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The Price of Capital Goods: A Driver of Investment Under Threat

by Weicheng Lian, Natalija Novta, Evgenia Pugacheva, Yannick Timmer and Petia Topalova

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Abstract

Over the past three decades, the price of machinery and equipment fell dramatically relative to other prices in advanced and emerging market and developing economies. Using cross-country and sectoral data, we show that the decline in the relative price of tangible tradable capital goods provided a significant impetus to the capital deepening that took place during the same time period. The broad-based decline in the relative price of machinery and equipment, in turn, was driven by the faster productivity growth in the capital goods producing sectors relative to the rest of the economy, and deeper trade integration, which induced domestic producers to lower prices and increase their efficiency. Our findings suggest an additional channel through which rising trade tensions and sluggish productivity could threaten real investment growth going forward.

JEL Classification Numbers: F10, F40, E31, O40

Keywords: Relative price of investment goods, trade integration, trade barriers, capital deepening, global value chain

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I. INTRODUCTION

For decades real investment in machinery and equipment has outpaced real GDP growth in many emerging market and developing economies. Since 1970, the real investment rate in machinery and equipment has tripled, rising from about 2 to 6 percent of real GDP (Figure 1). This capital deepening coincided with a steep decline in the price of capital goods relative to the price of consumption. The relative price of tangible tradable capital goods fell by over 50 percent since 1970 for the median emerging market and developing economy.[1] This process seemed to be accompanied by stronger trade integration in the capital goods producing sectors, with the rise in import penetration in this sector exceeding that in other sectors of the economy (Figure 2).

Economists have long argued that the relative price of replaceable capital goods, especially machinery and equipment, is one of the key determinants of economic performance.[2] The fact that, in the cross-section, the price of capital goods, relative to the price of consumption, is much higher in poor countries was considered crucial in explaining the lower investment rates, living standards and growth observed in these economies. Yet, there is little consensus on the underlying causes of the cross-country heterogeneity in the relative price of capital goods. Some have argued that it mainly reflects differences in countries' productivity in the making of machinery and equipment or other tradable goods that could be exchanged for machinery and equipment (Hsieh and Klenow 2007). Others link it to distortionary policy choices, such as higher barriers to trade, taxes on capital goods, monopoly power in the production of machinery and equipment),[3] or discriminatory pricing by exporters (Alfaro and Ahmed 2007). While the literature on the cross-country differences in relative capital goods prices blossomed, existing studies have largely neglected to examine the drivers of the changes in the relative price of capital goods over time.

In this paper, we revisit the debate about the key drivers of the relative price of investment and study the macroeconomic implications of the falling relative price of capital goods. First, we use newly available data from the 2011 round of the International Comparison Project

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[1] In this paper, unless otherwise noted, the terms tradable capital goods, tradable investment goods, and machinery and equipment are used interchangeably to denote tangible tradable investment goods—namely, machinery, equipment, and transportation capital goods.

[2] See, for example, de Long and Summers (1991, 1992, 1993); Jones (1994); Lee (1995); Sarel (1995); Restuccia and Urrutia (2001); Collins and Williamson (2001).

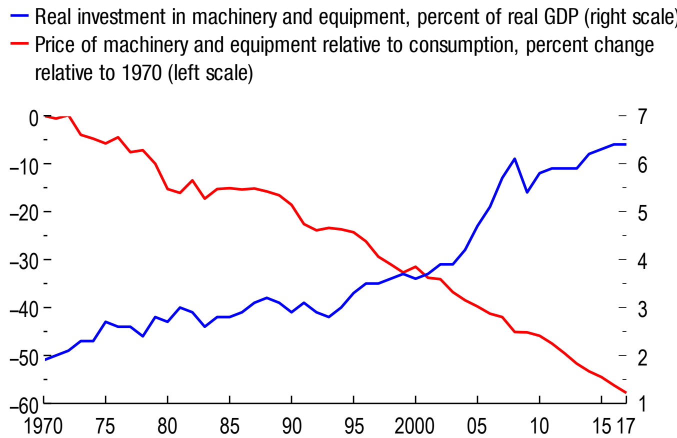
[3] See, for example, Jones (1994), Taylor (1998a), Eaton and Kortum (2001), Sen (2002), Restuccia and Urrutia (2001), Estevadeordal and Taylor (2013), Sposi (2015) and Johri and Rahman (2017). Hsieh and Klenow (2007) question the role of trade frictions by showing that poorer countries do not have higher absolute prices of capital goods. On the other hand, Sposi (2015) suggests that Hsieh and Klenow's (2007) findings may not necessarily rule out trade frictions. Instead, he shows that trade can lower the relative price of tradable goods by increasing specialization and productivity thanks to cheaper inputs in the production of tradable goods. Similarly, Mutreja et al. (2014) argue that smaller dispersion in absolute prices does not necessarily imply the absence of large trade costs.

(ICP) database to study whether absolute and relative prices of machinery and equipment are higher in countries with higher trade barriers.[4] Previous studies highlight poor data quality as an important constraint in understanding the drivers of the cross-country dispersion of the relative price of investment goods (see, for example, Hsieh and Klenow, 2007, Alfaro and Ahmed 2007). The 2011 ICP round introduces many methodological improvements to address data quality concerns of older rounds (see Feenstra, Inklaar and Timmer 2015, Deaton and Aten 2017, and Alfaro and Ahmed 2007).

Second, we analyze the roles of trade integration and productivity in the decline of the relative price of capital *over time*. We combine sector-level tariff data constructed by Feenstra and Romalis (2014) and the World Input and Output database, which provides output prices and trade flows at the sector level, to study how trade-policy-induced changes in import penetration affected producer prices.

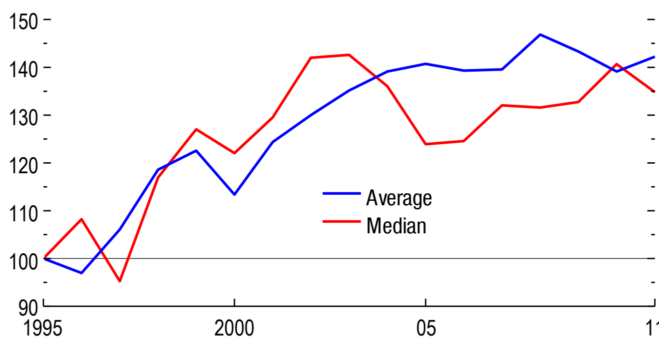
Third, we examine the effect of relative prices of capital goods on real investment rates over the last 30–60 years. While the theoretical link between the relative price of capital goods and investment is not hard to establish, the empirical evidence on this issue is scant and relies mostly on aggregate cross-sectional data from earlier periods (see, for example, Sarel 1995, and Restuccia and Urrutia 2001). Using both country-level and

Figure 1. Evolution of the Relative Price of Machinery and Equipment and Investment Rates
(Percent)



Sources: Penn World Table (PWT) 9.1; and authors' calculations.
Note: Figure shows the cross-country median for emerging market and developing economies of the real investment in machinery and equipment to real GDP ratio (blue line) and the year fixed effects from a regression of log relative prices on year fixed effects and country fixed effects to account for entry and exit during the sample period and level differences in the price of machinery and equipment relative to the price of consumption (red line). Year fixed effects are normalized to show percent change from the relative investment prices in 1970.

Figure 2. Relative Import Penetration
(Percent)



Sources: World Input-Output Database (WIOD); and authors' calculations.
Note: The figures show the cross-country average and median for emerging market and developing economies of the ratio of import penetration for capital goods sector to overall economy. Import penetration is defined as total imports over value added.

[4] Comparable cross-country data on the price of capital goods are scarce. The key source is the ICP, which collects detailed price data through cross-country surveys every 5 to 10 years. Previous studies relied on the 1985 and 1996 ICP rounds of data (Eaton and Kortum 2001, and Hsieh and Klenow 2007).

sectoral data, we quantify how much of the increase in the real investment rate in machinery and equipment that occurred since the 1990s can be attributed to the decline in the relative prices of machinery and equipment.

Our analysis shows that the reduction in trade costs, and the associated rise in trade integration, was an important factor in the decline of the relative price of machinery and equipment in the past decades. Two pieces of evidence are consistent with this conclusion. First, according to the latest (2011) ICP data, across countries, those with higher trade costs tend to pay a higher price for a comparable basket of machinery and equipment both in absolute terms and relative to the price of consumption. Second, analysis of sectoral producer price data suggests that relative prices are highly responsive to changes in import penetration. We find that rising import penetration lowers domestic producer prices both directly, as producers lower prices due to foreign competition, and indirectly, by boosting their productivity, which ultimately leads to lower prices. We combine the estimated coefficients with the change in the relative trade exposure in the capital goods sectors to provide an illustrative quantification of how much trade has contributed to the decline in the relative price of machinery and equipment during 2000–11. We find that, on average, more than two-thirds of the fall in the relative price of tradable investment goods between 2000 and 2011 can be attributed to trade integration.

We also show that the decline in the relative price of capital goods has played a crucial role in increasing real investment rates over the past three decades. Cross-country panel regressions relying on over 60 years of data across 180 economies suggest that real investment in machinery and equipment is highly sensitive to its relative price, even after controlling for all global shocks, time-invariant country characteristics, and a host of other policies and time-varying factors shown by economic theory and previous studies to shape investment rates. A 1 percent decline in the relative price of machinery and equipment is associated with about 0.4 percent increase in the real investment rate. The estimated sensitivity is very similar if we use sectoral data instead. We analyze sectoral investment rates across 15 broad sectors in 18 economies during 1971-2015 from the EU KLEMS database. The sectoral analysis allows us to properly account for the role of all factors that affect overall investment within a country in a particular year, such as financial conditions, economy-wide growth prospects, quality of regulations and the like. The empirical estimates suggest that a 1 percent decline in the relative price of machinery and equipment is associated with a 0.3 percent increase in real investment in machinery and equipment. Overall, the decline in the relative price of capital goods can explain about 40 percent of the increase in real investment rates in the average economy since the 1990s.

These results are important not only to shed light on the academic debate on the underlying drivers of relative prices, but to draw attention to possible emerging risks, which may hamper much-needed capital deepening in low-income countries. Since trade integration has indeed played a key role in driving down the relative price of investment goods, the waning pace of trade liberalization and the slowdown in global trade would limit further declines in the price of capital goods. Even more immediate is the threat from higher trade barriers in some advanced economies.

The rest of the paper is organized as follows. Section II describes some key stylized facts on the absolute and relative price of capital goods from a variety of sources. Section III analyzes the drivers of the prices of machinery and equipment, while Section IV presents estimates of the sensitivity of real investment to changes in relative prices. Section V concludes summarizing the key results and policy implications.

II. STYLIZED FACTS

Since the 1990s, capital goods prices relative to consumption prices have displayed three key patterns.[5] First, the relative prices of the four main types of fixed capital assets—structures, machinery and equipment, transportation equipment, and intellectual property products—have evolved quite differently (Figure 3, panels 1–4). According to data in the Penn World Table version 9.1 across 180 countries, the prices of *tradable* investment goods, namely machinery and equipment and transportation equipment have declined very significantly since the early 1990s when compared with the consumption deflator. The price of residential and nonresidential structures, on the other hand, has more closely tracked consumption prices and even increased since the mid-2000s, in relative terms, in advanced economies. Within tangible tradable capital goods, the dramatic decline in the relative prices of computing equipment (such as computer hardware, whose prices fell by 90 percent since 1990) and to a lesser extent communications equipment (whose prices fell by almost 60 percent) (Figure 3, panels 5–6), supports the hypothesis that advances in information technology have played an important role in driving down the relative price of investment.[6]

These patterns also suggest that deepening trade integration and efficiency gains from globalization and the associated specialization of production around the world have supported the downward trend in capital goods prices. The decline was most pronounced in those tangible capital goods that can be more easily traded across borders. The production of machinery and equipment is also strongly embedded in global value chains, as depicted in Figure 4.

The second notable pattern is the slowdown in the pace of decline in the relative price of machinery and equipment in recent years (Figure 5). While up-to-date data are not widely available, recent data from 10 advanced economies suggest that the decline in relative prices of capital goods has been less pronounced since the global financial crisis, coinciding with a slowdown in global trade and the process of trade liberalization. Byrne and Pinto (2015) document a similar slowdown in the decline of high-tech equipment price in the case of the United States.

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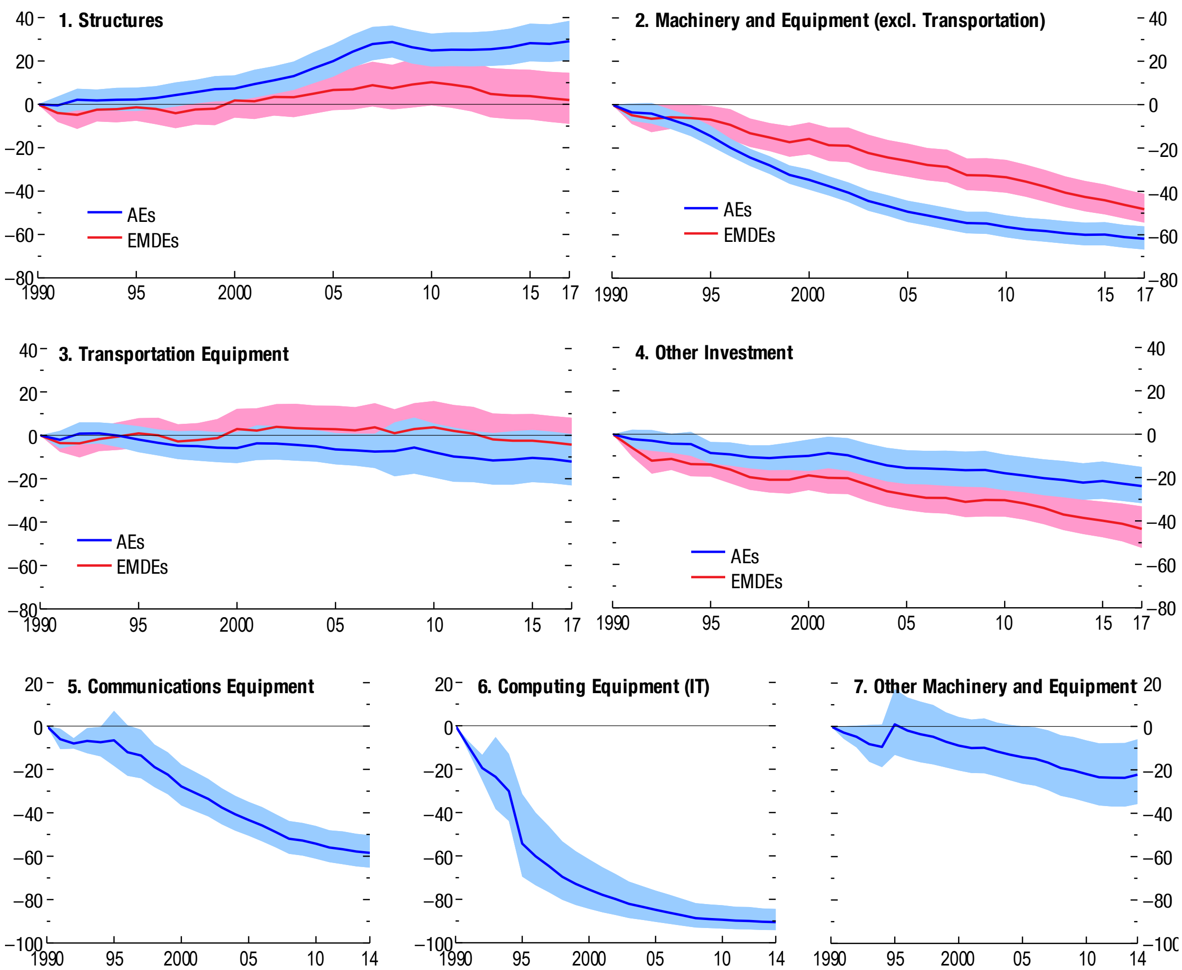
[5] See Annex1 for country coverage, data sources, and variables definitions.

[6] Measuring changes in the prices of goods that undergo substantial quality improvements, such as computers, communications equipment, and so on, is a daunting task because of the difficulty of comparing products with very different attributes (Schreyer 2002). Statistical offices make substantial efforts to accurately reflect these changes in price indices, although methodologies likely differ significantly across countries. The paper relies on the data provided by national authorities and compiled in Penn World Table 9.1.

Third, despite the broad-based decline in the relative price of tradable capital goods over time, the prices of these goods vary substantially across countries, especially relative to the price of consumption. According to the latest data from ICP, the absolute price of machinery and equipment in 2011 was inversely related to countries' development levels, with lower-income countries facing slightly higher prices than advanced economies. The same basket of machinery and equipment costs about 8 percent more in the median low-income country compared to the median advanced economy (Figure 6, panel 1).

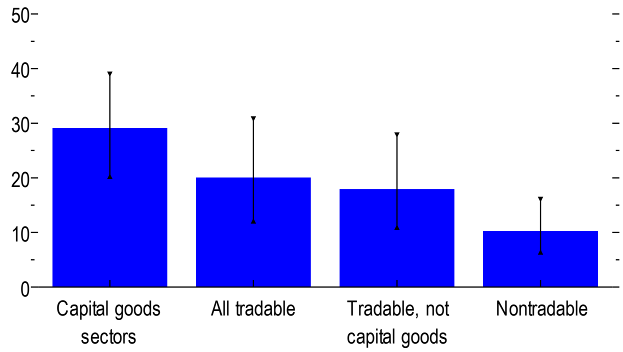
As established by earlier studies (see, for example, Hsieh and Klenow 2007), the difference between advanced economies and lower-income countries is particularly striking for the relative price of machinery and equipment (i.e. relative to the countries' consumption price level). The relative price of machinery and equipment in the median low-income country is 2.7 times the price in the median advanced economy (Figure 6, panel 2).

Figure 3. Dynamics of Relative Prices across Types of Capital Goods and Broad Country Groups
(Percent change relative to 1990)



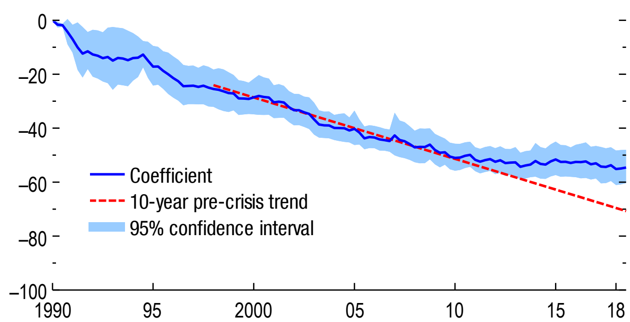
Sources: EU KLEMS; Penn World Table 9.1; World KLEMS; and authors' calculations.
Note: Panels 1–4 use data from the Penn World Table 9.1 capital detail file, while panels 5–7 use data from the EU and World KLEMS databases. The relative price of investment (for each type of capital good) is obtained by dividing the relevant investment deflator by the consumption deflator. The solid line plots year fixed effects from a regression of log relative prices on year fixed effects and country fixed effects to account for entry and exit during the sample period and level differences in relative prices. Year fixed effects are normalized to show percent change from the relative investment prices in 1990. Shaded areas indicate 95 percent confidence intervals. AEs = advanced economies; EMDEs = emerging market and developing economies.

Figure 4. Backward Participation in GVCs
(Percent of exports, foreign value added)



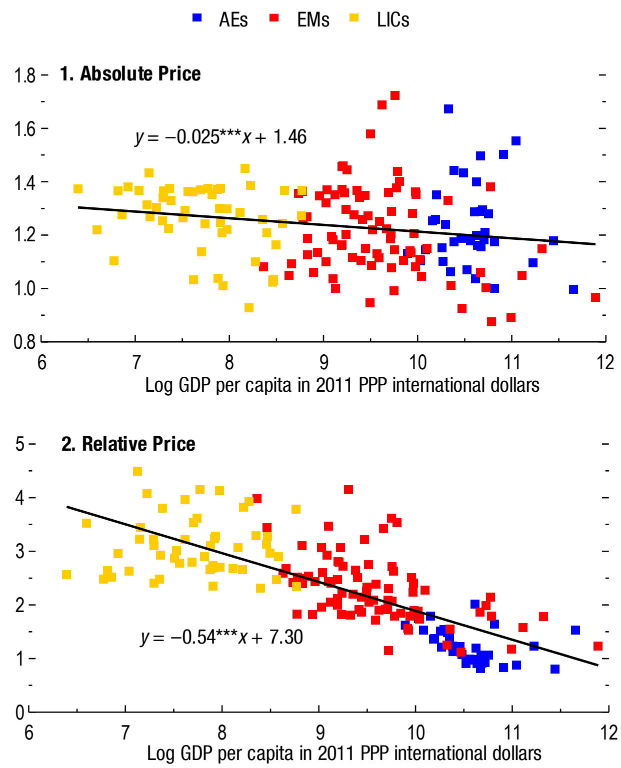
Sources: Eora MRIO database; and authors' calculations.
Note: The figure depicts the median and interquartile range of the sector's backward global value chain participation (defined as the foreign value added in exports) across all economies in the Eora MRIO database deemed to have sufficient data quality at the sectoral level during 1995–2015.

Figure 5. Relative Price of Machinery and Equiment for Select Advanced Economies
(Percent change relative to 1990Q1)



Sources: Haver Analytics; and authors' calculations.
Note: Figure shows the quarter fixed effects from a regression of log relative prices on quarter fixed effects and country fixed effects to account for entry and exit during the sample period and level differences in the price of machinery and equipment relative to the price of consumption. Quarter fixed effects are normalized to show percent change from the relative investment prices in 1990Q1. Based on quarterly data from select advanced economies, including: Australia, Canada, Germany, Hong Kong, Italy, Norway, Portugal, Spain, United Kingdom, United States.

Figure 6. Absolute and Relative Prices of Machinery and Equipment across Countries in 2011
(Ratio)



Sources: International Comparison Program (ICP) 2011; World Economic Outlook; and authors' calculations.
Note: The absolute price of machinery and equipment is the price level of machinery and equipment relative to its US level, derived by the ICP using a similar basket of products across countries. The relative price is the price of machinery and equipment relative to the price of consumption. AEs = advanced economies; EMs = emerging market economies; LICs = low-income countries; PPP = purchasing power parity.

III. Drivers of Relative Investment Prices

In this section, we examine empirically the key sources of differences in the relative price of tradable capital goods across countries, and the factors underpinning the dramatic declines in the relative price of machinery and equipment over time.

In theory, the relative price of capital goods is shaped by several factors. Of prime importance is the efficiency with which an economy can produce machinery and equipment (or other tradable goods that it can exchange for investment goods) compared with the efficiency in other sectors.[7] In countries that import a significant fraction of investment goods (as in many emerging market and developing economies), the relative price of machinery and equipment also reflects prices that international suppliers charge for these goods, as well as other factors that drive a wedge between international and domestic prices. These include transportation costs, the efficiency of the domestic distribution sector, import tariffs, customs regulations, and the time and costs associated with the logistics of importing goods. Tax policies, such as accelerated depreciation, investment tax credits, and subsidies, as well as the extent of corruption, also influence the relative investment price.[8] We proceed to shed light on the importance of these factors in explaining both the cross-country heterogeneity in relative capital goods prices and their evolution over time.

A. Cross-country analysis

Determining which factors explain the observed differences in the absolute and relative prices of tradable capital goods in the 2011 ICP data is a daunting task. Because price levels of capital goods that are comparable across countries are available only at one point in time, it is difficult to disentangle the causal contribution of various potential drivers. We examine each potential source of differences in capital goods prices across countries—namely, the prices charged by key exporters, trade costs, and relative efficiency in the production of tradable goods—and relate these to the relative price of capital goods from the 2011 ICP data.

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[7] Hsieh and Klenow (2007) present a simple two-sector model that delivers these patterns for relative prices, under the assumption that markups, factor intensities, and factor prices are equal across sectors. The relative productivity in the production of capital goods across countries is conceptually tightly linked to countries' relative efficiency in the production of all tradable goods, including tradable consumer goods (the well-known Balassa-Samuelson effect).

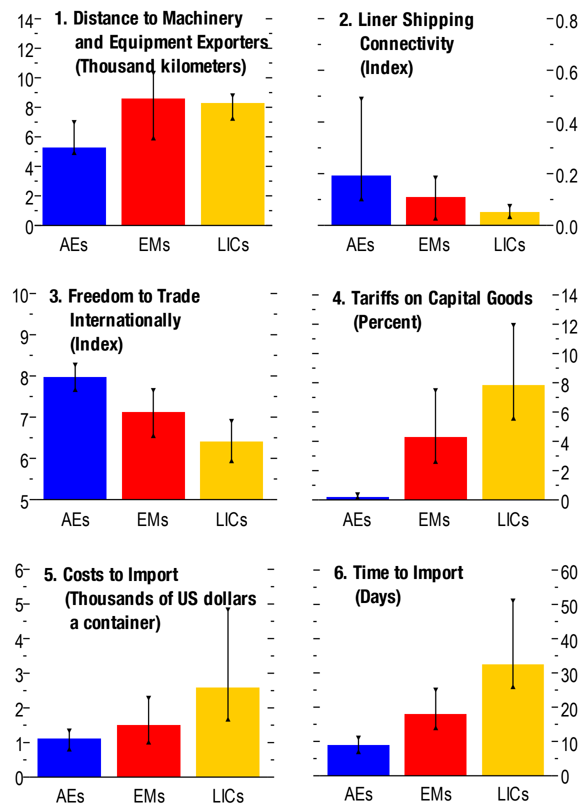
[8] See Estevadeordal and Taylor (2013) for the role of tariffs; Sarel (1995) for the role of taxes; and Justiniano, Primiceri, and Tambalotti (2011) for investment-specific technology shocks that would affect relative sectoral productivity. Cross-country differences in the relative prices of capital have been emphasized as an important factor explaining the lack of capital flows from rich to poor economies, as discussed in Caselli and Feyrer (2007).

To assess whether differences in prices charged by key capital goods exporters can explain the higher relative prices of machinery and equipment observed in emerging market and developing economies (compared with advanced economies), we examine highly disaggregated data on trade in capital goods. Since a small number of countries account for the bulk of global exports of machinery and equipment (Eaton and Kortum 2001), and since most emerging market and developing economies import a significant proportion of these goods, we compare unit values of various types of machinery and equipment from five of the largest capital goods exporters—United States, China, Germany, France, and Japan.[9] This approach, which builds on Alfaro and Ahmed (2009), ensures the cross-country comparability of capital goods, since quality differences within such narrowly defined products sourced from the same exporter are likely minimal.[10] It also allows us to isolate the differences in the price charged by exporters from other sources of cross-country price variation that are reflected in the ICP data, such as trade, transportation, delivery, and installation costs paid by buyers and discounts that may be available to them.

Our analysis uncovers little systematic correlation between the price of capital goods and the per capita income of the importing country, when trade data from the five large capital goods exporters are pooled (Annex Table 1). Trade costs, on the other hand, exhibit a clear pattern: they tend to be much lower for

Figure 7. Trade Costs in 2011

(Median, and interquartile range)



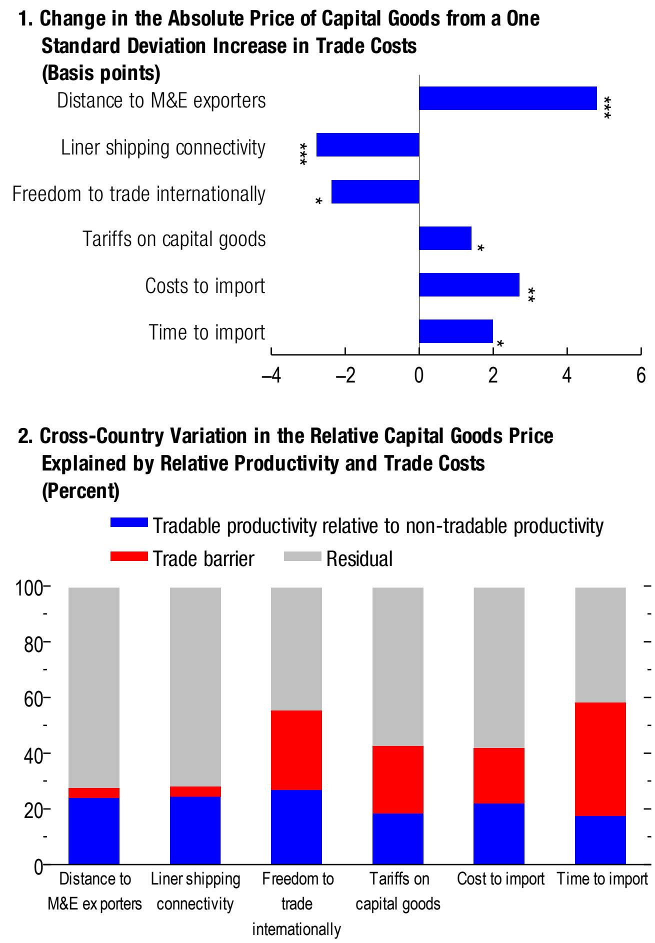
Sources: CEPII, GeoDist database; Eora MRIO database; Feenstra and Romalis (2014); Fraser Institute; United Nations Conference on Trade and Development (UNCTAD); World Bank, Doing Business Indicators; and authors' calculations.
Note: Distance to exporters of machinery and equipment (M&E) is calculated as the weighted average of a country's distance to all other countries, where the weights are equal to the partner countries' exports of capital goods as a share of global capital goods exports. The UNCTAD liner shipping connectivity index captures how well countries are connected to global shipping networks based on five components of the maritime transport sector: number of ships, their container-carrying capacity, maximum vessel size, number of services, and number of companies that deploy container ships in a country's port. The Fraser Institute's Freedom to Trade Internationally index is based on four different types of trade restrictions: tariffs, quotas, hidden administrative restraints, and controls on exchange rate and the movement of capital. The cost and time indicators measure the cost (excluding tariffs) and time associated with three sets of procedures—documentary compliance, border compliance, and domestic transport—within the overall process of importing a shipment of goods. AEs = advanced economies; EMs = emerging market economies; LICs = low-income countries.

[9] While exports of capital goods continue to be concentrated in a few countries, emerging market and developing economies have gained significant market share, accounting for about one-third of global exports in 2016, up from 5 percent in 1990. China has played a particularly prominent role, with its share in global exports rising from 1 to 2 percent in the 1990s to 18 percent in 2017.

[10] In particular, the analysis relates the unit value of each product to the importing country's per capita GDP, controlling for exporter-product-year fixed effects, similar to Schott (2004), Manova and Zhang (2012), and Alfaro and Ahmed (2009).

advanced economies.[11] Despite significant progress in liberalizing the international exchange of goods and services and reducing trade costs, emerging markets, and especially low-income developing countries, still face significantly higher policy-related barriers to trade than advanced economies, in addition to their larger natural trade barriers (Figure 7). They tend to be located farther from key capital goods exporters and are less connected to global shipping networks. They impose significantly higher tariffs on imports of capital goods, and the time and cost associated with the logistics of importing goods—such as documentary and border compliance and domestic transportation—are substantially higher. We find that countries with higher trade costs in any of these measures tend to have higher absolute prices of machinery and equipment in the 2011 ICP data (Figure 8, panel 1).

Figure 8. Trade Costs, Relative Productivity, and the Price of Capital Goods in 2011



Source: Authors' calculations.
Note: Panel 1 depicts the percent change in the 2011 International Comparison Program (ICP) absolute price of machinery and equipment associated with a one standard deviation increase in alternative measures of trade costs. In panel 2, the cross-country variation in the 2011 ICP price of machinery and equipment relative to consumption is decomposed into the share explained by differences in the labor productivity in the tradable goods sectors relative to the non-tradable goods sectors, and alternative measures of trade costs. M&E = machinery and equipment. ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Putting together the two key contending explanations of the cross-country dispersion in relative capital goods prices, namely trade costs and relative productivity differences, we examine their contribution to the cross-country variation in relative prices of capital goods. We estimate a simple OLS regression of the log of the relative price of machinery and equipment (using ICP 2011 data) on the log of the relative labor productivity in the tradable goods producing sector and alternative measures of trade costs, which are included one at a time. In a second step, we use these regression estimates to decompose the cross-country variation in the log of relative prices into the variance that can be explained by the relative productivity measure versus trade costs. Given the cross-sectional nature of the data, this analysis is purely illustrative. As elaborated in the next section, relative productivity and trade costs are not independent of one

[11] Data limitations prevent examination of the potential contribution of tax policies, such as accelerated depreciation or investment tax credits.

another, complicating the interpretation of their estimated contribution to the variation in relative prices. The relative productivity in the tradable goods sector may be affected by trade barriers, as production of tradable goods likely relies on imported inputs. Furthermore, policy-related trade barriers may be erected with the goal of protecting low-productivity tradable goods sectors.

With these caveats in mind, Figure 8, panel 2 shows that both relative productivity differences and trade costs are important in explaining the cross-country heterogeneity in relative prices. Together, relative productivity differences in the production of tradable goods and trade costs can explain up to 60 percent of the cross-country variation in the relative price of machinery and equipment, depending on which measure of trade cost is used.[12] Interestingly, policy-related trade barriers, such as tariffs and cost and time of importing, are a more powerful predictor of relative prices than natural barriers to trade such as distance and connectivity. While causal interpretation is difficult in the cross-country setting and in light of the likely relationship between relative productivity and trade barriers, these findings are consistent with the idea that the relative prices of capital goods are higher in emerging market and developing economies in part due to their higher trade barriers.

B. Time-Series Analysis

Prior studies have primarily focused on the cross-country variation in relative capital goods prices (for example, Hsieh and Klenow 2007, and Sposi 2015), as they explored the roles of trade and productivity. We aim to shed light on the drivers of the big declines in the relative prices of tradable capital goods over time. We show that differences in the rate of trade integration and relative productivity growth within countries over time can lead to large variations in relative prices.

We use sectoral producer price data across 33 sectors and 40 advanced and emerging market economies during 1995–2011 from the Socioeconomic Accounts of the World Input-Output Database. This allows us to control for all factors that affect prices equally across sectors within a country in a particular year (such as exchange rate fluctuations and policies, commodity price changes, aggregate demand and productivity shocks, and the like) and all time-invariant differences in prices across countries and sectors.[13]

This approach faces two challenges. First, trade integration, in the sense of more market access for foreign producers (as measured by the ratio of imports to domestic sectoral value-added) fosters competition, inducing domestic producers to reduce markups of prices over marginal costs. In practice, the feedback from higher domestic prices to greater ability of foreign producers to gain market share complicates the interpretation of the estimated

[12] Given the high correlation among different components of trade costs, including all the measures considered in the same regression, does not significantly increase the share of variation in relative prices that can be explained by trade costs.

[13] The analysis relies on producer prices due to their availability for a wide range of sectors and countries. All sectoral variables are measured relative to their economy-wide equivalent.

(continued…)

relationship between the two variables. To overcome this challenge, the analysis uses import tariffs as an instrument for exposure to trade, thus isolating changes in import penetration that were triggered by policy choice, rather than those driven by changes in domestic prices.[14] Second, exposure to foreign competition affects relative domestic prices indirectly, through its impact on sectoral labor productivity as documented in numerous studies (see, for example, Ahn et al. (forthcoming), Amiti and Konings 2007, Topalova and Khandelwal 2011). Thus, simply applying the elasticities estimated in the regression in the first step will understate the contribution of trade to producer price changes. To correct for this, we quantify the changes in labor productivity that can be attributed to changes in import penetration, and, in the second step, distinguish the contribution of trade-related changes in labor productivity from changes in productivity due to other factors (such as sectoral technological advances) to the decline in the relative price of machinery and equipment.

Regression Framework

We estimate two separate regressions to understand the contributions of global integration and productivity growth to the decline in the relative price of machinery and equipment in the past decades.

First, we estimate the sensitivity of relative producer prices at the sector level to changes in relative labor productivity and import penetration, using the following equation:

$$\ln\left(\frac{P_{i,j,t}}{\bar{P}_{i,t}}\right) = \alpha_{i,j} + \mu_{i,t} + \beta\left[\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\overline{VA}_{i,t}}\right)\right] + \gamma\ln\left(\frac{LP_{i,j,t}}{\overline{LP}_{i,t}}\right) + \varepsilon_{i,j,t},$$

where $\frac{P_{i,j,t}}{\bar{P}_{i,t}}$ is the relative price of sector j in country i at time t; $\alpha_{i,j}$ denotes country-sector fixed effects; $\mu_{i,t}$ denotes country-year fixed effects; $\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\overline{VA}_{i,t}}\right)$ is the relative import penetration (measured as imports divided by value-added); and $\frac{LP_{i,j,t}}{\overline{LP}_{i,t}}$ is the relative productivity of labor (measured as real value-added per employee).[15]

The relative import penetration, $\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\overline{VA}_{i,t}}\right)$ is instrumented by relative import tariff, defined as $\tau_{i,j,t} - \bar{\tau}_{i,t}$, with $\bar{\tau}_{i,t}$ defined as $\frac{\sum_{j=1}^{J}\tau_{i,j,t}}{J}$ and $\tau_{i,j,t}$ is defined as

$$\tau_{i,j,t} = \frac{\sum_{l\in\Lambda_j} m_{i,k,l,t}\hat{\tau}_{i,k,l,t}}{\sum_{l\in\Lambda_j} m_{i,k,l,t}},$$

[14] While widely used in the literature, the choice of tariffs as an instrument for trade integration does not fully address endogeneity concerns as policy makers may set tariff rates in response to various political economy considerations.

[15] $\bar{Z}_{i,t} = \sum_{j=1}^{J} Z_{i,j,t}$, for $Z \in \{M, VA\}$.

in which $m_{i,k,l,t}$ is the import of country i from country k in sector l at time t, and $\hat{\tau}_{i,k,l,t}$ is the tariff imposed on these imports. $\hat{\tau}_{i,k,l,t}$ comes from the SITC 4-digit level bilateral *preferential tariff data* compiled by Feenstra and Romalis (2014).

Second, we estimate the impact of trade liberalization on relative labor productivity through the following equation:

$$\ln\left(\frac{LP_{i,j,t}}{\overline{LP}_{i,t}}\right) = \alpha_{i,j}^{LP} + \mu_{i,t}^{LP} + \beta^{LP}\left[\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\overline{M}_{i,t}}{\overline{VA}_{i,t}}\right)\right] + \varepsilon_{i,j,t}^{LP},$$

where $\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\overline{M}_{i,t}}{\overline{VA}_{i,t}}\right)$ is also instrumented by relative import tariff, due to the concern of reverse causality: if a country's capital goods producing sector becomes more productive, it may import less machinery and equipment from abroad. The estimation results indeed confirm the need to address this endogeneity issue: the OLS coefficient is much smaller than the estimate obtained using the instrumental variable.

Import tariffs are assumed to satisfy the exogeneity conditions:

$$cov\left(\tau_{i,j,t} - \bar{\tau}_{i,t}, \varepsilon_{i,j,t}\right) = cov\left(\tau_{i,j,t} - \bar{\tau}_{i,t}, \varepsilon_{i,j,t}^{LP}\right) = 0.$$

In Table 1, column 1, we present the results from the first stage, the relationship between import tariffs and import penetration. As expected, country-sectors which experience larger cuts in import tariffs have higher import penetration. Column (2) of the same table contains the reduced form relationship between the instrument and the dependent variable of interest, namely relative producer prices. There is a strong negative link between import tariffs and producer prices, controlling for labor productivity.

Table 1. First-Stage Relationship, Effects of Import Tariff on Producer Prices

Dependent Variables:	Relative Import Penetration	Relative Producer Prices
	OLS	OLS
	(1)	(2)
Import Tariff	–0.014***	0.010***
	(0.003)	(0.003)
Relative Productivity$_{t-1}$	0.003	–0.308***
	(0.014)	(0.036)
Number of Observations	16,077	16,077
R^2	0.96	0.62

Source: Authors' calculations.

Note: All regressions include country-year and country-sector fixed effects. Standard errors clustered at the country and sector level in parentheses.

***p < 0.01; **p < 0.05; *p < 0.1

Tables 2 and 3 report the main estimation results. A general pattern that emerges is that deeper import penetration increases the relative labor productivity of a domestic sector. It also reduces producer prices directly. As robustness tests, we allow β, γ and β^{LP} to differ across advanced economies and emerging market and developing economies, and the results are broadly the same.

The impact of import tariffs on import penetration and the association between import penetration and producer prices are economically significant. A 1 percent increase in the import ratio, which can be achieved by a 0.7 percentage point cut in tariffs, reduces the sectoral producer price by about 0.6 percent. Changes in labor productivity also have a significant impact on producer prices, with a 1 percent increase in sectoral labor productivity reducing producer prices by about 0.3 percent.

Table 2. Labor Productivity and Trade Integration

Dependent Variable: Relative Productivity	OLS (1)	IV (2)	OLS (3)	IV (4)	IV (5)	IV (6)	IV (7)
Relative Import Penetration$_{t-1}$	0.054	1.639	0.044	1.363***	0.793***	2.403**	1.251***
	(0.049)	(0.000)	(0.054)	(0.363)	(0.305)	(1.041)	(0.449)
Relative Import Penetration$_{t-1}$ × Capital Goods Dummy			0.064	1.407**	1.965***	0.160	2.810
			(0.123)	(0.671)	(0.665)	(1.648)	(1.751)
Number of Observations	16,077	16,077	16,077	16,077	12,575	3,502	12,321
R^2	0.95	0.91	0.95	0.91	0.92	0.88	0.92
Relative Import Penetration for Capital Goods Sectors			0.108	2.771***	2.758***	2.563***	4.061***
			(0.110)	(0.564)	(0.624)	(1.089)	(1.686)
Sample	All	All	All	All	AE	EMDE	All, Post 2000

Source: Authors' calculations.
Note: All regressions include country-year and country-sector fixed effects. Standard errors clustered at the country and sector level in parentheses.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 3. Relative Producer Prices, Trade Integration and Relative Productivity

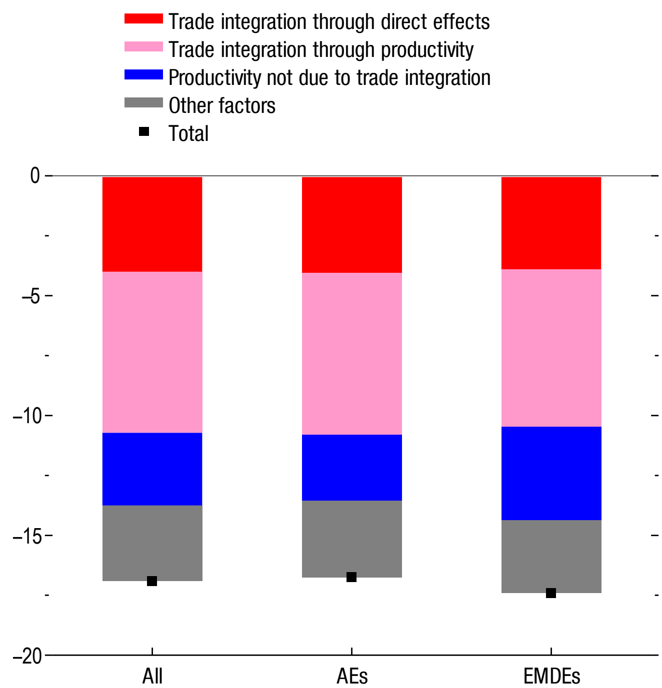
Dependent Variable: Relative Producer Prices	OLS (1)	IV (2)	OLS (3)	IV (4)	IV (5)	IV (6)	IV (7)	IV (8)
Relative Import Penetration$_{t-1}$	–0.135***	–0.568***	–0.107***	–0.574***	–0.413***	–0.964***	–0.461**	–0.458***
	(0.033)	(0.146)	(0.037)	(0.163)	(0.148)	(0.374)	(0.200)	(0.177)
Relative Import Penetration$_{t-1}$ × Capital Goods Dummy			–0.191**	0.033	0.037	0.183	–0.375	–0.040
			(0.081)	(0.322)	(0.384)	(0.617)	(0.574)	(0.359)
Relative Productivity$_{t-1}$	–0.316***	–0.328***	–0.314***	–0.328***	–0.349***	–0.274***	–0.302***	–0.368***
	(0.035)	(0.032)	(0.035)	(0.032)	(0.041)	(0.034)	(0.031)	(0.039)
Number of Observations	16,077	16,077	16,077	16,077	12,575	3,502	12,321	15,086
R^2	0.62	0.56	0.62	0.56	0.63	0.40	0.71	0.61
Relative Import Penetration for Capital Goods Sectors			–0.298***	–0.541*	–0.375	–0.781*	–0.836	–0.498
			(0.071)	(0.287)	(0.375)	(0.420)	(0.561)	(0.340)
Sample	All	All	All	All	AE	EMDE	Post 2000	All[1]

Source: Authors' calculations.
Note: All regressions include country-year and country-sector fixed effects. Standard errors clustered at the country and sector level in parentheses.
[1] Relative labor productivity$_{t-2}$ is used as an instrument for relative labor productivity$_{t-1}$.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Moreover, labor productivity of the capital goods producing sector is particularly sensitive to deepening trade integration, a finding consistent with the larger reliance on global value chains for the production of these goods.[16]

Figure 9 decomposes the average decline in the relative price of the machinery and equipment producing sectors between 2000 and 2011 into four parts: (1) the direct effect of deepening trade integration; (2) the effect of trade integration through higher labor productivity; (3) the effect of higher labor productivity, which is not due to deepening trade integration; and (4) a residual. Rising trade integration accounts for the bulk of the decline in relative prices of machinery and equipment, both through its direct effect on producer prices and indirectly, through higher labor productivity of domestic capital goods producers. Productivity gains in the capital goods sector, which cannot be directly linked to trade integration, were also a significant factor.[17]

Figure 9. Contributions to Changes in Relative Producer Prices of Capital Goods: 2000–11
(Percent)



Source: Authors' calculations.
Note: The figure combines the estimated elasticities of producer prices to trade integration and relative labor productivity, and changes in these factors for the capital goods sector between 2000 and 2011 to compute their contribution to the observed change in the producer price of capital goods relative to the price of consumption. AEs = advanced economies; EMDEs = emerging market and developing economies.

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[16] These results suggest that if low income countries were to bring capital goods' tariffs to the level of those in advanced economies (in other words they reduce tariffs by roughly 8 percentage points), the price of investment goods would decline by about 16 percent (with roughly 40 percent of the decline coming from the direct trade integration effect and the rest coming from higher productivity in the capital goods sector due to greater import competition).

[17] To decompose the change in the relative price of tradable capital goods from 2000 to 2011, we use the coefficients in column (4) of Table 2 and column (4) of Table 3 and calculate : (i) the direct effect of deepening trade integration, as the average of $\beta \times \{\left[\ln\left(\frac{M_{i,j,2011}}{VA_{i,j,2011}}\right) - \ln\left(\frac{\bar{M}_{i,2011}}{\overline{VA}_{i,2011}}\right)\right] - \left[\ln\left(\frac{M_{i,j,2000}}{VA_{i,j,2000}}\right) - \ln\left(\frac{\bar{M}_{i,2000}}{\overline{VA}_{i,2000}}\right)\right]\}$ across countries and sectors classified as capital goods; (ii) the effect of trade integration through higher labor productivity, defined as the average of $\gamma \times \beta^{LP} \times \{\left[\ln\left(\frac{M_{i,j,2011}}{VA_{i,j,2011}}\right) - \ln\left(\frac{\bar{M}_{i,2011}}{\overline{VA}_{i,2011}}\right)\right] - \left[\ln\left(\frac{M_{i,j,2000}}{VA_{i,j,2000}}\right) - \ln\left(\frac{\bar{M}_{i,2000}}{\overline{VA}_{i,2000}}\right)\right]\}$ across countries and sectors classified as capital goods; (iii) the effect of higher labor productivity, which is not due to deepening trade integration, defined as the average of $\gamma \times \{\left[\ln\left(\frac{LP_{i,j,2011}}{\overline{LP}_{i,2011}}\right) - \ln\left(\frac{LP_{i,j,2000}}{\overline{LP}_{i,2000}}\right)\right] - \beta^{LP} \times \{\left[\ln\left(\frac{M_{i,j,2011}}{VA_{i,j,2011}}\right) - \ln\left(\frac{\bar{M}_{i,2011}}{\overline{VA}_{i,2011}}\right)\right] - \left[\ln\left(\frac{M_{i,j,2000}}{VA_{i,j,2000}}\right) - \ln\left(\frac{\bar{M}_{i,2000}}{\overline{VA}_{i,2000}}\right)\right]\}$ across countries and sectors classified as capital goods; (iv) the contributions of other factors, i.e., the residual term.

IV. Relative Price of Investment Goods and Real Investment Rate

This section aims to quantify the impact of relative investment prices on real investment rate. In particular, how much does the relative price of capital goods matter for a country's investment rate? What share of the dramatic increase in machinery and equipment investment over the past 60 years can be attributed to the decline in the relative price of these goods? To answer these questions, we focus on medium-term changes in investment goods prices and its link with real investment rate.[18]

A. Cross-Country Empirical Evidence

The empirical framework used to assess the role of relative investment prices for investment-to-GDP ratios is inspired by the reduced form relationship that can be derived from a number of theoretical papers, such as Restuccia and Urrutia (2001) and Sarel (1995). The general intuition from these models is that a shock that leads to a decline in the relative price of investment, such as productivity increase in the capital goods sector or a decline in capital goods tariffs, would raise the optimal (steady-state) level of capital stock as a share of output. Because a higher level of capital stock needs to be maintained, real investment would rise permanently as a share of real output in order to keep up with capital stock's depreciation.

The general regression relates the log of the real investment-to-GDP ratio in machinery and equipment and the log of the price of machinery equipment relative to the price of consumption,[19] controlling for all time-invariant differences across countries (μ_i) and period fixed effects (θ_t) to capture common global shocks:

$$\ln\left(\frac{Real\ M\&E\ Investment}{Real\ GDP}\right)_{i,t} = \beta \cdot \ln\left(\frac{P_{M\&E}}{P_Y}\right)_{i,t} + \text{Controls}_{i,t} + \mu_i + \theta_t + \varepsilon_{i,t}.$$

Based on empirical studies of the long-run determinants of the aggregate investment rates,[20] the set of additional controls includes lagged level and growth rate of real GDP per capita in purchasing-power-parity terms to account for possible convergence effect, lagged dependent variable to account for persistence in investment rates, availability and cost of finance (proxied by real interest rates, credit-to-GDP ratio, and the extent of openness of the capital account), access to foreign markets (proxied by the degree of trade openness), exposure to commodity shocks (as a weighted measure of commodity prices and country-specific

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[18] Investment decisions are shaped by numerous factors. A comprehensive analysis of the relative importance of all potential factors is beyond the scope of this paper. The goal of the analysis is to zoom in on the relative price as a potential driver of investment and attempt to provide suggestive evidence of its quantitative importance.

[19] Real investment is used to reflect "quantities", whereas nominal measures convolute quantities with prices. The price of machinery and equipment, $P_{M\&E}$, is constructed as a weighted average of the prices of machinery and of transport equipment: $P_{M\&E} = \frac{I_{Machinery}}{I_{M\&E}} P_{Machinery} + \frac{I_{Transport}}{I_{M\&E}} P_{Transport}$. Results are broadly similar if we focus only on investment in machinery and equipment and its relative price, instead.

[20] For instance, IMF (2018) looks at the institutional drivers of private fixed investment, Lim (2013) analyses the impact of a range of institutional and structural determinants of investment rates, Salahuddin and Islam (2008) account for factors affecting investment rates in developing economies, Magud and Sosa (2017) analyze the influence of commodity prices on firm-level investment, Collins and Williamson (2001) document the evolution of relative prices since the 1870s and their correlation with investment rates for eleven advanced economies.

commodity exports), overall institutional quality and political risks, and the quality of infrastructure (proxied by kilometers of paved roads per capita). The choice of control variables is driven by availability of data for a longer sample of countries and years and is primarily aimed at attenuating potential omitted variable bias. The full list of data sources can be found in Annex 1.

Estimation results, based on OLS and IV regressions, are reported in Table 4 and confirm that real investment rates are shaped by a variety of factors. The regressions are estimated on five-year non-overlapping window averaged data. This approach aims to smooth the influence of short-term fluctuations, and to capture the potential medium-run relationship. Although estimates are often imprecise, a stronger regulatory environment, higher trade and financial integration, lower-cost finance, and greater financial development—as well as better infrastructure—are all associated with a higher ratio of real investment in machinery and equipment to real output. Importantly, we find a strong and statistically significant negative relationship between real investment in machinery and equipment and its relative price.

The estimates are robust to alternative specifications, choice of sub-samples, estimation methods, and use of annual data.[21] In the instrumental variable (IV) regressions, the relative price is instrumented using its own lag. This strategy allows to minimize the bias (towards finding a negative relationship) stemming from the potential negative correlation in the measurement errors of real investment and its price, under the assumption that measurement error is unlikely to be correlated over time.[22] Similar findings are obtained using system GMM estimator, and an alternative IV specification where the relative price is instrumented with the average relative price of all other countries except the country's own. This approach allows to isolate technologically driven changes in the relative price from those that may occur due to changes in demand for investment goods within a country, thus minimizing the measurement error bias as measurement error in a country's own prices is unlikely to be correlated with measurement error in other countries' prices.

Across specifications, a 1 percent decline in the relative prices of tradable capital goods is associated with a 0.3–0.5 percent increase in the real investment rate over a five-year period. It is important to note that these empirical estimates likely represent an upper bound of the true effect of changes in relative price on real investment rates. As discussed above, relative investment prices are endogenous and reflect many factors, including changes in policies that could have a direct impact on investment rates.

[21] With annual data the relative price, as well as the institutional and structural variables, are lagged to minimize endogeneity concerns. The coefficient on the relative price of investment is, as expected, smaller. The long-run effect can be approximated with the annual data by dividing the coefficient on the relative price of investment with (1 – coefficient on the lagged dependent variable), which gives an estimate closer to the five-year average regressions.

[22] If nominal values of investment rates are easier to observe, positive measurement error in investment volumes would imply negative measurement error in prices, thus imparting a negative correlation between the two variables. This is a standard measurement error bias (towards finding a negative correlation) that arises when attempting to estimate the elasticity of a quantity with respect to its price.

Table 4. Real Investment Rate and Relative Price of Machinery and Equipment: Country-Level

Dependent Variable: Log Real Investment-to-GDP Ratio	OLS (1)	OLS (2)	OLS Lagged (3)	OLS Annual (4)	IV (5)	IV (6)	IV (7)	IV (8)	IV (9)	IV P_I/P_{GDP} (10)	GMM (11)	IV Excluding Own (12)
Log Relative Price	–0.689***	–0.517***	–0.159**	–0.083**	–0.307***	–0.283**	–0.461***	–0.281**	–0.367***	–0.303***	–0.408***	–0.508***
	(0.089)	(0.092)	(0.072)	(0.040)	(0.101)	(0.140)	(0.139)	(0.122)	(0.121)	(0.105)	(0.110)	(0.083)
Log Investment Rate$_{t-1}$		0.488***	0.558***	0.795***	0.535***	0.540***	0.499***	0.484***	0.524***	0.528***	0.502***	0.490***
		(0.084)	(0.092)	(0.032)	(0.082)	(0.093)	(0.085)	(0.072)	(0.082)	(0.089)	(0.059)	(0.072)
Log GDP per Capita$_{t-1}$		–0.207***	–0.109	–0.023	–0.156**	–0.186**	–0.190***	–0.212	–0.140**	–0.147**	–0.153***	–0.205***
		(0.069)	(0.073)	(0.030)	(0.064)	(0.075)	(0.073)	(0.132)	(0.068)	(0.062)	(0.053)	(0.064)
GDP per Capita Growth$_{t-1}$		0.152	0.236	0.166**	0.121	0.133	0.030	–0.474	0.061	0.132	0.601	0.150
		(0.341)	(0.420)	(0.074)	(0.320)	(0.375)	(0.342)	(0.560)	(0.330)	(0.339)	(0.383)	(0.304)
Real Interest Rate		–0.009	–0.011	–0.053*	–0.015	–0.074	–0.012	–0.625	–0.014	–0.011	–0.052	–0.009
		(0.048)	(0.063)	(0.027)	(0.052)	(0.053)	(0.053)	(0.496)	(0.051)	(0.053)	(0.063)	(0.043)
Log Credit-to-GDP		–0.019	–0.035	–0.006	–0.028	–0.021	–0.026	–0.015	–0.041	–0.038	0.010	–0.019
		(0.047)	(0.051)	(0.012)	(0.043)	(0.054)	(0.060)	(0.028)	(0.045)	(0.042)	(0.048)	(0.042)
Capital Account Openness		0.143**	0.152**	0.036**	0.145***	0.105	0.172**	0.110	0.126**	0.139***	–0.102	0.143**
		(0.063)	(0.059)	(0.017)	(0.053)	(0.064)	(0.068)	(0.067)	(0.061)	(0.053)	(0.067)	(0.056)
Log Export Commodity Price		0.560*	0.320	0.105	0.435*	0.373	0.454	0.003	0.412	0.207	0.072	0.555**
		(0.294)	(0.291)	(0.091)	(0.259)	(0.298)	(0.297)	(0.299)	(0.268)	(0.243)	(0.307)	(0.270)
Log Trade Openness		0.285**	0.210*	0.118***	0.245**	0.210	0.315**	0.120*	0.284**	0.248***	0.126	0.283***
		(0.117)	(0.106)	(0.024)	(0.100)	(0.131)	(0.123)	(0.072)	(0.111)	(0.092)	(0.091)	(0.104)
Institutional Quality and Political Risk		0.008***	0.005*	0.002	0.006**	0.005	0.008**	0.009**	0.007**	0.006**	0.009***	0.008***
		(0.003)	(0.003)	(0.001)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
Log Paved Roads per Capita		0.094	0.124*	0.053***	0.114**	0.162**	0.096	–0.008	0.125*	0.124**	0.036	0.095*
		(0.060)	(0.063)	(0.020)	(0.054)	(0.075)	(0.069)	(0.089)	(0.066)	(0.051)	(0.030)	(0.053)
Long-Run Effect				–0.406**								
				(0.193)								
Number of Observations	1,863	769	769	3,167	769	664	537	232	635	769	769	769
Number of Countries	173	127	127	126	127	127	93	34	108	127	127	127
R^2	0.72	0.86	0.84	0.91	0.504	0.493	0.518	0.600	0.519	0.51		0.518
First Stage F-Statistic					24.37	12.42	11.95	117	18.07	46.68		196.2
AR(1) Test P-Value											0.00	
AR(2) Test P-Value											0.19	
Hansen Test P-Value											0.29	
Number of Instruments											131	
Sample	All	All	All	All	All	Post 1990	EMDE	AE	Capital Goods Importers[1]	All	All	All

Source: Authors' calculations.

Note: Regressions are estimated with data averaged over non-overlapping five-year windows. The dependent variable is log machinery and transport equipment investment-to-GDP ratio. Columns 1–4 are estimated using ordinary least squares (OLS) regressions. In Column 1 the independent variable is log price of machinery and transport equipment relative to price of consumption. Column 2 is estimated with full controls specification. In column 3 log relative price is lagged. Column 4 is estimated using annual data, where log relative price and policy variables are lagged. The long-run effect is given by $\beta_X / (1 - \beta_{Y,t-1})$. Columns 5–9 are estimated using instrumental variable (IV) regressions, where log relative price is instrumented with its lagged value. In column 10 price of machinery and transport equipment is measured relative to the overall GDP price level. Column 11 is based on the system generalized method of moments (GMM) estimator following the two-step procedure with Windmeijer's finite-sample correction, treating the regressors as endogenous and instrumented with one lag, while fixed effects and several institutional variables (regulatory quality, infrastructure quality, and capital account openness) are treated as exogenous. In column 12, log relative price is instrumented with log of average relative price of all other countries except own. All regressions control for country and year fixed effects. Standard errors

[1] Capital importing countries are defined by excluding Top-20 capital exporting countries in 2016: China, Germany, United States, Japan, Hong Kong SAR, Korea, Mexico, France, Singapore, Italy, United Kingdom, Taiwan Province of China, the Netherlands, Canada, Spain, Thailand, Czech Republic, Belgium, Malaysia, Poland.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

B. Sectoral Empirical Evidence

A sectoral perspective can complement the cross-country analysis in an important way. The relative price of capital goods is but one of the considerations that shape investment decisions. While the cross-country analysis attempts to control for many factors, the estimated relationship between real investment rates and prices could be biased due to the omission of factors that may correlate with relative prices but are not properly captured in the estimation. Sectoral analysis allows us to isolate the relationship between real investment rates and the price of investment across different sectors while properly accounting for the role of all factors that affect investment within a country in a particular year. These include financial conditions, economy-wide growth prospects, quality of regulations that affect investment returns, exchange rate fluctuations and policies, international capital flows, availability of complementary public infrastructure, and the like.

The data come from EU KLEMS and World KLEMS, which offers detailed information about the price level of different types of capital goods within Machinery and Equipment: IT (computer hardware), CT (telecommunications equipment), Transport Equipment and Other machinery and equipment. The price of machinery and equipment, $P_{M\&E}$, is constructed as a weighted average of the prices of each of the four types of capital, as in the equation below.

$$P_{M\&E} = \frac{I_{IT}}{I_{M\&E}} P_{IT} + \frac{I_{CT}}{I_{M\&E}} P_{CT} + \frac{I_{TraEq}}{I_{M\&E}} P_{TraEq} + \frac{I_{OMach}}{I_{M\&E}} P_{OMach}.$$

The sample varies somewhat depending on the specification and data availability for specific variables. Typically, the analysis relies on 18-19 countries, mostly European, with the addition of United States, United Kingdom, Brazil and Colombia, and uses 15 broad sectors, covering the period 1971-2015. This is an unbalanced panel.

The baseline specification mirrors that of country-level regressions, using 5-year averaged data, which is common in the literature when looking at long-term, slow-moving factors. In the main specification, the log relative price of investment (expressed relative to the price of consumption) is instrumented with is lagged value.

$$\ln\left(\frac{Real\ M\&E\ In}{Real\ VA}\right)_{i,t,s} = \beta \cdot \ln\left(\frac{P_{M\&E}}{P_C}\right)_{i,t,s} + \gamma \cdot \ln\left(\frac{Real\ M\&E\ In}{Real\ VA}\right)_{i,t\text{-}1,s} + \mu_{i,t} + \theta_{i,s} + \varepsilon_{i,t,s}$$

A range of possible estimates using slightly different specifications are presented in Table 5. The estimated elasticity, according to which a 1 percent decline in the relative price of machinery and equipment investment is associated with a 0.2–0.5 percent increase in real investment in these capital goods, is comparable to those uncovered in the cross-country analysis. The baseline specification includes country-period and country-sector fixed effects, where the period refers to five-year non-overlapping periods. However, country-period fixed effects may absorb too much variation, for example if there is an aggregate effect of the relative price of investment that is common to all sectors within a country-year. For that reason, an alternative specification includes country-sector and period (or year) fixed effects, where this problem is addressed (columns 5–8, Table 5).

Table 5. Sectoral Real Investment Rate and Relative Prices of Machinery and Equipment: Range of Possible Estimates

Dependent Variable: Log Real Investment-to-GDP Ratio	IV (1)	OLS (2)	OLS Lagged (3)	IV P_I/P_{VA} (4)	IV (5)	OLS (6)	OLS Lagged (7)	IV P_I/P_{VA} (8)
Log Relative Price	–0.326***	–0.567**	–0.201	–0.325***	–0.528***	–0.695***	–0.344	–0.521***
	(0.078)	(0.201)	(0.254)	(0.078)	(0.068)	(0.181)	(0.247)	(0.067)
Number of Observations	971	971	971	971	971	971	971	971
R^2	0.94	0.94	0.93	0.94	0.93	0.93	0.92	0.93
First Stage F-Statistic	645			643	729			729
Period Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
Country-Period Fixed Effects	Yes	Yes	Yes	Yes	No	No	No	No
Country-Sector Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' calculations.

Note: Regressions 1 and 5 show results based on the main specification, which uses lagged log relative prices to instrument for log relative prices. Regressions 2 and 6 present reduced form results, with the contemporaneous log relative prices. Regressions 3 and 7 present reduced form results, using the lagged log relative prices instead of contemporaneous. In regressions 4 and 8, the relative price of investment is defined relative to the sectoral value added, and follows the main specification as in regressions 1 and 5. All variables are averaged over non-overlapping five-year windows. All regressions include lagged dependent variable. The log relative price of machinery and equipment is a weighted average of computer equipment (IT), telecommunications equipment (CT), transport equipment, and other machinery and equipment. Standard errors clustered at the country level in parentheses.

***p < 0.01; **p < 0.05; *p < 0.1

Table 6 presents the baseline results first with country-period and country sector fixed effects (columns 1–4), followed by period and country-sector fixed effects (columns 5–8), for each of four dependent variables: the machinery and equipment investment rate, followed by machinery and equipment investment, value added, and output per worker.

As a robustness check, Table 7 presents all the regressions presented in Table 6 but using annual data. As expected, the estimated coefficients are smaller in magnitude when annual data are used instead of five-year averages. However, all the results have the correct signs, and are statistically significant, except for sectoral output per worker.

Table 6. Relative Prices of Machinery and Equipment and Sectoral Outcomes: Five-Year Averages

Dependent Variables:	Log Real Investment-to-GDP	Log Real Investment	Log Value Added	Log Value Added per Worker	Log Real Investment-to-GDP	Log Real Investment	Log Value Added	Log Value Added per Worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Relative Price	–0.326***	–0.192**	–0.061***	–0.016	–0.528***	–0.444***	–0.058***	–0.033
	(0.078)	(0.079)	(0.018)	(0.025)	(0.068)	(0.071)	(0.015)	(0.021)
Number of Observations	971	1,046	972	747	971	1,046	972	747
R^2	0.94	0.99	0.99	0.99	0.93	0.98	0.99	0.99
First Stage F-Statistic	645	456	991	378	729	500	1339	434
Period Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
Country-Period Fixed Effects	Yes	Yes	Yes	Yes	No	No	No	No
Country-Sector Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' calculations.

Note: All regressions show results based on the main specification, which uses lagged log relative prices to instrument for log relative prices. All variables are averaged over non-overlapping five-year windows. All regressions include lagged dependent variable. The log relative price of machinery and equipment is a weighted average of computer equipment (IT), telecommunications equipment (CT), transport equipment, and other machinery and equipment. Standard errors clustered at the country level in parentheses.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 7. Relative Prices of Machinery and Equipment and Sectoral Outcomes: Annual

Dependent Variables:	Log Real Investment-to-GDP	Log Real Investment	Log Value Added	Log Value Added per Worker	Log Real Investment-to-GDP	Log Real Investment	Log Value Added	Log Value Added per Worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Relative Price	–0.170***	–0.264***	–0.013***	–0.005	–0.203***	–0.279***	–0.011***	–0.007*
	(0.018)	(0.018)	(0.003)	(0.004)	(0.017)	(0.017)	(0.003)	(0.004)
Number of Observations	5,629	6,004	5,644	4,430	5,629	6,004	5,644	4,430
R^2	0.96	0.99	0.99	0.99	0.95	0.99	0.99	0.99
First Stage F-Statistic	20770	18595	26232	12603	23442	20477	33690	14700
Year Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
Country-Year Fixed Effects	Yes	Yes	Yes	Yes	No	No	No	No
Country-Sector Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

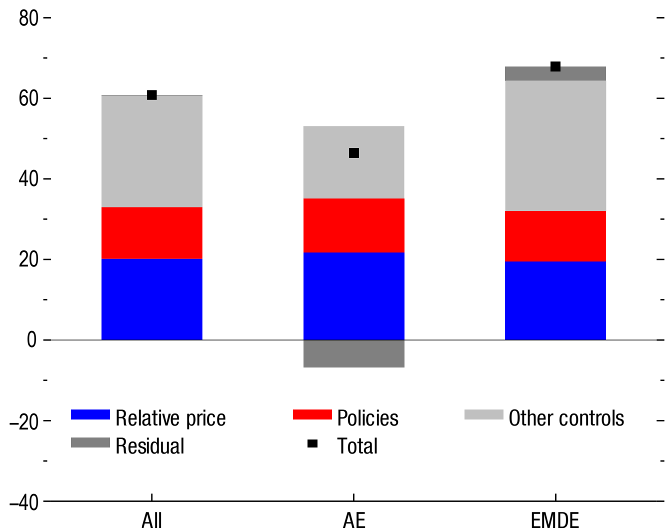
Source: Authors' calculations.

Note: Data are at annual frequency. All regressions show results based on the main specification, which uses lagged log relative prices to instrument for log relative prices. All regressions include lagged dependent variable. The log relative price of machinery and equipment is a weighted average of computer equipment (IT), telecommunications equipment (CT), transport equipment, and other machinery and equipment. Standard errors clustered at the country level in parentheses.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Across both country-level and sector-level regressions, the evidence that the relative price of capital goods matters for investment decisions is strong. It is challenging to obtain an unbiased estimate of the elasticity of real investment with regard to prices, given the endogenous nature of relative price changes and problems with measurement. With those difficulties in mind, Figure 10—as a purely illustrative exercise—uses the estimated elasticity from the cross-country (instrumented variable) analysis and the post-1990 change in the relative price of capital goods in each country to decompose the change in real investment rate. These changes comprise the parts attributable to (1) the decline in real investment prices; (2) the change in relevant policies; (3) other factors, such as global trends in investment, convergence, and growth expectations; and (4) the residual. The figure confirms that the dramatic decline in the relative prices of tradable capital goods can explain a sizable share of the increase in investment in tradable capital goods in advanced and emerging market and developing economies.

Figure 10. Contributions of Relative Prices to Increases in Real Investment in Machinery and Equipment, 1990–94 to 2015–17
(Percent)



Source: Authors' calculations.
Note: The figure presents the contribution to the observed increase in real machinery and transport equipment investment-to-GDP ratios between 1990–94 and 2015–17 from the relative price of machinery and transport equipment, various policies, and other controls. Black square indicates the total change in real machinery equipment investment to GDP ratios. AEs = advanced economies; EMDEs = emerging market and developing economies.

V. CONCLUSION

Our analysis provides new evidence on the drivers of the relative price of machinery and equipment and its macroeconomic implications. Leveraging the dramatic changes in capital goods prices that have taken place over the past few decades across countries and sectors, and the latest available comparable cross-country data on prices from the ICP and detailed trade flow statistics, we provide evidence that trade costs and relative productivity both play an important role in shaping the relative prices of machinery and equipment across countries and over time. Across countries, those with higher trade costs and lower productivity in the tradable goods sectors tend to pay a higher price for a comparable basket of machinery and equipment both in absolute terms and relative to the price of consumption. Analysis of sector-level producer price data shows that, over time, reductions in distortionary trade policies and improvements in productivity both contributed to the decline in the relative prices of capital goods.

We also show that the decline in the relative price of capital goods has played a crucial role in increasing real investment rates over the past three decades. While exact quantification is challenging, empirical evidence suggests that a nontrivial share of the rise in real investment rates in machinery and equipment can be attributed to the dramatic fall in the relative price of these goods.

Taken together, our analyses suggest that the slowing pace of trade liberalization since the mid-2000s, and especially the possibility of its reversal in some advanced economies, could interfere with the tailwind to machinery and equipment investment generated by the falling price of capital goods. This finding provides an additional, often overlooked, argument in support of policies aimed at reducing trade costs and reinvigorating international trade.

Many emerging market and developing economies still maintain tariff and other trade barriers that significantly raise the relative price of investment paid by domestic investors.[23] Effective import tariffs on capital goods in 2011 were about 4 percent in emerging market and 8 percent in low-income developing countries, compared with close to zero in advanced economies. Fully implementing commitments under the World Trade Organization's Trade Facilitation Agreement could mean a reduction in trade costs equivalent to a 15-percentage point tariff cut in less-developed economies (WTO 2015).

In advanced economies, avoiding protectionist measures and resolving disagreements without raising trade costs will be crucial to prevent further weakening of the lackluster investment growth since the global crisis of a decade ago.[24]

[23] While the vast majority of emerging market and developing economies still have large investment needs, other countries (such as China) face the complex task of rebalancing growth models toward consumption and services, after decades of investment-led stimulus and policy interventions aimed at strengthening capital goods production and exports. Policy challenges are also different in some low-income developing countries where import tariffs represent a significant source of government revenue, and tariff reform would need to be accompanied by measures to compensate for revenue losses.

[24] Cavallo and Landry (2018) find that the rise in capital imports in the United States has added 5 percent to its output per hour since the 1970s, and that the imposition of tariffs on capital goods could lead to sizable productivity losses over the next decade.

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APPENDIX

Annex 1. Sources and Country Groupings

Data Sources

The primary data sources for this paper are the IMF World Economic Outlook database, the Penn World Table (PWT) 9.1 database, including supplemental datasets on national accounts and capital detail, the World Input-Output Database (WIOD) Release 2013 and 2016, including both Socio Economic Accounts and World Input-Output tables, and the EU and World Klems databases.

Data Definitions

Several sources of data on prices are used in the paper. The relative price of investment is defined relative to the price of consumption.

The cross-country stylized facts on relative prices and the associated analysis relies on the International Comparison Program (ICP) 2011, which provides the price level of machinery and equipment and the price level of consumption measured for a comparable basket of goods across countries in 2011.

The stylized facts presented in Figures 1 and 3 and country-level panel regressions use data from the PWT 9.1 capital detail dataset, which provides data on deflators of various types of investment, and capital stocks. The corresponding consumption deflator comes from the PWT 9.1 National Accounts dataset.

The sector-level panel regressions, which examine the relationship between investment in machinery and equipment and its relative price, use data from the EU and World KLEMS databases. The relative price of investment is likewise defined as the ratio of deflators, in this case the machinery and equipment deflator and the country-wide consumption deflator.

The sector-level panel regressions, which examine the drivers of sectoral producer prices, rely on the sectoral gross output deflator from the WIOD Socio Economic Accounts database.

The unit-price analysis is based on highly disaggregated bilateral trade data (US export data at the harmonized system (HS) 10-digit level, Japanese export data at the HS 9-digit level, French and German export data at the HS 8-digit level, and Chinese export data at the HS 6-digit level).

The real interest rate is derived from the nominal interest rate and is adjusted for inflation as measured by the GDP deflator.

Data Sources

Indicator	Source
Investment and GDP Prices	International Comparison Program 2011; Penn World Table 9.1; KLEMS; WIOD; Bureau of Economic Analysis
Investment-to-GDP Ratios	Penn World Table 9.1, including capital detail and national accounts; KLEMS; WIOD
Unit Prices of Exports at the Product Level	US Census Bureau, Eurostat, COMTRADE, Ministry of Finance of Japan
Real GDP per Capita in Purchasing-Power-Parity International Dollars	Penn World Table 9.1
Nominal Interest Rate	IMF, World Economic Outlook database; IMF, International Financial Statistics; Organisation for Economic Co-operation and Development; Haver Analytics; Bloomberg; Caceres and others (2016)
Credit-to-GDP Ratio	World Bank, Global Financial Development Database
Capital Account Openness	Chinn and Ito (2006)
Bilateral Distance	Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) GeoDist Database
Trade Openness	IMF, World Economic Outlook database
Export Commodity Price	Gruss and Kebhajz (2019)
Political Risk Rating	International Country Risk Guide
Global Value Chain Participation	Eora MRIO database; IMF staff calculations
Tariffs	UNCTAD, Trade Analysis Information System; WTO Tariff Download Facility; Feenstra and Romalis (2014)
Freedom to Trade Internationally Index	Fraser Institute
Cost to Import	World Bank, Doing Business Indicators
Time to Import	World Bank, Doing Business Indicators
Liner Shipping Connectivity Index	UNCTAD, World Maritime Review
Paved Roads Kilometers per Capita	Calderón, Moral-Benito, and Servén (2015); World Bank, World Development Indicators database; Chapter 3 of the October 2014 *World Economic Outlook*

Source: Authors' compilation.

Country Groupings

The definition of advanced economies, emerging market economies, and low-income countries follows the October 2018 IMF World Economic Outlook's definition.

Tradable capital goods sectors, which, for the purpose of this paper, include machinery and equipment and transport equipment, are identified in the following manner across data sources. In the WIOD database, sectors 400, 410 and 521 are considered capital goods producing sectors. In the Eora MRIO database, sectors 9 and 10 are considered capital goods producing sectors. When using trade data at the harmonized system (HS) level, HS codes are first matched to the Broad Economic Categories (BEC) classification and BEC levels 41 (capital goods) and 521 (industrial transport equipment) are considered in the analysis.

Sample of Economies Included in the Analytical Exercises

Unit-price analysis	China, France, Germany, Japan, United States
Country-level analysis	Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, The Bahamas, Bahrain, Bangladesh, Belarus, Belgium, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Cameroon, Canada, Chile, China, Colombia, Democratic Republic of the Congo, Republic of Congo, Costa Rica, Croatia, Cyprus, Czech Republic, Côte d'Ivoire, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Finland, France, Gabon, The Gambia, Germany, Ghana, Greece, Guatemala, Guinea-Bissau, Haiti, Honduras, Hong Kong SAR, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea, Kuwait, Latvia, Lebanon, Liberia, Lithuania, Madagascar, Malawi, Malaysia, Mali, Malta, Mexico, Moldova, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Senegal, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Suriname, Sweden, Switzerland, Syria, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe
Sector-level analysis of drivers of relative producer prices	Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Spain, Sweden, Taiwan Province of China, Turkey, United Kingdom, United States
Sector-level analysis of relative investment prices and investment rates	Austria, Brazil, Colombia, Czech Republic, Denmark, Finland, France, Germany, Italy, Latvia, Luxembourg, Netherlands, Portugal Slovak Republic, Slovenia, Spain, Sweden, United Kingdom, United States

Source: Authors' compilation.

Annex 2. Using Trade Data to Uncover Differences in Capital Goods Prices Across Countries

This annex describes the approach used to document variation in the price of capital goods using unit values from highly disaggregated export level data. We build on Alfaro and Ahmed (2009), who use US export data to test whether unit values for the same product across countries are correlated with the importing country GDP per capita. The analysis is motivated by the fact that most capital goods are produced in a few countries (Eaton and Kortum, 2001) and therefore most countries rely on importing capital goods. Imported capital goods prices may exhibit variation either due to mark-ups or trade costs. The advantage of using export-level data is that the value of the exports is reported free-on-board (FOB), which excludes trade costs.

We obtain detailed export data from the following five large capital goods exporters: the US, China, France, Germany and Japan. For each product, destination and exporting country, we calculate the unit value by dividing the overall export value by the reported quantity. The estimated specification regresses the log unit value for each product *p* by exporting country *x* to importing country *i* in year *t* on the log GDP per capita of country *i* in year *t* weighted by the FOB value of the exports. We include product*exporting country*year fixed effects to make a within product-exporting country comparison, which minimizes price differences due to quality. Standard errors are clustered at the importing country level:

$$\ln(p*)_{p,x,i,t} = \alpha + \beta \cdot \ln(GDPPC)_{i,t} + \alpha_{p,x,t} + \epsilon_{p,x,i,t}$$

The level of aggregation of the products varies by country. For the US, we obtain exports at the 10-digit HS codes for 1989–2005 from the US Census Bureau, accessed through Peter Schott's webpage: http://faculty.som.yale.edu/peterschott/sub_international.htm; for Japan, 9-digit product level data for 1988–2017 are provided by the Ministry of Finance; for China, we use 6-digit product level data for 1992–2017 from COMTRADE; for Germany and France, we take 8-digit HS export data for 1988–2017 from Eurostat.[25] To assess whether patterns of correlation may vary depending on the exporting country, we estimate the regression separately for each exporting country.[26]

Annex Table 1 shows that capital goods' unit values are not significantly correlated with GDP per capita when the five exporting countries are pooled together. The point estimate of the coefficient on GDP per capita is not statistically distinguishable from zero (column 1).

However, the coefficient exhibits substantial heterogeneity across exporting countries. When the sample is restricted to exports only from the US (column 2) and/or China (column 3), there is a statistically significant negative correlation between unit values and GDP per capita, confirming Alfaro and Ahmed (2009)'s findings, using US export data from 1978–

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[25] To identify capital goods at the HS level, the analysis uses the Broad Economic Categories (BEC) classifications.

[26] When the regression is estimated separately for each country, the observations are not weighted by the value, but the results are robust to doing so.

2011. The estimated correlations suggest that US and Chinese firms charge importers from poorer countries higher prices for the same product. We find the opposite result for exports from Germany and France: unit values of exports from these countries are significantly higher when shipments are sent to countries with higher GDP per capita. Since quality differences cannot be ruled out even within narrowly defined HS codes, and richer countries are likely importing higher quality goods (Feenstra and Romalis, 2014), the coefficient could capture such quality differences.

Annex Table 1. Unit Values of Capital Goods Across Countries: Evidence from Trade Data

Dependent Variable: Log Unit Value	(1) Top 5	(2) US	(3) China	(4) France	(5) Germany	(6) Japan
Log GDP per Capita	0.027	–0.058***	–0.157***	0.106***	0.033**	0.028
	(0.026)	(0.014)	(0.018)	(0.014)	(0.011)	(0.023)
Number of Observations	7,132,542	1,607,743	999,810	1,479,250	2,025,791	1,022,125
Number of Unique Products	812	1,929	674	2,380	2,373	1,352
R^2	0.98	0.78	0.84	0.92	0.94	0.80
Level of Product Disaggregation		HS 10-digit	HS 6-digit	HS 8-digit	HS 8-digit	HS 9-digit

Source: Authors' calculations.

Note: Regression for Top 5 exporting countries in column 1 includes country-commodity-year fixed effects. Regressions for individual exporting countries in columns 2–6 include commodity-year fixed effects. Standard errors clustered at the country level in parentheses.

***p < 0.01; **p < 0.05; *p < 0.1

In an alternative exploration of the trade data, Annex Table 2 replaces the GDP per capita with indicator variables for emerging market (EM) and low-income countries (LIC). Similar to the findings presented in Annex Table 1, there is no strong evidence of systematic differences in unit values of capital goods exports across broad country groups. The coefficients on the indicator variables are insignificant when all exporting countries are pooled together. However, when firms in emerging markets and low-income countries import from the US or China they seem to pay higher prices than advanced economies. In contrast, advanced economies importing from France pay higher prices than poorer countries.

Following Manova and Zhang (2012), in Annex Table 3, we augment the baseline specification to control for the size of the market and the remoteness of the importing country, as well as the bilateral distance between importing and exporting country. Controlling for these factors does not change the sign and significance of the baseline results.[27]

[27] The finding of a robust negative correlation between unit values and importer GDP per capita for Chinese exports is at odds with the pattern documented for all Chinese exports by Manova and Zhang (2012). The reason for the difference in findings is the paper's focus on capital goods.

Annex Table 2. Unit Values of Capital Goods by Broad Country Group: Evidence from Trade Data

Dependent Variable: Log Unit Value	(1) Top 5	(2) US	(3) China	(4) France	(5) Germany	(6) Japan
Emerging Market Economies	–0.047	0.077*	0.236***	–0.149**	–0.037	–0.062
	(0.046)	(0.032)	(0.044)	(0.050)	(0.037)	(0.047)
Low Income Countries	0.093	0.239***	0.564***	–0.280***	–0.009	–0.078
	(0.048)	(0.058)	(0.054)	(0.046)	(0.036)	(0.094)
Number of Observations	7,132,542	1,607,743	999,810	1,479,250	2,025,791	1,022,125
Number of Unique Products	812	1,929	674	2,380	2,373	1,352
R^2	0.98	0.78	0.84	0.92	0.94	0.80
Level of Product Disaggregation		HS 10-digit	HS 6-digit	HS 8-digit	HS 8-digit	HS 9-digit

Source: Authors' calculations.

Note: Regression for Top 5 exporting countries in column 1 includes country-commodity-year fixed effects. Regressions for individual exporting countries in columns 2–6 include commodity-year fixed effects. Standard errors clustered at the country level in parentheses.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Annex Table 3. Unit Value of Capital Goods Across Countries: Robustness

Dependent Variable: Log Unit Value	(1) Top 5	(2) Top 5	(3) US	(4) China	(5) France	(6) Germany	(7) Japan
Log GDP per Capita	0.027	0.046	–0.050***	–0.092***	0.110***	0.066***	0.018
	(0.026)	(0.029)	(0.013)	(0.020)	(0.022)	(0.016)	(0.021)
Log Remoteness		–0.173*	–0.400***	0.040	–0.010	0.043	–0.338***
		(0.091)	(0.047)	(0.062)	(0.136)	(0.084)	(0.058)
Log Distance		0.075***	0.197***	–0.191***	0.087**	0.083***	0.182***
		(0.017)	(0.043)	(0.030)	(0.041)	(0.024)	(0.042)
Log GDP		–0.013	–0.047***	–0.070***	0.023	0.003	–0.033***
		(0.011)	(0.007)	(0.009)	(0.015)	(0.010)	(0.009)
Number of Observations	7,077,421	7,077,421	1,603,753	987,463	1,466,711	2,000,981	1,018,513
Number of Unique Products	812	812	1,929	674	2,380	2,373	1,352
R^2	0.98	0.98	0.78	0.84	0.92	0.95	0.81
Level of Product Disaggregation			HS 10-digit	HS 6-digit	HS 8-digit	HS 8-digit	HS 9-digit

Source: Authors' calculations.

Note: Remoteness is a weighted average of an exporting country's bilateral distance to all other trade partner countries in the world, using countries' GDP as weights. Distance is bilateral distance between importing and exporting countries. Regression for Top 5 exporting countries in columns 1–2 include country-commodity-year fixed effects. Regressions for individual exporting countries in columns 3–7 include commodity-year fixed effects. Standard errors clustered at the country level in parentheses.

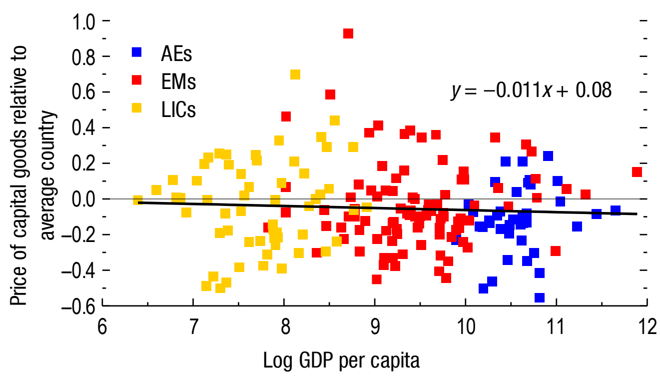
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

The table also indicates that the log of the bilateral distance is positively correlated with the unit values, consistent with the Alchian-Allen effect that states that with fixed transportation costs for two goods with different quality, consumption will shift towards the higher quality good as the relative price difference falls. Moreover, if a country is more remote, measured as the log distance to other countries, weighted by GDP in US dollars, they receive lower prices. One explanation could be that their quality of imports is lower because they must import even low-quality products from far away locations. If anything, there is also evidence that larger market size is correlated with lower unit values, which can be interpreted as a mark-up that is a decreasing function of competition. If the market is larger, it is more likely that the country is producing a similar good domestically.

We compute the price index depicted in Annex Figure 1 by aggregating the unit values from the trade data described above for the year 2011. First, for each exporting country and product, we compute deviation of the log unit value paid by an importing country when importing from country *x* from the log of the average of the unit values charged by the exporting country *x* for this product across destinations (i.e. $uv_{p,i,x} - \overline{uv_{p,x}}$). The simple average of these log differences across products for each country gives an average percent deviation that importing country *i* pays for the same product compared to the average importing country from exporting country *x*. Since some countries may be more important exporters to some destinations than others, the price index for each country pair is aggregated up by the relative importance of the exporting country *x* for importing country *i*, $w_{x,i}$. $w_{x,i}$ is defined as the US dollar value of capital goods imported by country *i* from country *x* divided by the overall value that country *i* imports from all capital good exporters in the dataset.

$$Price_i = \sum_{x=1}^{X} \left(\frac{1}{P}\left[\sum_{p=1}^{P} (uv_{p,i,x} - \overline{uv_{p,x}})\right]\right) * w_{x,i}.$$

Annex Figure 1. Unit Values of Tradable Capital Goods across Countries, 2011



Sources: Eurostat; Ministry of Finance of Japan; UN Comtrade database; US Census Bureau; and authors' calculations.
Note: Figure uses export data for major capital goods exporters. AEs = advanced economies; EMs = emerging market economies; LICs = low-income countries.

Annex 3. Drivers of Relative Investment Prices: Across Countries

This annex section provides technical details on the analysis, which compares the level of capital goods prices across countries. The analysis relies on the ICP 2011 data, which provides the price level of comparable baskets of capital goods for 168 countries. The ICP reports absolute prices as a ratio to the corresponding US prices. When analyzing relative capital goods prices, the absolute price of machinery and equipment are divided by the absolute consumption price.

To establish if there is correlation between absolute prices and various measures of trade cost, we estimate the following equation using ordinary least squares, with standard errors adjusted for heteroskedasticity.

$$\ln(P_I)_\mathrm{i} = \alpha + \beta \cdot \ln(\mathrm{TradeCost})_\mathrm{i} + \epsilon_\mathrm{i}$$

where P_I is the absolute price of machinery and equipment in country *i* in 2011. A separate regression is estimated for each measure of trade costs.

We consider the following measures of trade costs: (1) distance to exporters of capital goods, calculated as the weighted average of a country's distance to all other countries, where the weights are equal to the partner countries' exports of capital goods as a share of global capital goods exports; (2) the UNCTAD liner shipping connectivity index, which captures how well countries are connected to global shipping networks based on five components of the maritime transport sector: number of ships, their container-carrying capacity, maximum vessel size, number of services, and number of companies that deploy container ships in a country's port; (3) the Fraser Institute's Freedom to Trade Internationally, which is based on four different types of trade restrictions: tariffs, quotas, hidden administrative restrains, and controls on exchange rate and the movement on capital; (4) the average applied tariffs on capital goods imports, from Feenstra and Romalis (2014); (5) the cost to import and time to import indicators, which measure the cost (excluding tariffs) and time associated with three sets of procedures – documentary compliance, border compliance, and domestic transport – within the overall process of importing a shipment of goods from the World Bank, Doing Business Indicators.

Annex Table 4 provides the estimated coefficients as well as the percent change in absolute prices associated with a one standard deviation change in the alternative measures of trade costs.

When examining the determinants of relative prices in the cross section of countries, we estimate the following equation using ordinary least squares, with standard errors adjusted for heteroskedasticity.

$$\ln\left(\frac{P_I}{P_C}\right)_\mathrm{i} = \alpha + \beta \cdot \ln(\frac{a_T}{a_{NT}})_\mathrm{i} + \gamma \cdot \ln(\mathrm{TradeCost})_\mathrm{i} + \epsilon_\mathrm{i}$$

The trade costs considered (one at a time) are the same as discussed above. Labor productivity is measured as the ratio of the value added of the tradable goods producing sectors divided by the total employment in those sectors, and the value added of all non-tradable sectors in the economy divided by their employment. This measure is constructed using 2011 data from the Eora MRIO database and adjusted using 2011 ICP prices to make productivity levels comparable across countries.

Annex Table 5 provides the estimated coefficients. The regression-based decomposition is based on Shorrocks (1982). The contribution of each variable is calculated as the covariance between the (i) product of the estimated coefficient and the value of the independent variable and (ii) the dependent variable, divided by the variance of the dependent variable.

Annex Table 4. Absolute Price of Capital Goods

Dependent Variable: Absolute Price of Capital Goods	Measure of Trade Barrier					
	Distance	Connectivity	Freedom to Trade	Tariffs	Cost to Import	Time to Import
Trade Barrier	0.162***	–0.168***	–0.022*	0.016*	0.040***	0.030*
	(0.032)	(0.058)	(0.012)	(0.009)	(0.015)	(0.015)
Number of Observations	165	119	147	165	151	151
R^2	0.14	0.05	0.04	0.01	0.05	0.03
Coefficient × Standard Deviation	0.048***	–0.028***	–0.024*	0.014*	0.027**	0.020*

Source: Authors' calculations.

Note: Robust standard errors in parentheses.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Annex Table 5. Relative Price of Capital Goods

Dependent Variable: Relative Price of Capital Goods	Measure of Trade Barrier					
	Distance	Connectivity	Freedom to Trade	Tariffs	Cost to Import	Time to Import
Tradable productivity relative to non-tradable productivity	–0.467***	–0.467***	–0.499***	–0.352***	–0.396***	–0.314***
	(0.100)	(0.133)	(0.085)	(0.093)	(0.090)	(0.074)
Trade Barrier	0.226**	–0.322*	–0.237***	0.219***	0.285***	0.408***
	(0.104)	(0.225)	(0.041)	(0.049)	(0.052)	(0.045)
Number of Observations	120	93	116	121	108	108
R^2	0.28	0.28	0.55	0.43	0.42	0.58

Source: Authors' calculations.

Note: The relative productivity variable is defined as the log of real value added per employee in the tradable goods sectors divided by the real value added per employee in the non-tradable sectors, using the Eora MRIO database. Robust standard errors in parentheses.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$