spatial differentiation and price discrimination in the cement industry: evidence from a structural model," *The RAND Journal of Economics*, 45, 221–247.

——— (2014b): "Spatial differentiation and price discrimination in the cement industry: evidence from a structural model," *The RAND Journal of Economics*, 45, 221–247.

MONGEY, S. ET AL. (2017): "Market structure and monetary non-neutrality," *Job market paper. http://www. simonmongey. com/uploads/6/5/6/6/65665741/mongey_market_structure_monetary_nonneutrality_draft. pdf*.

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-govern 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.

Schmitz Jr, J. A. (2001): "Government production of investment goods and aggregate labor productivity," *Journal of Monetary Economics*, 47, 163–187.

Syverson, C. (2004a): "Market structure and productivity: A concrete example," *Journal of Political Economy*, 112, 1181–1222.

——— (2004b): "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.

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 (2014): *Purchasing Power Parities and the Real Size of World Economies: A Comprehensive Report of the 2011 International Comparison Program*, The World Bank.

——— (2015a): "Chapter 3- Data Requirements; Purchasing power parities and the real size of world economies: a comprehensive report of the 2011 International Comparison Program," .

——— (2015b): "Construction and Civil Engineering: Approach and Data Requirements - Operational Guidelines and Procedures for Measuring the Real Size of the World Economy; 2011 International Comparison Program," .

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

——— (2020): *Purchasing Power Parities and the Size of World Economies: A Comprehensive Report of the 2017 International Comparison Program*, The 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.

Appendix (For Online Publication)

A. Data

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

Table A.1: Data Summary

Variable	Source
Key Input Prices	ICP (2011 and 2017)
Market Structure	Global Cement Report 10 and 13, online database
GDP	ICP (2011 and 2017)
Scale Controls	World Development Indicators
Governance	World Governance Indicators
Cost to obtain a construction permit	Doing Business Indicators[15]
Cost of starting a business	Doing Business Indicators
Price of Coal	UN COMTRADE
Price of Machinery	UN COMTRADE
Limestone imports	UN COMTRADE
Cement imports	UN COMTRADE
Clinker imports	UN COMTRADE

Notes: This table summarizes the various sources of data used in the paper.

A.1. ICP

We use price data collected in the context of the 2011 and 2017 International Comparison Project. The price surveys contains 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, 2015b).

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).

In an OECD paper, Bacchini et al. (2003) attempt to construct an alternative index of construction sector production. In their analysis, they use industrial turnover in certain relevant sectors as a proxy for raw material inputs in the construction sector. They chose six categories of intermediate goods to calculate the index. They find the most important group 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 will 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 major constituent of plaster and mortar).

A report by ECORYS, a consultancy, and the Copenhagen resource institute, called "Resource efficiency in the construction sector" 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 pipe. Therefore, we include the 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

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

A.2. Market structure

The plant-level database is the based on daily research and annual reviews, including primary research: 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

We compute the trade-weighted market structure in the following way: for each country we use data on the countries from which a country imports cement, and keep the main importer in terms of value of imports. We only use data for countries that import more than 1500 tons of Portland cement, equalling the amount of cement needed for about 100 single-family homes.[16] We exclude countries that are mainly importing from China due to lack of data on the market structure in China.

[16]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 8 key inputs across space. Precise definitions of the inputs are listed in the appendix.

Figure A.1: Cement share and per capita consumption

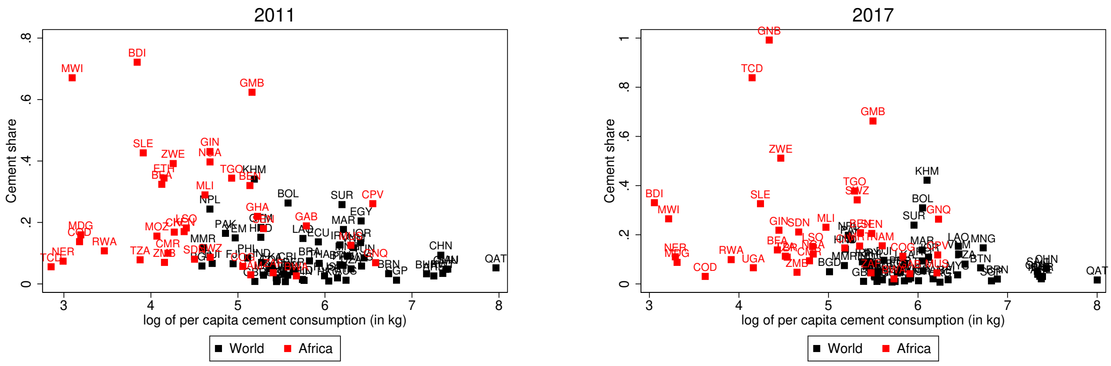


Table B.2: Percentage change in k^* from entry of one firm - 2011 data

	Elasticity	Mean	Std. Dev.	Min.	Max.	N
$\frac{\Delta k^*}{k^*}$	$\varepsilon = 3.7$	0.24	0.36	0	1.88	64
	$\varepsilon = 2.96$	0.31	0.47	0	2.41	64
	$\varepsilon = 2.22$	0.43	0.65	0	3.36	64

Table B.3: Percentage change in k^* from 10 percent decrease in price - 2011 data

	Elasticity	Mean	Std. Dev.	Min.	Max.	N
$\frac{\Delta k^*}{k^*}$	$\varepsilon = 3.7$	1.18	1.05	0.07	4.92	64
	$\varepsilon = 2.96$	1.11	1	0.07	4.68	64
	$\varepsilon = 2.22$	1.05	0.95	0.06	4.45	64

Table B.4: Percentage change in k^* from entry of one firm - including monopoly markets

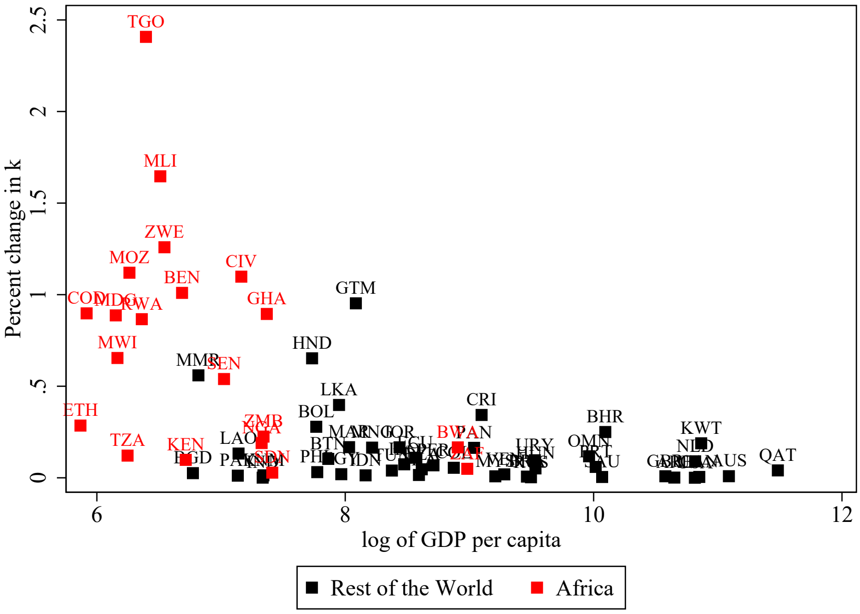
	Elasticity	Mean	Std. Dev.	Min.	Max.	N
$\frac{\Delta k^*}{k^*}$	$\varepsilon = 3.7$	0.38	0.9	0	5.87	81
	$\varepsilon = 2.96$	0.5	1.19	0	7.79	81
	$\varepsilon = 2.22$	0.73	1.77	0	11.59	81

Table B.5: Percentage change in k^* from 10 percent decrease in price - including monopoly markets

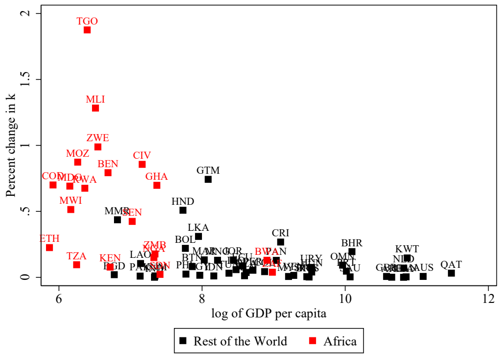
	Elasticity	Mean	Std. Dev.	Min.	Max.	N
$\frac{\Delta k^*}{k^*}$	$\varepsilon = 3.7$	1.02	0.9	0.06	4.32	81
	$\varepsilon = 2.96$	0.97	0.85	0.06	4.11	81
	$\varepsilon = 2.22$	0.91	0.8	0.06	3.89	81

Figure A.2: Long run effect of Entry and price decrease - 2011 data

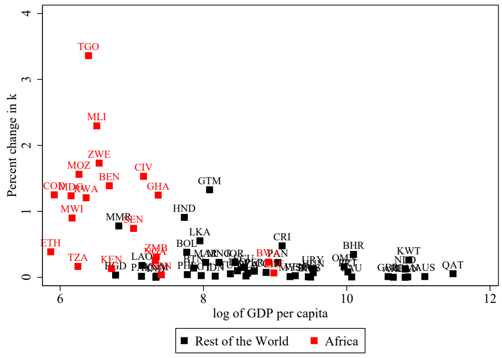
(a) $\varepsilon = 2.96$



(b) $\varepsilon = 3.7$



(c) $\varepsilon = 2.22$



(d) 10 percent price decrease $\varepsilon = 2.96$

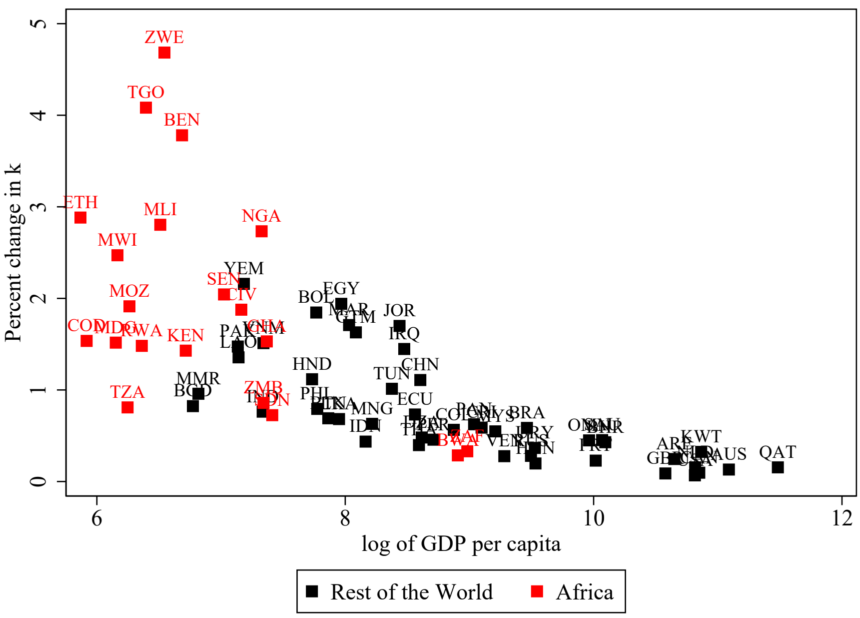
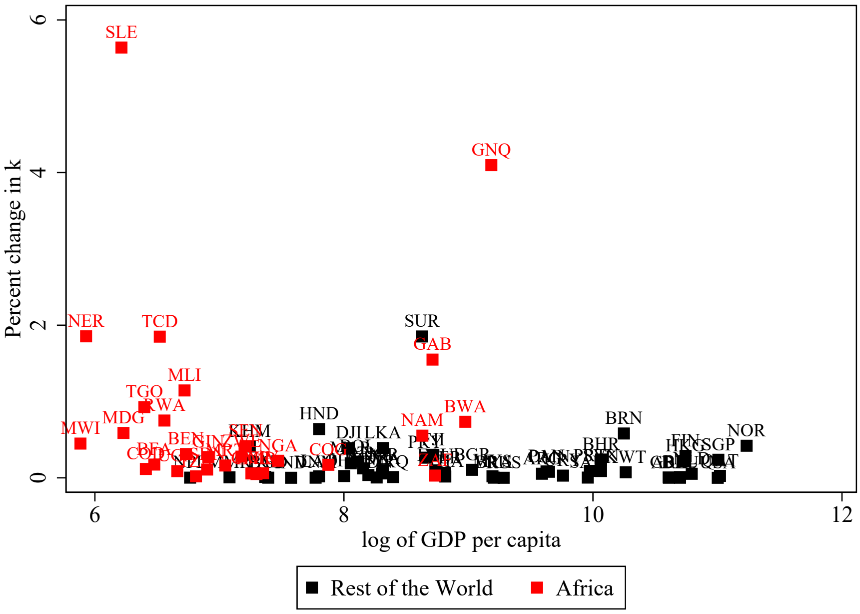
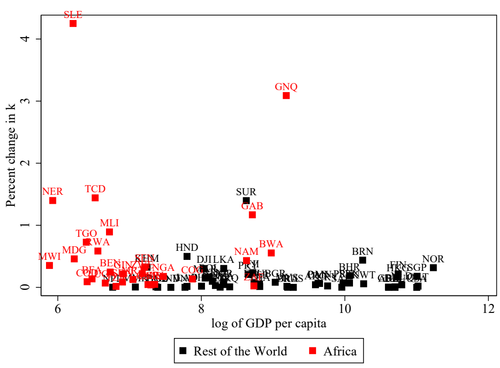


Figure A.3: Long run effect Entry and price decrease - including monopoly markets

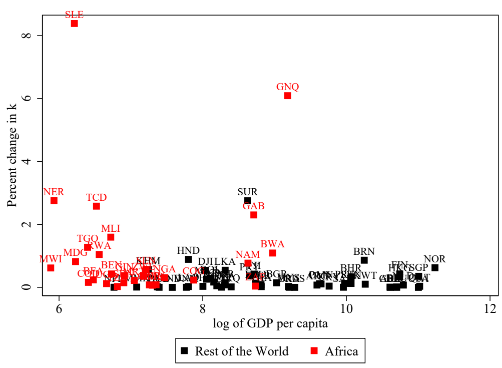
(a) $\varepsilon = 2.96$



(b) $\varepsilon = 3.7$



(c) $\varepsilon = 2.22$



(d) 10 percent price decrease $\varepsilon = 2.96$

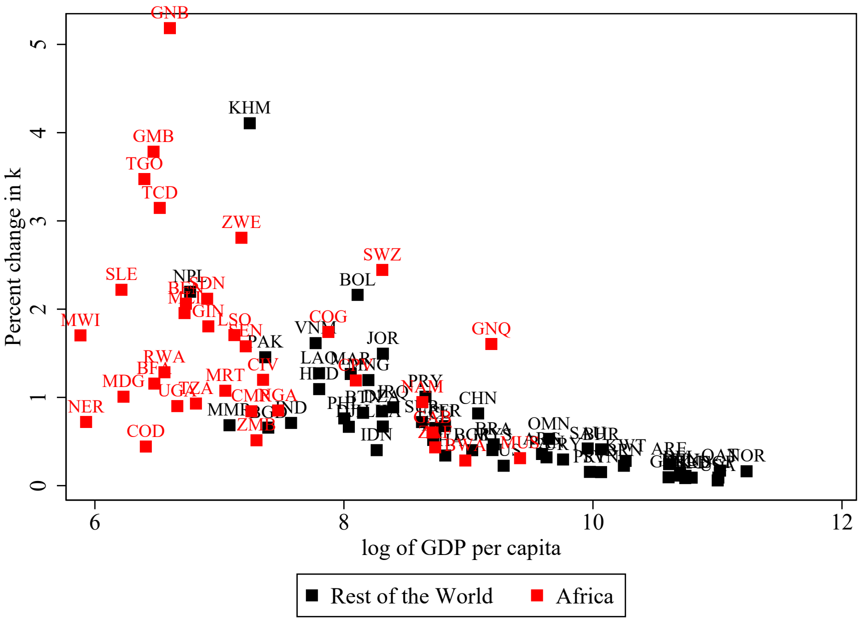
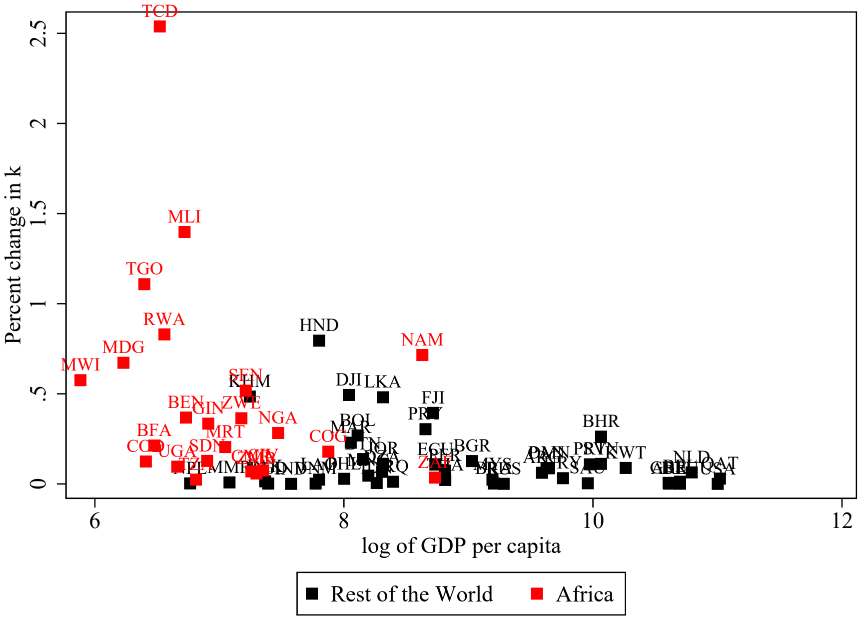
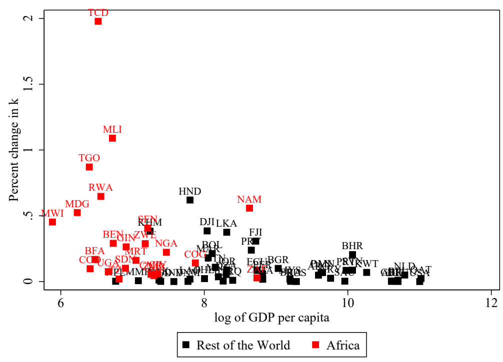


Figure A.4: Long run effect of entry and price decrease - variable α_I

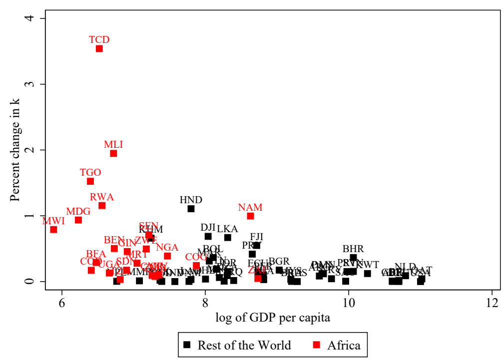
(a) $\varepsilon = 2.96$



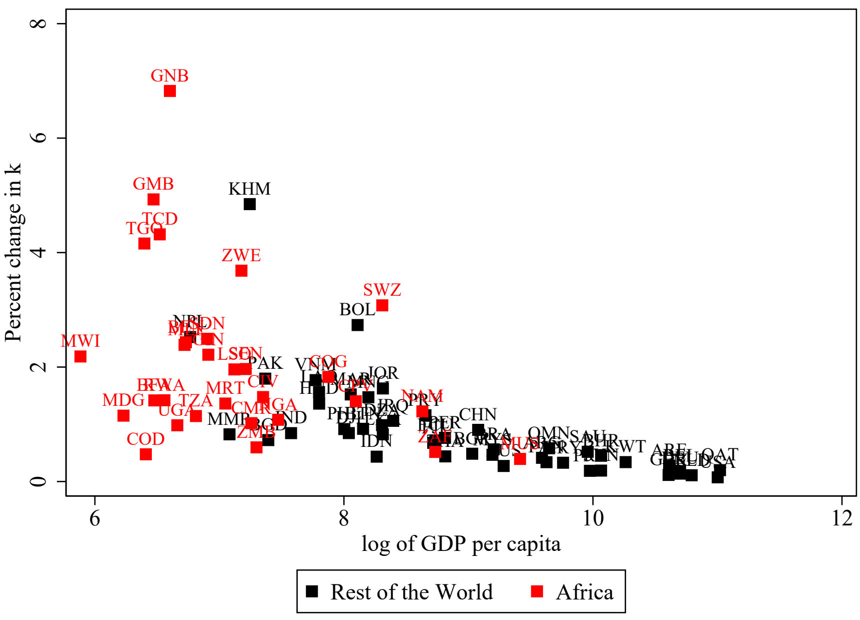
(b) $\varepsilon = 3.7$



(c) $\varepsilon = 2.22$



(d) 10 percent price decrease $\varepsilon = 2.96$



C. Model Derivations

Proof of proposition 1

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

$$\ln p^c = \gamma \frac{1}{n} + x\beta + \eta$$

implies the statement is equivalent to stating $COV(n,\eta) > 0$. Therefore, we wish to prove the unobserved component of prices is positively correlated with the number of firms producing in the market. It should be noted that η is the only stochastic element of the system, meaning it is sufficient to show n is an increasing function of η.

First we show n^* is an increasing function of η. Totally differentiating unconditional expected profits $\mathbb{E}[\pi\big(n^*(\eta), p(\eta)\big)] = \bar{\pi}\big(n^*(\eta), p(\eta)\big)$ 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 implies

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

which implies that $COV(n^*, \eta) > 0$. The definition of n^e given by equation (7) trivially implies it is a non-decreasing function of n^*. Therefore

$$\frac{dn^e}{d\eta} = \frac{dn^e}{dn^*}\frac{dn^*}{d\eta} \geq 0$$

Finally, the definition of a CDF trivially implies $G(p(\eta))$ is an increasing function of η. This along with the above result together imply

$$\frac{dn^e}{d\eta} \geq 0 \longleftrightarrow COV(n,\eta) \geq 0$$

according to equation (7) Q.E.D.

Proof of proposition 2

We first derive an expression for changes in the steady state of investment p. Shepard's lemma applied to a cost minimising investment producer (with constant technology) implies that

$$d\log p = d\log\mu_I + \sum_j \lambda_{Ij} d\log p_j + \lambda_{Ik} d\log r^k + \lambda_{IL} d\log w$$

while applying Shepard's lemma to producer j yields

$$d\log p = d\log\mu_I + \sum_j \lambda_{Ij}(d\log\mu_j) + d\log r^k\Big(\sum_j \alpha_j + \lambda_{Ik}\Big) + d\log w\Big(\sum_j (1-\alpha_j) + \lambda_{IL}\Big)$$

using the steady state condition $d\log r^k = d\log p$ and the definition of α_I we obtain

$$d\log p = (1-\alpha_I)^{-1}\Big(d\log\mu_I + \sum_j \lambda_{Ij}(d\log\mu_j) + (1-\alpha_I)d\log w\Big).$$

Fixed labour supply implies that $d\log\Lambda_L = d\log w$, while $d\log\Lambda_L = d\log k + d\log w$ which we can use to obtain

$$d\log p = d\log\Lambda_k - d\log\Lambda_L - (1-\alpha_I)^{-1}\Big(d\log\mu_I + \sum_j \lambda_{Ij}(d\log\mu_j)\Big).$$