**EXECUTIVE BOARD MEETING**

EBS/19/7

March 1, 2019

To: Members of the Executive Board

From: The Secretary

Subject: **April 2019 World Economic Outlook—Analytical Chapter 3**

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|---|---|
| Board Action: | Executive Directors' **consideration** (Formal) |
| Tentative Board Date: | **Thursday, March 21, 2019** |
| Publication: | Yes, it is intended that the full set of the World Economic Outlook documents will be released to the public at the time of the World Economic Outlook press conference, tentatively scheduled for **Tuesday, April 9, 2019**.<br><br>The analytical chapters will be made available to the public on the IMF website in advance of the publication of the full document. |
| Questions: | Ms. Topalova, RES (ext. 39557)<br>Ms. Novta, RES (ext. 34998) |
| Additional Information: | The paper will be revised for publication in light of the Executive Board discussion. If Executive Directors have additional comments, they should notify Ms. Topalova and Ms. Novta by **5:30 p.m. on Friday, March 15, 2019**. |

CHAPTER 3

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CHAPTER 3

# THE PRICE OF CAPITAL GOODS: A DRIVER OF INVESTMENT UNDER THREAT?

*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 alike. Could rising trade tensions, a slowing pace of trade integration, and sluggish productivity growth threaten this potential driver of investment going forward? This chapter sets out to answer this question by documenting key patterns in the price of capital goods, its drivers and impact on real investment rates. Worldwide, investment growth has slowed considerably since the global financial crisis. Yet, when compared to its levels in early 1990s, real investment in machinery and equipment as a share of real GDP has increased significantly. The chapter finds that the decline in the relative price of tradable investment goods has provided sizable impetus to the rise in real investment rates in machinery and equipment over the past three decades. The broad-based decline in the relative price of machinery and equipment, in turn, was driven by faster productivity growth in the capital goods producing sector and rising trade integration. Yet emerging market and developing economies still face higher relative prices of tradable investment goods, consistent with their higher policy-induced trade costs and lower productivity in the tradable goods sector. Taken together, the chapter's findings provide an additional, often overlooked, argument in support of policies aimed at reducing trade barriers and reinvigorating international trade. The analysis also highlights the importance of continued technological progress to maintain the pace of decline in relative capital goods prices, which has provided an important tailwind to investment around the world.*

## Introduction

The investment needs of most emerging market and developing economies remain substantial. These economies still have only a small fraction of the capital available in advanced economies even though their investment rates have increased significantly over the past three decades, with a near doubling of real investment rates in machinery and equipment (Figure 3.1, panels 1–2). Meeting the United Nations Sustainable Development Goals would also require a sizable boost to investment in many low-income developing countries (Gaspar and others 2019). High investment rates have been a key reason for significantly higher growth in emerging market and developing economies than in advanced economies since the early 2000s, which has helped narrow income gaps. The assumption of continued strength in investment in emerging market and developing economies underpins the projection that they will grow faster than advanced economies in the medium term (Figure 3.1, panels 3–4).[1]

The capital deepening in emerging market and developing economies over the past three decades coincided with sizable declines in the price of investment goods, and in particular of tradable capital goods such as machinery and equipment, relative to other prices in the economy

The main authors of this chapter are Weicheng Lian, Natalija Novta, Evgenia Pugacheva, Yannick Timmer, and Petia Topalova (lead), with support from Jilun Xing and Candice Zhao and contributions from Michal Andrle, Christian Bogmans, Lama Kiyasseh, Sergii Meleshchuk, and Rafael Portillo. The chapter benefited from comments and suggestions by Andrei Levchenko and Maurice Obstfeld.

[1] Advanced economies experienced a similar increase in real investment rates in machinery and equipment until the 2008 global financial crisis. For an analysis of the investment slump in these economies in the aftermath of the global financial crisis, see Chapter 3 of the April 2015 *World Economic Outlook*.

(Figure 3.1, panels 5 and 6).[2] Economists have long hypothesized that the relative price of investment is one of the key drivers of investment rates and therefore economic development.[3] The decline in relative investment prices, in turn, is often attributed to faster growth in the productivity of sectors that produce capital goods than in sectors producing consumption goods and services, linked in part to advances in information technology. Efficiency gains from globalization and the associated specialization of production around the world have also supported the downward trend in capital goods prices, because the production of machinery and equipment is strongly embedded in global value chains (Figure 3.1, panel 7). As emerging market and developing economies became increasingly integrated into the world economy and reduced barriers to trade, they were able to benefit from and contribute to this engine of economic expansion, thus further reducing the relative prices of tradable capital goods.

Could this potential driver of investment come under threat going forward? The slowdown in global trade, the potential maturation of global value chains, and the waning pace of trade liberalization since the mid-2000s, discussed in Chapter 2 of the October 2016 *World Economic Outlook* (WEO), may limit further declines in the price of investment. Even more immediate is the threat from higher trade barriers in some advanced economies, which could jeopardize the benefits from free trade—taken for granted for so long in these economies. Hikes in tariffs and nontariff barriers could disrupt cross-border supply chains and, by making production less efficient, slow or even reverse the downward trend in capital goods prices. Even if not directly involved in the current trade tensions, many emerging market and developing economies stand to lose if the disputes escalate. As net importers of capital goods, they may face higher prices of machinery and equipment and, more broadly, diminished opportunities to benefit from the cross-border spread of knowledge and technology brought on by globalization (see Chapter 3 of the April 2018 WEO).

Sluggish productivity growth in advanced economies, a concern even before the 2008 global financial crisis, poses another threat to the further decline in capital goods prices. Productivity in the world's leading capital goods producing economies has slowed further, with the global financial crisis leaving lasting scars on research and development spending and technology adoption (see Adler and others 2017 and Chapter 2 of the October 2018 WEO). Aging and the rise of market power in some of the main capital goods producing economies (see Chapter 2 of the April 2019 WEO) also cast a shadow on the innovation and continued technological advances that may be needed to spur further decline in the price of investment goods. The pace of decline in the relative price of machinery and equipment has already slowed considerably in

[2] In this chapter, the relative price of investment refers to the ratio of the price of investment to the price of consumption. (All stylized patterns and findings are qualitatively similar if the price of investment is instead compared with the overall GDP price level.) The capital deepening also occurred in the context of improved macroeconomic policy and institutional frameworks, a synchronized pickup in economic activity until the 2008 global financial crisis and falling global real interest rates.

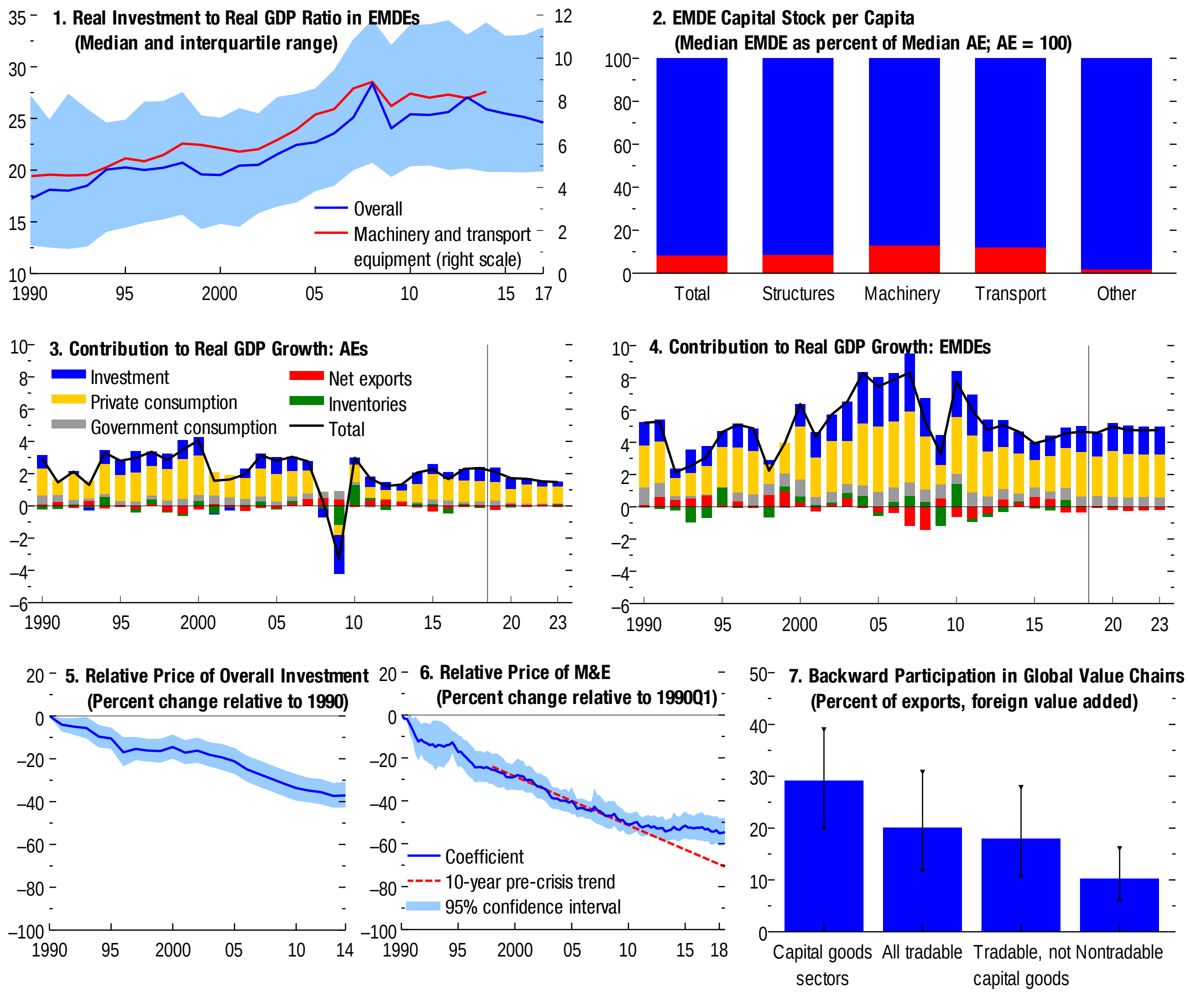
[3] See, for example, de Long and Summers (1991, 1992, 1993), Sarel (1995), Collins and Williamson (2001), Hsieh and Klenow (2007), Armenter and Lahiri (2012). The relative price of investment goods tends to be inversely related to investment or per capita growth (Jones 1994; Sarel 1995; Restuccia and Urrutia 2001), and high relative investment prices likely serve as a headwind to the structural transformation many low-income developing countries need to converge to advanced economies' income levels. High tariffs on imported equipment, part of many developing economies' import-substitution growth strategies in the 1970s and 1980s, have often been cited as an important impediment to development (Taylor 1998a; Estevadeordal and Taylor 2013; Sen 2002; Johri and Rahman 2017).

advanced economies in the past decade, potentially exerting an additional drag on these economies' lackluster investment since the global financial crisis (Figure 3.1, panel 6).

**Figure 3.1. Capital Stocks, Investment, and the Relative Price of Capital Goods**

*(Percent, unless noted otherwise)*

Real investment to real GDP ratios increased substantially in emerging market and developing economies, but capital stocks per capita remain very low. The rise in real investment to real GDP ratios coincided with large declines in the price of machinery and equipment relative to the price of consumption, with production of machinery and equipment being strongly embedded in global value chains.




Sources: Eora MRIO database; Haver Analytics; Penn World Table (PWT) 9.0; World Economic Outlook database; and IMF staff calculations.

Note: Panel 1 shows the median and interquartile range of the overall real investment to real GDP ratio (from WEO) and real investment in machinery and equipment to real GDP ratio (from PWT 9.0). Panels 3 and 4 show contributions to real GDP growth for AEs and EMDEs, respectively, based on WEO historical data and projections. In Panel 5 and 6, the solid line plots year (quarter) fixed effects from a regression of log relative prices on year (quarter) fixed effects and country fixed effects to account for entry and exit during the sample and level differences in the overall investment price relative to the price of consumption. Year (quarter) fixed effects are normalized to show percent change from the relative investment prices in 1990 (1990Q1). Shaded areas indicate 95 percent confidence intervals. The relative price of investment is obtained by dividing the investment deflator by the consumption deflator. For further details, see Online Annex 3.1. The figure in Panel 6 is based on quarterly data from select advanced economies, including: Australia, Canada, Germany, Hong Kong, Italy, Norway, Portual, Spain, United Kingdom, United States. Panel 7 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. AE = advanced economy; EMDE = emerging market and developing economy; M&E = Machinery and Equipment.

With this backdrop in mind, the chapter examines several interrelated questions.[4]

- How have prices of investment goods evolved over time and across countries? Do lower-income countries face higher capital goods prices, in absolute terms and/or relative to other prices in the economy?
- What drives the price of tradable capital goods over time and which factors explain differences across countries? How much have technological advances and trade integration contributed to the relative decline in the prices of machinery and equipment? To what extent are capital goods prices shaped by policy choices, particularly barriers to trade?
- How responsive is investment in machinery and equipment to the price of these assets? How much have changes in capital goods prices contributed to capital deepening in the past three decades?

The chapter's main findings are as follows:

- The relative price of tradable investment goods, namely machinery and equipment, has declined across advanced and emerging market and developing economies in the past three decades. The declines were significant and driven by faster productivity growth in capital goods production and rising trade integration.
- Yet the most recent available data on the price of comparable baskets of machinery and equipment across countries suggest that in 2011, emerging market and developing economies faced higher machinery and equipment prices, both in absolute terms and especially relative to the price of consumption. The higher relative prices of machinery and equipment reflect these economies' lower relative efficiency in producing investment goods and tradable goods, more broadly, and significantly higher trade costs, such as those arising from higher tariffs.
- Finally, model simulations and empirical evidence suggest that the relative price of investment goods is an important driver of real investment rates. There has been a slowdown in investment worldwide since the global financial crisis. Yet, over the last 30 years, real investment in machinery and equipment as a share of real GDP has increased significantly in both advanced and emerging market and developing economies. A nontrivial share of this increase can be attributed to the decline in the relative prices of machinery and equipment.

Taken together, the findings of this chapter provide 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 trade barriers that raise the relative price of capital goods for domestic investors. An effort to remove these barriers would provide further impetus for investment in tradable capital goods and support the capital deepening needed in many of these economies, helping to counterbalance headwinds from abroad. Advanced economies, whose real investment, recent weakness notwithstanding, has been similarly supported by declining prices of capital goods should also guard against protectionist measures that raise trade costs. For both sets of economies, reviving the process of trade

[4] In this chapter, 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.

liberalization, which has slowed down significantly since the mid-2000s, would be crucial to maintaining the pace of decline in relative capital goods prices. The impetus this would provide to real investment would come on top of the well-known welfare and productivity gains from international trade (for a discussion, see IMF-WB-WTO 2017).

The analysis in this chapter also highlights the importance of continued technological advances and innovation in capital goods production in advanced and emerging market and developing economies alike. Such advances, by lowering the relative price of investment goods, could generate dividends beyond their effect on aggregate productivity growth. As discussed in Adler and others (2017) and Chapter 2 of the April 2016 *Fiscal Monitor*, policies that stimulate research and development, entrepreneurship, and technology transfer, alongside continued investment in education and public infrastructure, can help.

## The Price of Capital Goods: Key Patterns

### Over Time

Since the 1990s, capital goods prices relative to consumption prices have displayed two key patterns.[5]

First, the relative prices of the four main types of fixed capital assets—structures, machinery and equipment (excluding transportation), transportation equipment, and intellectual property products—have evolved quite differently (Figure 3.2, panels 1–4). According to data in the Penn World Table version 9.0 across 180 countries, the prices of machinery and equipment and transportation equipment have declined significantly since the early 1990s when compared with the consumption deflator.[6] The relative price of machinery and equipment fell by about 60 percent in advanced and 40 percent in emerging market and developing economies. 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. The price of other investment, which consists mostly of intellectual property products such as research and development and computer software and databases, has also come down, although more modestly than for tangible tradable investment goods. Finally, 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), within the machinery and equipment asset type (Figure 3.2, panels 5–7), supports the hypothesis that advances in information technology have played an important role in driving down the relative price of investment.[7] Zooming in on the price of

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[5] See Online Annex 3.1 for country coverage, data sources, and variables definitions. All annexes are available online at www.imf.org/en/Publications/WEO.

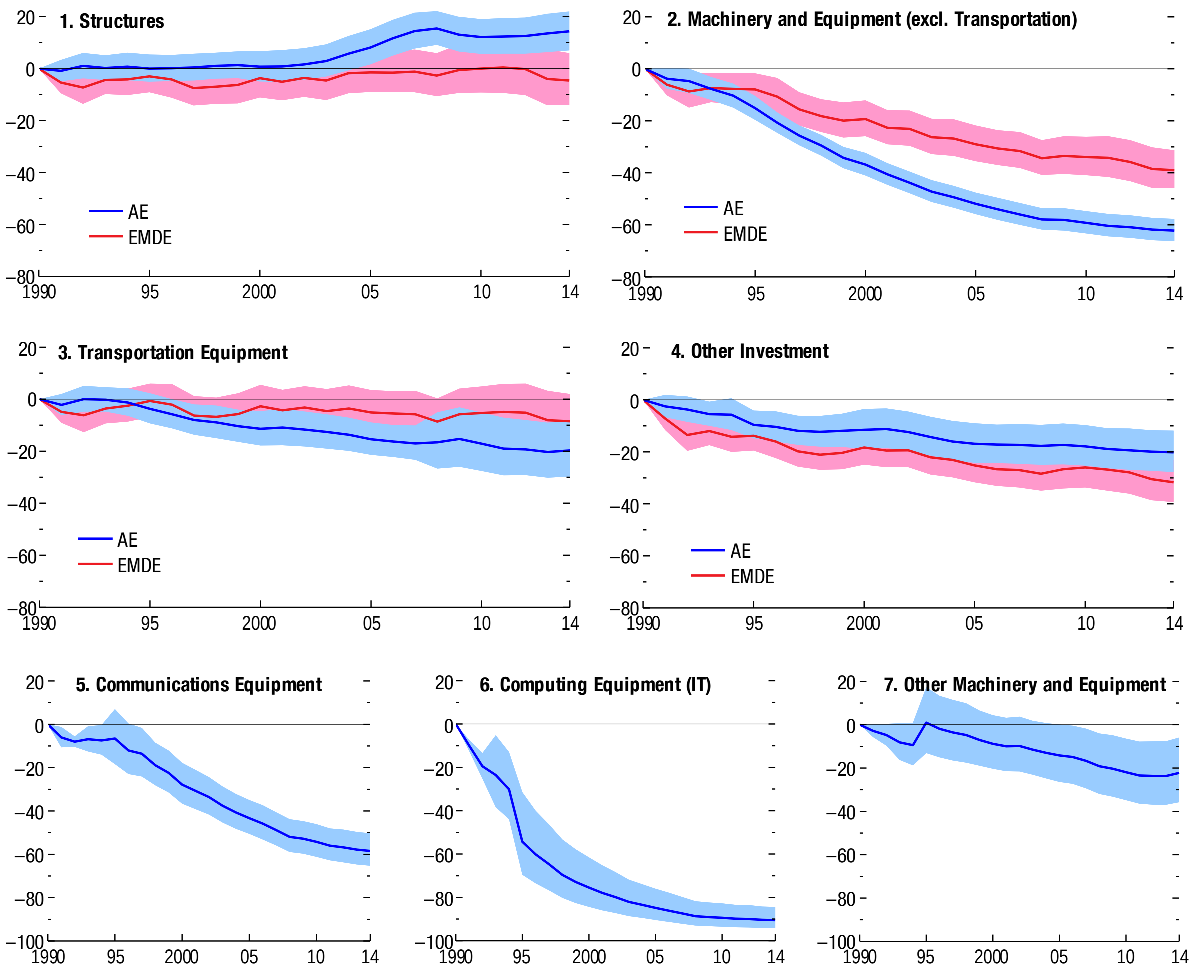
[6] The pace of decline in the relative price of tangible tradable capital goods prices accelerated significantly in the 1990s especially for the emerging market and developing economy country group, as discussed in Online Annex 3.2. Recent data from 10 advanced economies suggest that the rate of decline in the relative price of machinery and equipment has slowed since the global financial crisis. Online Annex 3.2 provides additional stylized facts on the evolution of investment rates across types of fixed capital assets and country groups and the composition of investment across types of capital.

[7] 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

green capital goods, Box 3.1 documents large declines in the cost of installing and operating low-carbon electric generation capacity for some renewable energy sources over the past decade.

**Figure 3.2. Dynamics of Relative Prices across Types of Capital Goods and Broad Country Groups**
*(Percent change relative to 1990)*

The decline in the relative price of investment was driven by a broad-based decline in the relative price of machinery and equipment. Within tangible tradable capital goods, computing equipment and hardware experienced the largest price decline.




Sources: EU KLEMS; Penn World Table 9.0; World KLEMS; and IMF staff calculations.
Note: Panels 1–4 use data from the Penn World Table 9.0, 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 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. AE = advanced economy; EMDE = emerging market and developing economy.

Second, the decline in the relative price of *tangible tradable* investment goods (namely, machinery and capital equipment and transportation equipment) is widespread. Compared with the early 1990s, by 2014, the price of machinery and equipment had declined relative to the consumption deflator in all advanced, 87 percent of emerging market economies and in 68 percent of low-

make substantial efforts to accurately reflect these changes in price indices, although methodologies likely differ significantly across countries. The chapter relies on the data provided by national authorities and compiled in Penn World Table 9.0.

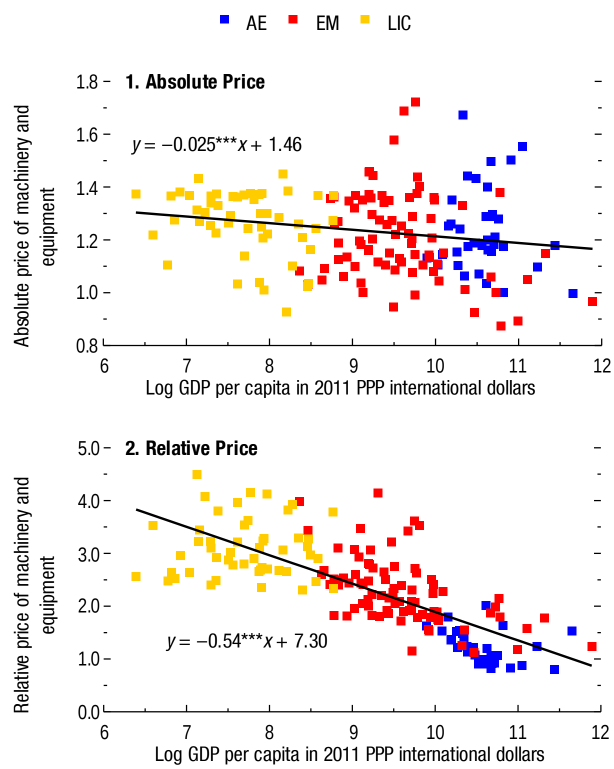
income developing countries. In contrast, trends in the relative price of structures are very different across broad country groups.

## Across Countries

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 the International Comparison Program (ICP), which collects prices of comparable baskets of goods and services across countries, 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. The difference between advanced economies and lower-income countries is particularly striking for the price of machinery and equipment relative to the countries' consumption price level, with the price in the median low-income country being 2.7 times the price in the median advanced economy (Figure 3.3).[8] Online price data from a global retailer of electronic goods such as computers, cellular phones, and tablets across a sample of 27 advanced and emerging market economies reveal a similar pattern, as discussed in Box 3.2.

**Figure 3.3. Absolute and Relative Prices of Machinery and Equipment across Countries in 2011**

Relative to the price level of consumption, the prices of machinery and equipment are significantly higher in emerging market and developing economies than in advanced economies. Lower-income countries also face marginally higher absolute prices of machinery and equipment.




Sources: International Comparison Program (ICP) 2011; and IMF staff calculations.
Note: The absolute price of machinery and equipment is the price level of machinery and equipment, derived by the ICP using a similar basket of products across countries, relative to its US level. The relative price is the price of machinery and equipment relative to the price of consumption. See Online Annex 3.1 for a detailed description of country coverage, data sources, and methodology. AE = advanced economy; EM = emerging market economy; LIC = low-income country; PPP = purchasing power parity.

The dramatic and widespread changes in the relative prices of capital goods over the past three decades, against a backdrop of large cross-country differences in these relative prices at a particular point in time, raise a number of questions. How significant is the relative price of

[8] Comparable cross-country data on the price of capital goods are extremely scarce. The key source is the International Comparison Program (ICP), which collects detailed price data through cross-country surveys every 5 to 10 years. Using data from the 1985 and 1996 ICP rounds, Eaton and Kortum (2001) and Hsieh and Klenow (2007) find a strong negative correlation between relative investment prices and the level of development, similar to findings in this chapter. At the same time, they find little correlation between absolute prices of capital goods and per capita GDP. As argued by Alfaro and Ahmed (2009), the absence of a correlation may be attributed to data quality issues, which were largely addressed by methodological improvements in the 2011 ICP round (Feenstra, Inklaar, and Timmer 2015; Deaton and Aten 2017). Mutreja and others (2014) demonstrate that the smaller dispersion in absolute prices does not necessarily imply the absence of large trade costs.

capital goods for countries' real investment rates? What are the drivers of the relative prices of tradable investment goods? What is required for the downward trend in these prices to continue? And, if the relative price of capital goods is indeed important for real investment, what can lower-income countries do to bring down the price of capital goods relative to the price level of consumption in their economies?

## The Relative Price of Capital Goods: A Simple Framework

Theoretically, the importance of the relative price of investment in investment decisions is not hard to establish. As economic agents decide how to allocate their limited resources between consuming today and investing in machinery and equipment that will increase their future output, the price at which they can trade consumption goods for capital goods will be among the key influences of that choice (see, for example, Sarel 1995 and Restuccia and Urrutia 2001 for a simple theoretical framework). All else equal, a decline in the price of capital goods relative to other prices in an economy would make it more attractive for agents to invest than to consume, and hence lead to higher real investment rates (in other words, a higher ratio of real investment to real output).[9] Of course, investment decisions, which hinge on a comparison between the user cost of capital and its marginal product, are influenced by many other factors, such as expectations of economic prospects, the availability and cost of finance, the quantity of capital already in use relative to the desired capital stock, the rate of depreciation of capital goods, agents' impatience, and the like.

The relative price of capital goods, in turn, 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.[10] 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 international suppliers charge for these goods and other factors that drive a wedge between international and domestic prices. These factors include transportation costs, the efficiency of the domestic distribution sector, import tariffs, customs regulations, and the time and cost 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 (see Chapter 2 of the April 2019 *Fiscal Monitor*), also influence the relative investment price.[11]

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[9] In a closed economy, where investment goods are produced only domestically, the relationship between the relative price of capital goods and investment is less clear-cut, as discussed in Foley and Sidrauski (1970).

[10] 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).

[11] 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).

Guided by this simple framework, the chapter proceeds to examine empirically the key sources of differences in the relative prices of tradable capital goods across countries, and the factors underpinning the dramatic declines in the relative price of machinery and equipment over time. In the subsequent section, the importance of changes in the relative prices of capital goods for real investment rates and output is quantified using model simulations and empirical analysis of country and sectoral data.

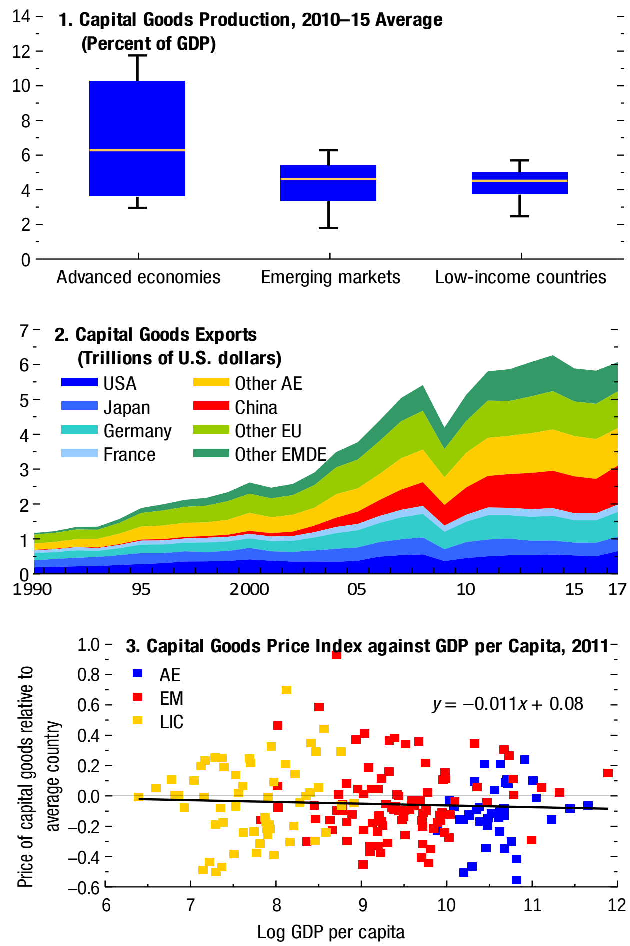
## Drivers of Relative Investment Prices

### Across Countries

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 bear comparison across countries are available only at one point in time, it is difficult to disentangle the causal contribution of various potential drivers. The chapter examines 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 relates these to the relative price of capital goods from the 2011 ICP data.

**Figure 3.4. Unit Values of Tradable Capital Goods across Countries**

A relatively small number of advanced economies and China account for a large share of global production and exports of capital goods. Unit values of capital goods exports by five major exporters are not systematically correlated with the per capita income of the importing country.




Sources: Eora MRIO database; Eurostat; Ministry of Finance of Japan; UN Comtrade database; US Census Bureau; and IMF staff calculations.
Note: Panel 1 uses Eora sectors 9 and 10 to identify capital goods. Panel 2 uses Comtrade SITC Revision 2, sector 7 to plot overall capital goods exports for the identified countries. Panel 3 uses export data for major capital goods exporters. For more details on data sources and methodology, see Online Annex 3.3. AE = advanced economy; EM = emerging market economy; LIC = low-income country; EU = European Union.

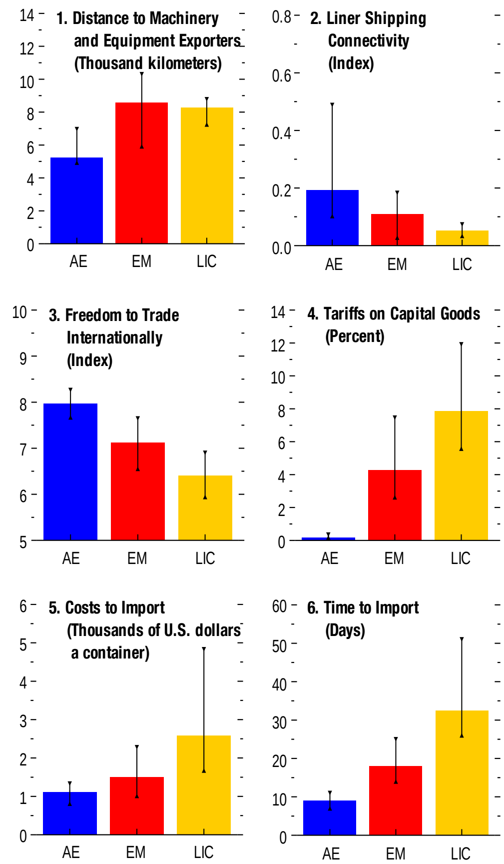
To assess whether differences in prices charged by key capital goods exporters can explain the higher relative prices of capital goods observed in emerging market and developing economies (compared with advanced economies), the chapter examines highly disaggregated data on trade in capital goods. Since a small number of countries account for the bulk of global exports of machinery and equipment (Figure 3.4, panels 1–2), and since most emerging market and developing economies import a significant proportion of these goods, unit values of various types of machinery and equipment from five of the largest capital goods exporters—United States, China, Germany, France, and Japan—are compared across importing countries.[12] 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.[13] It also permits isolating 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.

The 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 (Figure 3.4, panel 3). Trade costs, on the other hand, exhibit a clear pattern: they tend to be much lower for advanced economies.[14] 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 have significantly higher policy-related barriers to trade than advanced economies, in addition to their larger natural trade barriers (Figure 3.5). They tend to be located farther from 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. 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 3.6, panel 1).

**Figure 3.5. Trade Costs in 2011**

*(Median, and interquartile range)*

Trade costs are higher in emerging market and developing economies.




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 IMF staff calculations.

Note: Distance to exporters of machinery and equipment 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. AE = advanced economy; EM = emerging market economy; LIC = low-income country.

[12] 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.

[13] 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). See Online Annex 3.3 for details on the specification and findings.

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

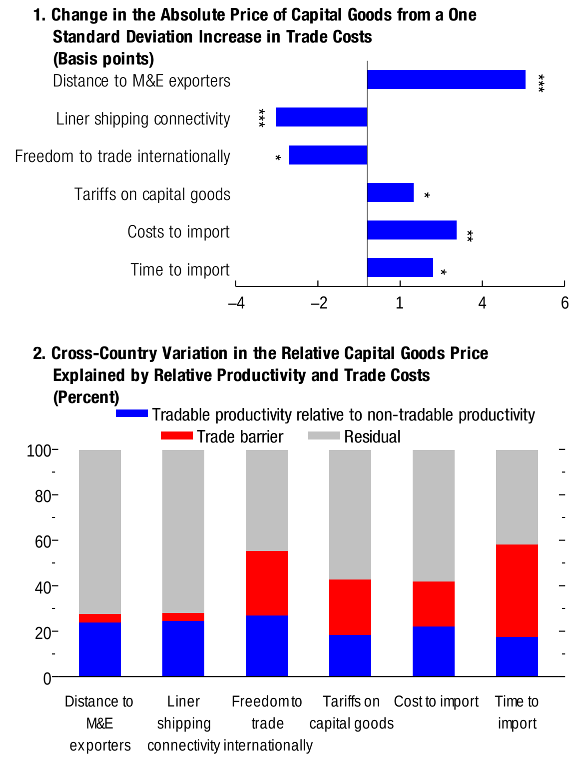
Putting all the pieces together as outlined in the simple framework, the chapter next examines the contribution of efficiency in the production of tradable goods relative to efficiency in the nontradable sector, as well as alternative measures of trade costs' contribution to the cross-country variation in the relative prices of capital goods.[15] As shown in Figure 3.6, panel 2, relative productivity differences in the production of tradable goods and trade costs can together 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.[16] 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 due both to higher trade barriers and lower productivity in the production of capital goods and tradable goods more broadly.[17]

## Over Time

While cross-country variation in relative capital goods prices has been the focus so far, this section aims to shed light on the drivers of

**Figure 3.6. Trade Costs, Relative Productivity, and the Price of Capital Goods in 2011**

The absolute price of machinery and equipment in 2011 was higher in countries with larger trade costs. Trade costs and labor productivity in the tradable versus the non-tradable sector can together explain a significant share of the cross-country variation in the relative price of machinery and equipment.




Source: IMF staff 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, based on estimates in Online Annex Table 3.4.1. 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, based on estimates in Online Annex Table 3.4.2. See notes to Figure 3.5 for definitions and sources of trade costs. M&E = machinery and equipment.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

[15] The chapter estimates a simple ordinary least squares 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, the regression estimates are used to decompose the 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 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. See Online Annex 3.4 for further details on the specification and findings.

[16] 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.

[17] Sposi (2015) similarly argues that trade barriers play an important role in explaining the relative price of tradable goods and services across countries, noting that removing trade barriers would eliminate more than half of the observed gap in relative prices between rich and poor countries.

the big declines in the relative prices of tradable capital goods seen in most countries over the past 30 years. The analysis attempts to disentangle the roles of technological progress—which may have boosted productivity of the capital goods sectors—and deepening trade integration. To do so, it follows a two-step approach. First, sectoral producer price data across 40 advanced and emerging market economies during 1995–2011 from the World Input-Output Database are analyzed to estimate the elasticity of producer prices to changes in sectoral labor productivity and exposure to international trade (as measured by the import penetration, the ratio of imports to domestic value added). The analysis controls 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.[18] Given the endogenous nature of trade exposure, the analysis isolates changes in import penetration that were triggered by policy choice, by using import tariffs as an instrument.[19] Second, the estimated elasticities are combined with the change in relative labor productivity and trade exposure of the capital goods sector to estimate how much each factor can account for the decline in the relative prices of machinery and equipment during 2000–11. Recognizing that exposure to foreign competition affects relative domestic prices indirectly through its impact on sectoral productivity,[20] the decomposition attempts to separate out the contributions made by trade-related changes in labor productivity and changes in productivity due to other factors (such as sectoral technological advances) in the decline in the sectoral price of machinery and equipment.

**Table 3.1. Trade Integration, Productivity and Sectoral Producer Prices**

| Dependent Variables: | Relative Producer Prices | | | Relative Productivity |
|---|---|---|---|---|
| | OLS | OLS | IV | IV |
| | (1) | (2) | (3) | (4) |
| Relative Import Penetration$_{t-1}$ | −0.135*** | −0.107*** | −0.574*** | 1.363*** |
| | (0.033) | (0.037) | (0.163) | (0.363) |
| Difference for Capital Goods Sectors | | −0.191** | 0.033 | 1.407** |
| | | (0.081) | (0.322) | (0.671) |
| Relative Productivity$_{t-1}$ | −0.316*** | −0.314*** | −0.328*** | |
| | (0.035) | (0.035) | (0.032) | |
| Number of Observations | 16,077 | 16,077 | 16,077 | 16,077 |
| $R^2$ | 0.62 | 0.62 | 0.56 | 0.91 |
| Relative Import Penetration for Capital Goods Sectors | | −0.298*** | −0.541* | 2.770*** |
| | | (0.071) | (0.287) | (0.564) |

Source: IMF staff calculations.
Note: All regressions include country-year and country-sector fixed effects. Standard errors clustered at the country and sector level are in parentheses. Difference for capital goods sectors refers to the interaction term between import penetration and a dummy indicating whether a sector produces capital goods. OLS = ordinary least squares; IV = instrumental variable. See Online Annex 3.5 for details.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

18 See Online Annex 3.5 for further details. 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.

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

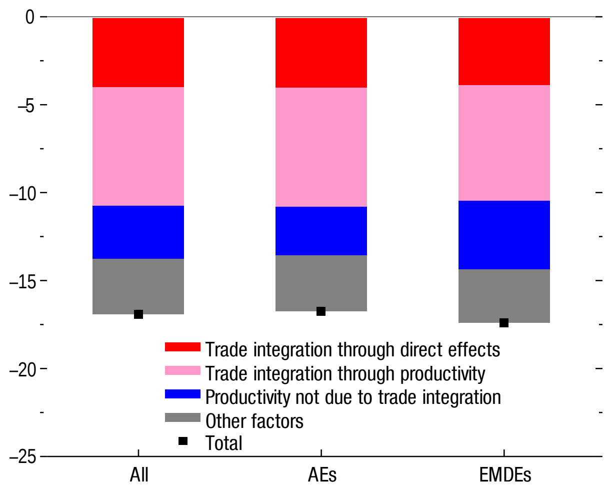
20 For evidence on the productivity-enhancing effects of trade reforms, see, among others, Ahn and others (forthcoming), Amiti and Konings (2007), and Topalova and Khandelwal (2011).

The econometric analysis (details of which can be found in online Annex 3.5 and Table 3.1) confirms that greater exposure to trade and faster productivity growth both lead to lower domestic producer prices. 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 0.5 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. Confirming findings of other studies, the analysis also uncovers a strong positive effect of policy-induced changes in import penetration on labor productivity at the sector level (Table 3.1, column 4). 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 (Figure 3.1, panel 6).[21]

Figure 3.7 decomposes the decline in the relative price of the machinery and equipment producing sectors relative to the price of consumption 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.

**Figure 3.7. Contributions to Changes in Relative Producer Prices of Capital Goods: 2000–11**
*(Percent)*

The decline in the price of capital goods relative to the price of consumption has been supported by faster labor productivity growth and rising trade integration.




Source: IMF staff 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. See Online Annex 3.5 for a detailed description of country coverage, data sources, and methodology. AE = advanced economy; EMDE = emerging market and developing economy.

The empirical exercise also suggests that a nontrivial portion of the decline in the price of investment goods, especially in emerging market and developing economies, can be attributed to other factors. These could include the downward trend in world interest rates, financial liberalization, and the emergence of China as a

[21] 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).

key supplier of tradable investment goods over this time period (see Figure 3.4, panel 2, and Online Annex 3.2).[22]

## Macroeconomic Implications of Shocks to the Price of Capital Goods

The last section of this chapter aims to quantify the relevance of relative investment prices for macroeconomic outcomes. How much does the relative price of capital goods matter for a country's real investment rate? What share of the dramatic increase in machinery and equipment investment over the past 30 years can be attributed to the decline in the relative price of these goods? To answer these questions, the analysis relies both on model-based explorations and on empirical evidence.[23]

As discussed in Box 3.3, analysis of the macroeconomic effects of the relative price of investment within a structural model is insightful as it captures the aggregate effect of exogenous changes in relative investment prices in a general equilibrium environment, which accounts for all feedback mechanisms in the economy. Moreover, since relative prices within an economy are endogenously determined, model simulations make it possible to isolate changes in these prices that are driven by specific exogenous shocks. As a result, their effects on investment rates and other macroeconomic outcomes can be credibly traced. Using the IMF's Global Integrated Monetary and Fiscal (GIMF) model, the analysis reveals that both shocks to the relative productivity of the investment goods producing sector and tariff cuts that permanently lower the price of capital goods imports lead to sizable and long-lasting increases in the real investment rate in a representative emerging market economy. Shocks that result in a 1 percent decline in the price of investment relative to consumption lead to a roughly 0.8 percent increase in the ratio of the real investment rate to real GDP in the medium term.[24] Guided by these findings, the empirical analysis sets out to examine whether the model predictions are reflected in the historical relationship between the relative prices of machinery and equipment and real investment rates, at both the country and sectoral levels.

### Cross-Country Empirical Evidence

The cross-country analysis relies on over 60 years of data across 180 advanced and emerging market and developing economies from the latest release of the Penn World Table database. Using a reduced-form framework, the analysis relates real investment in machinery and equipment as a share of a country's real output and the price of machinery and equipment relative to the price of consumption. The analysis controls for all global shocks (for example, global financial conditions, commodity price changes, uncertainty, and world economic prospects), all time-invariant country characteristics, and a host of other country-specific and time-varying factors shown by economic theory and previous studies to shape investment rates.

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[22] Capital goods producing sectors tend to be more capital intensive than other sectors in developing economies. Hence, easier access to financing may benefit capital goods production more than other sectors, contributing to a decline in the relative price of investment.

[23] As discussed in the conceptual framework, investment decisions are shaped by numerous factors. A comprehensive analysis of the relative importance of all potential factors is beyond the scope of this chapter. The goal of the analysis is to zoom in on the relative price as a potential driver of real investment rates and attempt to provide suggestive evidence of its quantitative importance.

[24] For an average emerging market and developing economy with a ratio of real investment to real output of about 22 percent this finding would imply that a 1 percent decline in the relative price of investment would lead to an increase in the investment rate to 22.2 percent.

These include proxies for the availability and cost of finance within each country, the strength of economic prospects, exposure to global markets and commodity price fluctuations, and the quality of institutions and infrastructure. The estimation is based on five-year averages to smooth out cyclical fluctuations and approximate more closely the medium-term relationship between the relative price and investment rate uncovered in the structural model simulations.

Estimation results, detailed in Online Annex 3.6, confirm that real investment rates are shaped by a variety of factors. 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, the analysis reveals a strong and statistically significant negative relationship between real investment in machinery and equipment and its relative price (Table 3.2). The findings are robust to alternative specifications, focusing on the post-1990 period, examining the sample of emerging market and developing economies only, and using instrumental variable strategies to correct for the negative bias that may arise from potentially correlated measurement errors in the real investment rate and its price. 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.

**Table 3.2 Real Investment Rate and the Relative Price of Machinery and Equipment**

| Dependent Variable: Log Real Investment-to-GDP Ratio | Cross-Country Regressions: All | Cross-Country Regressions: Post 1990 | Cross-Country Regressions: EMDE | Sectoral Regressions | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Log Relative Price | –0.377*** | –0.292* | –0.491*** | –0.326*** | –0.528*** |
| | (0.116) | (0.171) | (0.161) | (0.078) | (0.068) |
| Number of Observations | 658 | 553 | 457 | 971 | 971 |
| Number of Countries | 127 | 127 | 93 | 18 | 18 |
| $R^2$ | 0.41 | 0.36 | 0.38 | 0.94 | 0.93 |
| First Stage F-Statistic | 118.80 | 81.81 | 64.04 | 644.60 | 728.80 |

Source: IMF staff calculations.

Note: The dependent variable is log real machinery and equipment investment-to-GDP ratio. Regressions are estimated with data averaged over non-overlapping five-year windows using instrumental variable (IV) regressions, where the main independent variable—log price of machinery and equipment relative to consumption—is instrumented with its lagged value. All cross-country panel regressions in columns 1–3 control for country and period fixed effects, and a set of other determinants of investment-to-GDP ratios. Sectoral regression in column 4 is estimated with country-period and country-sector fixed effects, and in column 5 with period and country-sector fixed effects, where period refers to the non-overlapping five-year windows. Standard errors clustered at the

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

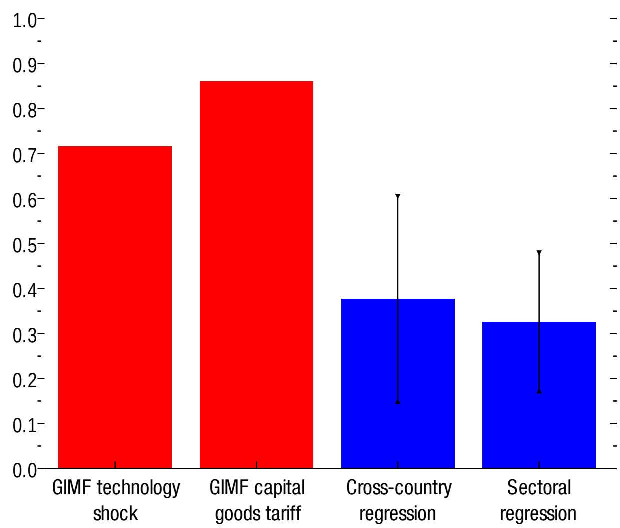
## Sectoral Empirical Evidence

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 makes it possible 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 overall 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 analysis relies on data from 18 (mostly advanced) economies during 1971–2015 from the EU and World KLEMS databases to construct measures of real investment in machinery and equipment and the relative prices of these capital goods specific to 15 broad economic sectors.[25] As in the cross-country analysis, the baseline estimation relates machinery and equipment investment as a share of sectoral real value added to relative prices, using five-year averages. 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. As in the model simulations presented in Box 3.3, declining investment prices are linked to higher output in the sector, and marginally higher labor productivity. Analysis of firm-level data from Colombia in Box 3.4 further confirms that lower capital goods prices because of a sizable tariff cut following trade reform in 2011 prompted firms to boost investment.

**Figure 3.8. Elasticity of Real Investment-to-GDP to Relative Price of Capital Goods: Model Simulations versus Empirical Evidence**
*(Percent)*

Model simulations and empirical evidence deliver broadly consistent estimates of the elasticity of the real investment to real GDP ratio to the relative price of capital goods.




Source: IMF staff calculations.
Note: The bars depict the simulated/estimated elasticity of the real investment-to-GDP to the price of capital goods relative to the price of consumption. See Box 3.3 for details on the model, and Online Annexes 3.6–7 for details on the empirical analyses. GIMF = Global Integrated Monetary and Fiscal model.

Figure 3.8 compares the findings across the structural model, cross-country, and sectoral analyses, revealing a consistent pattern. Across all three approaches, 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 3.9—as a purely illustrative exercise—uses the estimated elasticity from the cross-country analysis and the

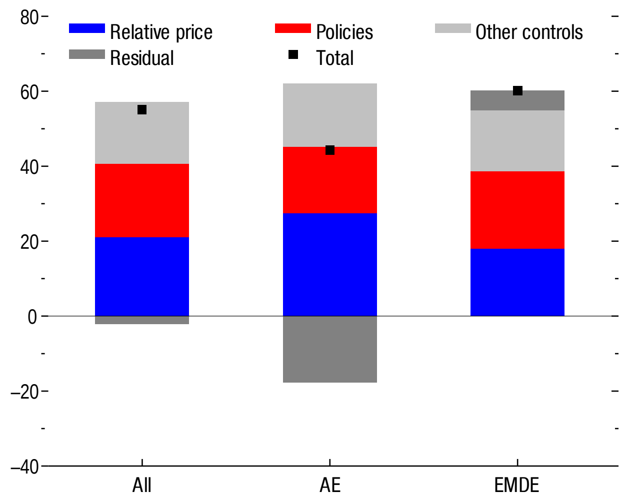
[25] See Online Annex 3.7 for details.

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. Improvements in policies and policy frameworks have contributed significantly to the rise of real investment in machinery and equipment in both advanced and emerging market and developing economies. The dramatic decline in the relative prices of tradable capital goods that occurred alongside can also explain a sizable share of the increase in investment in tradable capital goods in advanced and emerging market and developing economies. The cross-country empirical estimates of the exact contribution of relative prices should be taken with a grain of salt; however, the anecdotal evidence presented in Box 3.1 on the rapid rise in investment in low-carbon technologies with steeper declines in production costs—and firm-level evidence from Colombia on the investment effects of arguably exogenous changes in the price of capital goods, discussed in Box 3.4—also point to relatively high price-elasticity of investment.

**Figure 3.9. Contributions of Relative Prices to Increases in Real Investment in Machinery and Equipment, 1990–94 to 2010–14**

*(Percent)*

Between 1990–94 and 2010–14, real investment to real GDP ratios in machinery and transport equipment grew by approximately 60 percent. A significant portion of this increase can be explained by the precipitous fall in the relative price of machinery and transport equipment.




Source: IMF staff 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 2010–14 from the relative price of machinery and transport equipment, various policies, and other controls. See Online Annex 3.6 for a detailed description of the estimated model. Black square indicates the total change in real machinery equipment investment to real GDP ratios.

## Summary and Policy Implications

The strengthening of investment in emerging market and developing economies over the past three decades was supported by their improved macroeconomic policy and institutional frameworks, the synchronized pickup in economic activity until the 2008 global financial crisis, and falling global real interest rates. But it also coincided with dramatic declines in the relative price of tradable capital goods, likely reflecting efficiency gains from international trade and advances in information and communications technology that led to more efficient production of capital goods. Could rising trade tensions, slower trade integration, and sluggish productivity growth threaten this potential driver of investment going forward?

This chapter sets out to answer this question by (1) examining whether declines in the relative prices of machinery and equipment have historically provided a quantitatively important boost to investment rates; and (2) shedding light on the drivers of the precipitous fall in the price of tradable investment goods relative to other prices in the economy.

Using both structural model simulations and empirical evidence, the chapter finds that the relative price of investment goods is an important driver of real investment rates in both advanced and emerging market and developing economies. The global financial crisis left lasting scars on investment worldwide. However, from a long-term perspective, real investment rates in machinery and equipment have increased significantly in both advanced and emerging market and developing economies. While exact quantification is challenging, empirical evidence suggests that a nontrivial share of the rise in the real investment rates in machinery and equipment in both groups of economies can be attributed to the dramatic fall in the relative price of these goods over the past three decades. The chapter's sectoral analysis of relative producer prices reveals that the significant decline in the price of machinery and equipment, in turn, was driven by faster productivity growth in the capital goods producing sector and rising trade integration, which has bolstered price competition in domestic markets and improved the efficiency of production processes in the investment goods sector.

Taken together, the chapter's 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.[26] 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 (Figure 3.5, panel 4). Fully implementing commitments under the World Trade Organization's Trade Facilitation Agreement could mean a reduction in trade costs equal to a 15-percentage point tariff cut in less-developed economies (WTO 2015).

In advanced economies, which have similarly benefited from declining capital goods prices over the past three decades, 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.[27] For all economies, reviving trade liberalization, reducing trade costs from both tariff and other barriers, and addressing areas most relevant for continued integration in the contemporary global economy—such as regulatory cooperation, e-commerce, and leveraging complementarities between investment and trade—would help maintain the pace of decline in relative capital goods prices and further spur investment. These benefits would complement the better-known welfare and productivity gains from international trade (for a discussion, see Chapter 2 of the October 2016 WEO).

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[26] 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.

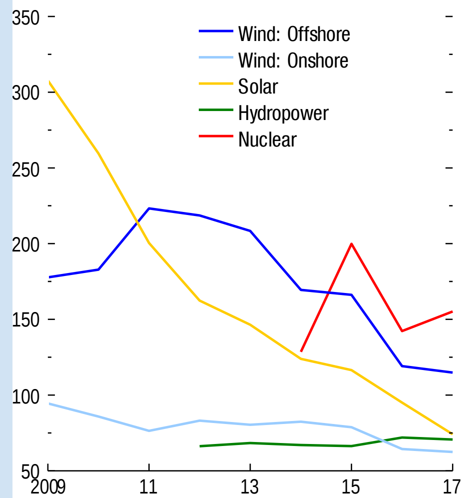
[27] Cavallo and Landry (2018) find that the rise in capital imports in the United States has added 5 percent to its output per hour since the 1970s, and that the imposition of tariffs on capital goods could lead to sizable productivity losses over the next decade.

The analyses in this chapter also highlight the importance of continued technological advances and innovation in the capital goods producing sector in both advanced and emerging market and developing economies. By lowering the relative price of investment goods, these generate dividends beyond the effect of such advances on aggregate productivity growth. As discussed in Adler and others (2017) and Chapter 2 of the April 2016 *Fiscal Monitor,* policies that encourage research and development, entrepreneurship, and technology transfer more broadly could also help the capital goods producing sector, as would continued investment in education and public infrastructure.

The economic benefits of declining capital goods prices notwithstanding, policymakers need to be mindful of their distributional consequences and potential for job disruptions. As discussed in Chapter 3 of the April 2017 WEO, the decline in the relative price of investment has eroded the share of economic output that goes to labor in economies where many jobs can be easily automated and performed by machines. Policies should be designed to help workers better cope with disruptions caused by technological progress and global integration, including through long-term investment in education, programs for skill upgrading throughout workers' careers, and policies facilitating the reallocation of displaced workers to new jobs (see IMF-WB-WTO 2017).

## Box 3.1. The Price of Manufactured Low-Carbon Energy Technologies

**Figure 3.1.1. Levelized Cost of Electricity of Low-Carbon Energy Sources**
*(U.S. dollars per megawatt hour)*




Sources: Bloomberg New Energy Finance; FRED; and IMF staff calculations.
Note: Levelized Cost of Electricity data has been deflated using GDP deflator and does not include subsidies and taxes.

Increasing use of renewable energy sources could help curb carbon emissions substantially—a necessary step to slow the pace of climate change, which threatens the economic future of countries across the globe (Chapter 3 of the October 2017 *World Economic Outlook*). Once considered uneconomical, in recent years the cost of installing *low-carbon* electric generation capacity has declined dramatically for some renewable energy sources.[1] Prices of solar photovoltaics (PV) and onshore wind turbines were the fastest decliners between 2009 and 2017. Solar PV price declines of 76 percent, and turbines that fell 34 percent during that time, made them competitive alternatives to fossil fuels and more traditional low-carbon energy sources (Figure 3.1.1).

Cost reductions, coupled with favorable policies, have indeed led to a substantial increase in global renewable energy capacity, which grew by about 6.5 percent a year between 2000 and 2017 and captured more than two-thirds of global investment in new generation capacity in recent years. It is only in the past decade, however, with solar and wind emerging as cost-effective power sources, that total investment in renewable energy capacity accelerated, suggesting a strong link between investment and its relative price. While hydropower dominated renewable energy investment up to 2008, investment in wind technologies took the lead in 2009. With its relative price falling precipitously, solar PV became the most popular investment choice in 2016 (Figure 3.1.2). In 2017, more was invested in solar PV than in all other low-carbon sources combined.

However, not all low-carbon energy technologies declined in cost. Nuclear energy and hydropower costs rose by 21 percent and 9 percent, respectively, over this period. What explains these divergent price paths for energy technologies? The different trajectories of prices of machinery and equipment and those of residential and nonresidential structures (see Figure 3.2) certainly played a role. Nuclear energy and hydropower share similarities with large-scale civil engineering projects, such as the construction of bridges and railroads.

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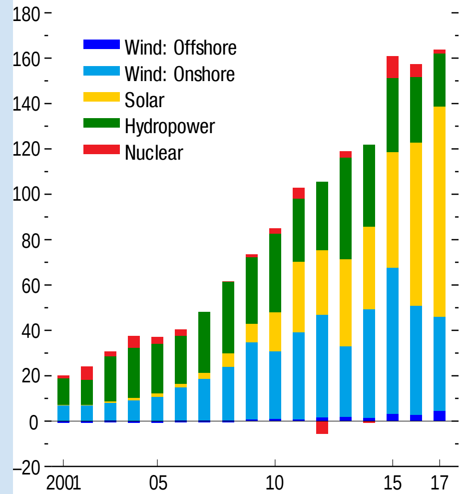
The authors of this box are Christian Bogmans and Lama Kiyasseh.

[1] This cost is typically measured by the so-called levelized cost of electricity (LCOE), which measures the lifetime costs of building and operating a power plant divided by its lifetime energy production, based on recently financed projects in countries where deployment took place.

Potential cost reduction for these kinds of projects is limited by the lumpiness of investment, relatively little component standardization (Sovacool, Nugent, and Gilbert 2014), construction delays (Berthélemy and Rangel 2015), and increasingly stringent, though necessary, local environmental and safety concerns.

In contrast, research and development in solar and wind technologies, their standardization, and economies of scale (through larger manufacturing plants) have resulted in increasingly efficient solar PV modules and larger wind turbines, with millions of quasi-identical experiences leading to continuous cost reductions achieved through learning by doing (Kavlak, McNerney, and Trancik 2018). Significant cost reductions in those sectors bode well for prices of electric batteries, whose production could become significantly more efficient with standardization and economies of scale and whose increased use could lastingly reduce carbon emissions, particularly those from the transportation sector.

**Figure 3.1.2. Annual Additions to Global Electricity Capacity**
*(Thousand megawatt)*




Sources: IAEA, IRENA; and IMF staff calculations.
Note: Solar includes Solar Photovoltaic, and Concentrated Solar Power. Hydropower refers to renewable hydropower and excludes pumped storage.

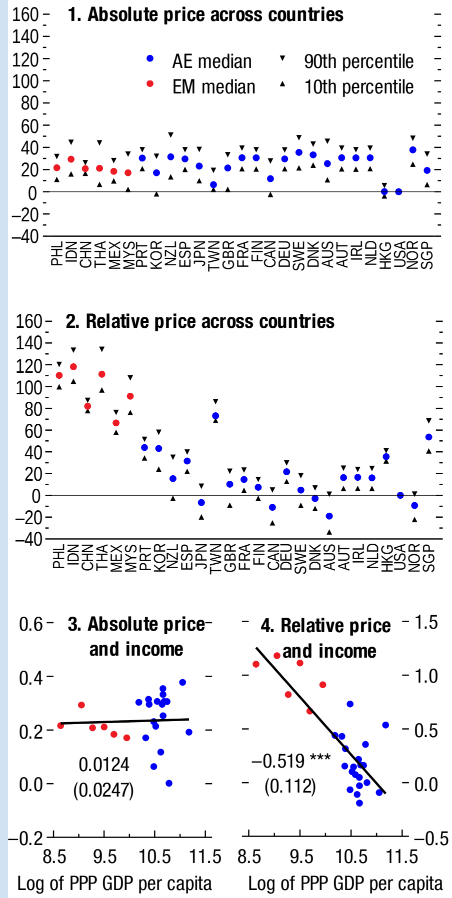
## Box 3.2. Evidence from Big Data: Capital Goods Prices across Countries

The International Comparison Project (ICP) has traditionally been the only data source for prices of comparable baskets of capital goods across countries. However, despite significant improvements, concerns about comparability across countries and methods of price collection remain. These potentially confound cross-country price comparisons (see, for example, Alfaro and Ahmed 2009; Deaton and Heston 2010; Inklaar and Rao 2017). A promising alternative is the use of big data, which allows the comparison of online prices of identical (capital) goods sold across the world. The newly available Billion Prices Project database (Cavallo, Neiman, and Rigobon 2014), used in this box, allows precisely that kind of comparison.

The analysis takes online price information for 674 distinct Apple products across 27 economies, with a monthly frequency from 2009 to 2012.[1] Normalized by US prices, the prices charged for each product sold within the same month across the 27 economies in the sample are compared.

Online retail prices of identical goods across countries differ because they include markups, local taxes and subsidies, transportation costs, and tariffs and other nontariff barriers. Across the 27 mostly advanced economies for which data are available, significant differences are observed in absolute prices of Apple products, although no clear correlation with the countries' per capita income is seen (Figure 3.2.1, panels 1 and 3). Relative to the overall GDP price level, however, the Billion Prices data confirm the regularity established with ICP data and reported in previous studies: the relative prices of capital goods tend to be significantly lower in richer countries (Figure 3.2.1, panels 2 and 4).

**Figure 3.2.1. Price of Apple Products and Income**
*(Percent)*




Sources: Billion Price Project; International Comparison Program (ICP); and IMF staff calculations.
Note: Countries on the *X*-axis in panels 1 and 2 are sorted by real GDP per capita in purchasing-power-parity international dollars. Dots denote medians of log prices for each country. Solid lines in panels 3 and 4 denote product level regression results at monthly frequency, with product-time fixed effects, and standard errors clustered at the country level. Products sold on the website of Apple Inc. but not produced by Apple Inc. are excluded from the sample. Country labels in Panels 1 and 2 use International Organization for Standardization (ISO) country codes.

The author of this box is Jilun Xing.

[1] Product categories are, for example, MacBooks, iPhones, iPods, and cables and accessories. Product identifiers specify model, memory, storage, display size, and so on. The online price information from the Billion Price Project database is identical to the offline price of Apple products except for shipping cost, local taxes, and store promotions (Cavallo, Neiman, and Rigobon 2014). Although Apple products could be considered consumer goods, they are increasingly used as capital goods—for example, roughly half of all iPads are bought by corporate and government users (Goel 2016).

## Box 3.3. On the Underlying Source of Changes in Capital Goods Prices: A Model-Based Analysis

The price of investment goods relative to other goods plays a significant role in capital accumulation. The price of investment goods in any country reflects multiple factors, such as the relative (1) price of investment goods in other, capital goods exporting, countries; (2) productivity of domestic investment goods producing sectors; (3) markups across sectors; and (4) incidence of tariffs and other trade costs. Although changes in any of these factors can affect the price of investment goods, and therefore trigger changes in capital accumulation, the macroeconomic effects may vary depending on the underlying source of variation.

A structural model helps to formalize and quantify these possible differences. In this box, we use the IMF's Global Integrated Monetary and Fiscal (GIMF) Model to study the medium-term macroeconomic effects—in a small emerging market economy—of two scenarios where the relative domestic price of investment goods (relative to the consumer price index) decreases. In the first scenario, the emerging market economy becomes permanently more efficient at producing new capital, in the spirit of Greenwood, Hercowitz, and Krussell (1997); in the second scenario, tariffs charged on imports of capital goods are permanently lowered.

The investment-specific technological change in the first scenario can be interpreted in several ways: greater international diffusion of technological know-how (possibly via global value chains) that disproportionately affects the production of capital (or durables more generally); lower domestic costs incurred by firms in capital goods sectors (for example, thanks to improvements in the regulatory environment); improved organizational efficiency; and so on.[1] In response, and assuming markups do not increase, firms in these sectors would lower their prices relative to the rest of the economy. The second scenario illustrates the effects of a decline in tariffs—or trade costs more broadly—on all imported capital. In this case, the decline in the overall investment price index reflects lower domestic prices of imported capital goods. Both simulations are normalized to obtain a 1 percent decline in the relative price of capital in the long run. Given the model's assumed share of capital goods imports in overall investment spending (about 33 percent), this requires a 4 percentage point permanent decline in investment goods tariffs in the second scenario, with a recurrent fiscal cost of about 0.25 percent of annual GDP.[2]

The medium-term impact (10 years after the shock) is presented in Figure 3.3.1. In both scenarios, the same decline in capital goods prices increases the returns to capital by similar amounts, thus triggering a similar increase in investment. The effect on output is different, however (0.7 and 0.5 percent of GDP, respectively). This difference is the result of a

The authors of this box are Michal Andrle and Rafael Portillo.

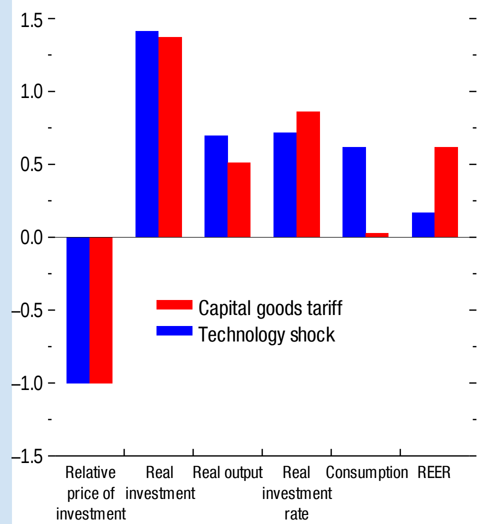
[1] It can be argued that there is greater scope for efficiency gains in capital goods sectors in emerging markets given the greater complexity of production.

[2] The required decrease in tariffs also reflects the real exchange rate depreciation observed in this scenario.

permanent increase in the efficiency of newly produced capital goods that expands the production possibility frontier of the local economy. As the economy becomes more productive, household income and consumption increase permanently.[3]

In the case of the decline in the tariff, there is no such initial expansion in the production possibility frontier (in the capital goods producing sector). The incentives to capital accumulation that come from lower capital goods prices can instead be thought of as reflecting a subsidy. Although it becomes cheaper to invest in capital projects, the tariff revenue forgone leads to a government revenue shortfall, which is resolved by lowering public transfers to households. Lower public transfers generate a headwind to private consumption. From a balance of payments perspective, higher relative demand for imports puts pressure on the real effective exchange rate to depreciate, which means an additional headwind to consumption because the domestic consumer basket becomes more expensive. As a result, there is little increase in consumption.

**Figure 3.3.1. Model Simulations**
*(Deviation from original steady state, percent)*




Source: IMF staff calculations.
Note: REER = real effective exchange rate.

It is worth stressing that the supply-side effects in both scenarios are largely a result of lower investment costs. To illustrate this point, we also simulate a decrease in general tariffs equivalent in fiscal revenue terms to the investment-specific tariff decrease. In this case there is no visible effect on the domestic relative price of investment. As a result, the increase in investment is much smaller (0.23 versus 1.34 percent in the investment-specific tariff scenario), as is the effect on output (0.18 versus 0.5 percent).

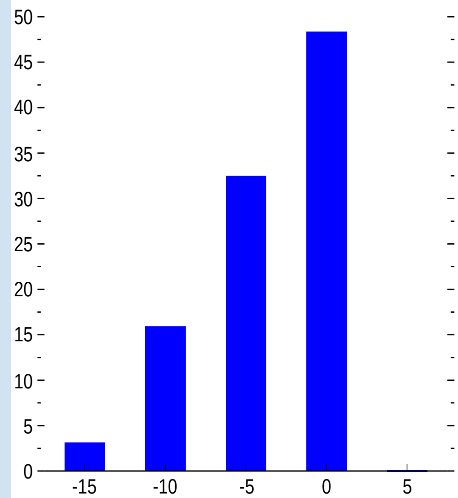
As these results emphasize, lowering barriers that hamper trade in capital goods and promoting research and development that improve efficiency in the capital goods sectors are good for output, investment, and consumption in the long run even if they entail some fiscal costs.

[3] A 1 percent decrease in investment goods prices caused by a decrease in markups in the investment goods sector produces very similar effects to an increase in investment-specific productivity.

## Box 3.4. Capital Goods Tariffs and Investment: Firm-Level Evidence from Colombia

This box uses data from Colombia to shed light on the effect of a reduction in the price of capital goods—induced by cuts in capital goods tariffs—on firm-level investment. Since capital goods prices within an economy are endogenously determined, it is difficult to pin down their causal effect on investment. Firm-level analysis helps overcome this issue by making use of differential, and arguably exogenous, changes in the prices of capital and other goods triggered by a substantial tariff reform in Colombia in 2011. The Colombian tariff reform aimed to simplify the tariff structure and boost economic growth (Torres and Romero 2013). Consequently, between 2010 and 2011, the average tariff rate on imported goods declined by close to 4 percentage points, from 12.5 percent in 2010 to 8.7 percent in 2011 (Figure 3.4.1).

**Figure 3.4.1. Distribution of Tariff Changes between 2011 and 2010**
*(Percent)*




Sources: Meleshchuk and Timmer (2019); and IMF staff calculations.
Note: The historgram shows the change in tariffs on the *X*-axis, and the percent of imported goods affected by this tariff change on the *Y*-axis.

Using an event study analysis, this box examines two different channels through which trade liberalization could affect firms' investment decisions: (1) increased competition, and (2) enhanced access to cheaper and potentially higher-quality inputs, including capital goods. While several studies have examined the productivity effect of tariff cuts through these channels (see, for example, Amiti and Konings 2007), evidence about their effect on investment is scant. The empirical approach relates the change in the firm-level investment rate before and after the tariff reform to reductions in capital goods input tariffs, other input tariffs, and output tariffs. In particular, the following equation is estimated:

$$\Delta Investment_i = \alpha + \beta_1 \Delta CapitalInputTariff_{s(i)} + \beta_2 \Delta OtherInputTariff_{s(i)} + \beta_3 \Delta OutputTariff_{s(i)} + \epsilon_i,$$

in which $Investment_i$ is defined as investment over total fixed assets for a given firm $i$.[1] $OutputTariff_{s(i)}$ is the simple average of most-favored-nation tariffs across Harmonized System six-digit products within the 33 sectors, $s(i)$, and is meant to capture the effect of higher competition on investment rates. $CapitalInputTariff_{s(i)}$ and $OtherInputTariff_{s(i)}$ are

The authors of this box are Sergii Meleshchuk and Yannick Timmer.

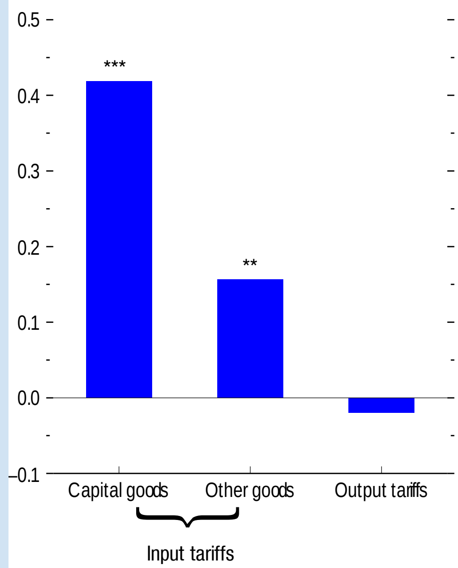
[1] The data for investment are taken from Encuesta Anual Manufacturera, an annual survey of manufacturing firms in Colombia. The data on tariffs come from Felbermayr, Teti, and Yalcin (2018). Use of fixed input-output matrices at the sector level alleviates endogeneity concerns that arise when firm-level input-output matrices are employed.

constructed following Amiti and Konings (2007) as weighted averages of output tariffs in all capital goods and other sectors, with weights reflecting the share of inputs from each of the sectors used in the production of the sector ***s*** output, based on the 2007 input-output table. The input tariff variables capture the effect of access to cheaper inputs. Unlike earlier studies, the analysis allows for a differential investment response to cuts in the tariffs of capital goods versus other inputs.

Figure 3.4.2 shows the estimated coefficients on the three types of tariffs. A 1 percentage point reduction in capital goods input tariffs is associated with a 0.4 percentage point increase in investment, a point estimate that is statistically significant at the 1 percent level.[2] A reduction in noncapital input tariffs leads to a smaller (0.15 percentage point) yet still statistically significant increase in investment. This finding echoes the results of model simulations discussed in Box 3.3, which similarly uncover a much smaller investment response to a general tariff cut, compared with a cut in capital goods tariffs. The effect of a reduction in output tariffs is not associated with significant changes in firms' investment decisions, at least in the short run.[3]

**Figure 3.4.2. Effect on Investment from Cuts in Tariffs on Capital Goods Inputs, Other Inputs, and Output**

*(Percent)*




Sources: Meleshchuk and Timmer (2019); and IMF staff calculations.
Note: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

These findings present further evidence—from a recent trade reform in a large emerging market economy—that firms' investment choices are sensitive to the price of capital goods.

[2] The coefficients on changes in input tariffs can be interpreted as the effects of changes in prices on investment rates under the assumption that tariffs are fully passed into the prices importers pay. If there is only partial pass-through, the estimated coefficients are attenuated toward zero relative to the true effect of prices.

[3] The results are robust to including standard controls, such as firm size or sales growth. The results are also robust to using a wider time window around the tariff cuts.

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## Annex 3.1. Data Sources and Country Groupings

### Data Sources

The primary data sources for this chapter are the IMF World Economic Outlook database, the Penn World Table (PWT) 9.0 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. All data sources used in the chapter's analysis are listed in Annex Table 3.1.1.

### Data Definitions

Several sources of data on prices are used in the chapter. 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 evolution of prices across time presented in the key patterns section of the chapter and online annex draws on the PWT 9.0, which incorporates data from several ICP vintages (1970, 1975, 1980, 1985, 1996, 2005, 2011) as well as the more frequent data from OECD and Eurostat to derive aggregate investment and consumption price levels. Following Restuccia and Urrutia (2001) and Karabarbounis and Neiman (2013), the relative price of overall investment is divided by the relative price of investment in the United States and then multiplied by the ratio of the investment price deflator to the consumption deflator for the United States, obtained from the Bureau of Economic Analysis. These steps cancel-out international prices that are embedded in this PPP-adjusted series.

The stylized facts presented in Figure 3.2 and country-level panel regressions use data from the PWT 9.0 capital detail dataset, which provides data on deflators of various types of investment, and capital stocks. The corresponding consumption deflator comes from the PWT 9.0 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.

**Annex Table 3.1.1. Data Sources**

| Indicator | Source |
|---|---|
| Investment and GDP Prices | International Comparison Program 2011; Penn World Table 9.0; KLEMS; WIOD; Bureau of Economic Analysis |
| Investment-to-GDP Ratios | Penn World Table 9.0, 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 9.0 |
| 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) |
| Capital Stock (by Asset Type) | Penn World Table 9.0, Capital Detail |
| 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: IMF staff compilation.

## Country Groupings

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

Tradable capital goods sectors, which, for the purpose of this chapter, 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.

**Annex Table 3.1.2. 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: IMF staff compilation.

## Annex 3.2. Supplementary Stylized Facts

This annex provides additional stylized facts on the evolution of the relative prices of capital goods, the composition of investment across capital types, and nominal and real investment rates, based on the PWT 9.0, and other sources.

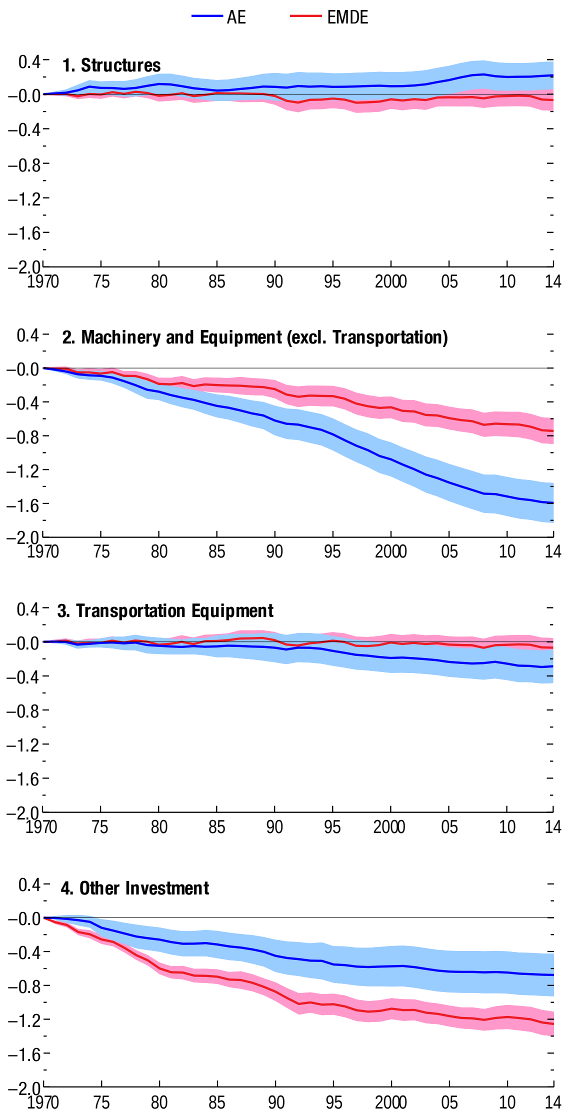
While the chapter's main stylized facts focus on the post-1990 period due to greater country coverage, annex Figure 3.2.1 presents the evolution of the relative prices of various types of investment since the early 1970s. As in the rest of the chapter, the relative price is defined as the ratio of the investment deflator (for each type of capital good) to the consumption deflator in the economy. To trace the evolution over time, the figure plots the year fixed effects from a regression of the log relative prices that also includes country fixed effects to account for entry and exit during the sample and level differences in relative prices. Year fixed effects are normalized to show log difference relative to 1970, while the shaded areas indicate the 95 percent confidence intervals.[1] In annex Figure 3.2.2, the same data are presented as percentage change relative to the 1970.

The longer time series confirm the key patterns in the dynamics of capital goods prices discussed in the chapter. The decline in the price of tradable capital goods (both tangible and intangible) has been widespread, while the price of structures has moved broadly in line with the price of consumption. Most notable is the difference in the pace of the decline in the relative price of machinery and equipment across broad country groups. For both advanced economies and emerging market and developing economies, relative prices of tangible tradable investment goods were on a declining trend since the beginning of the sample, with an acceleration in the pace of decline since the mid-1990s. This coincides with the pickup in real investment rates in emerging market and developing economies.

[1] Using log differences to capture the change in the relative prices over time is preferable as it facilitates visually detecting changes in the pace of decline once the cumulative decline relative to the reference point become very large, as is the case with the declines in the prices of some types of capital goods since the 1970s.

**Annex Figure 3.2.1. Dynamics of Relative Prices across Types of Capital Goods and Broad Country Groups: 1970–2014**

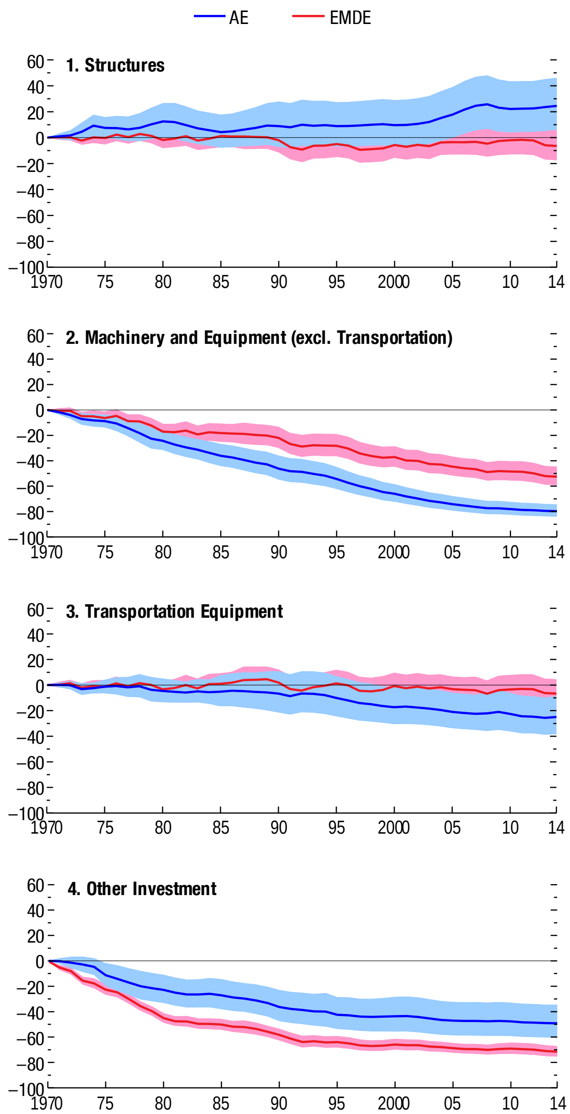
*(Log difference relative to 1970)*




Sources: Penn World Table 9.0; and IMF staff calculations.
Note: The relative price of investment (for each type of capital good) is obtained by dividing the relevant investment deflator with the consumption deflator. The solid line plots year fixed effects from a regression that also includes country fixed effects to account for entry and exit during the sample and level differences in relative prices. Year fixed effects are normalized to show log difference in price relative to 1970. Shaded areas indicate 95 percent confidence intervals. AE = advanced economy; EMDE = emerging market and developing economy.

**Annex Figure 3.2.2. Dynamics of Relative Prices across Types of Capital Goods and Broad Country Groups: 1970–2014**

*(Percent change relative to 1970)*

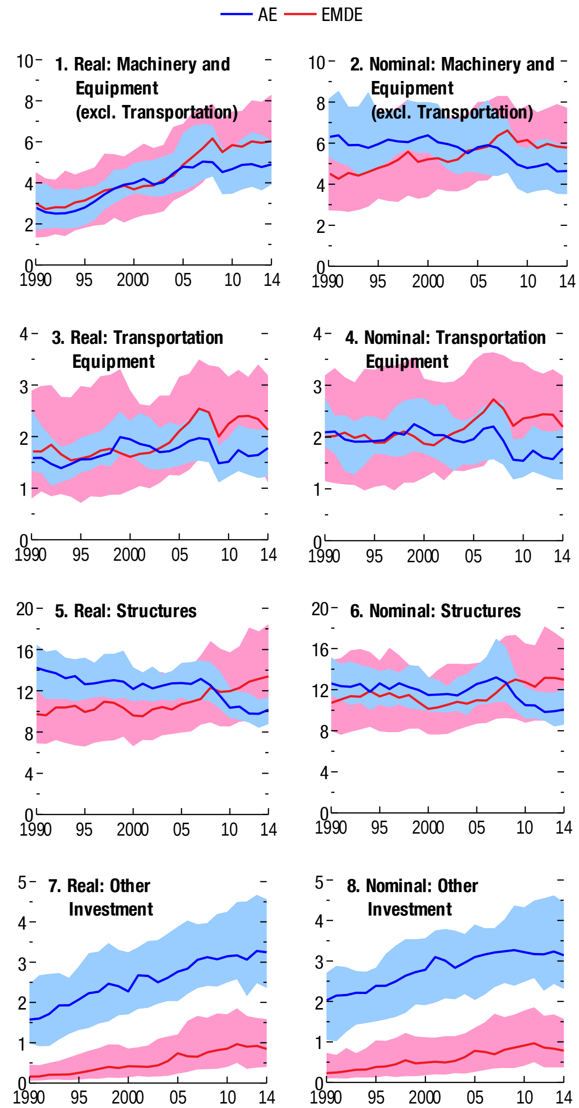



Sources: Penn World Table 9.0; and IMF staff calculations.
Note: The relative price of investment (for each type of capital good) is obtained by dividing the relevant investment deflator with the consumption deflator. The solid line plots year fixed effects from a regression of log relative prices on year fixed effects and country fixed effects to account for entry and exit during the sample and level differences in relative prices. Year fixed effects are normalized to show percent change from the relative investment prices in 1970. Shaded areas indicate 95 percent confidence intervals. AE = advanced economy; EMDE = emerging market and developing economy.

Annex Figure 3.2.3 provides further detail on investment rates across broad country groups and capital types. For each type of capital asset, the figure plots the median, 25th and 75th percentile of real and nominal investment-to-GDP ratios for the group of advanced and emerging market and developing economies. The figure reveals three interesting patterns. First, an investigation into the evolution of investment rates yields very different pictures, depending on whether investment rates are measures in real or nominal terms. For those types of capital assets, which experienced larger declines in relative prices (such as machinery and equipment and other investment), real investment rates have increased quite significantly across all economies since the 1990s. Nominal investment rates, on the other hand, have changed much less. Second, the dispersion in real investment rates is significantly larger in emerging market and developing economies relative to advanced countries. Third, real investment rates in tangible tradable capital goods were quite similar for the median advanced and emerging market and developing economy until the mid-2000s, but have since diverged. Real investment rates in machinery and equipment (including transport) continued to rise in emerging market and developing economies until the global financial crisis and have remained relatively robust since. In advanced economies, real investment rates seem to have plateaued since the mid-2000s with a dip around the time of the global financial crisis. The difference between advanced and emerging market and developing economies is even more pronounced when it comes to investment in structures. Real investment rates in structures declined significantly since the global financial crisis in advanced economies while they have steadily increased in emerging market and developing economies.

**Annex 3.2.3. Real and Nominal Investment-to-GDP Ratios**

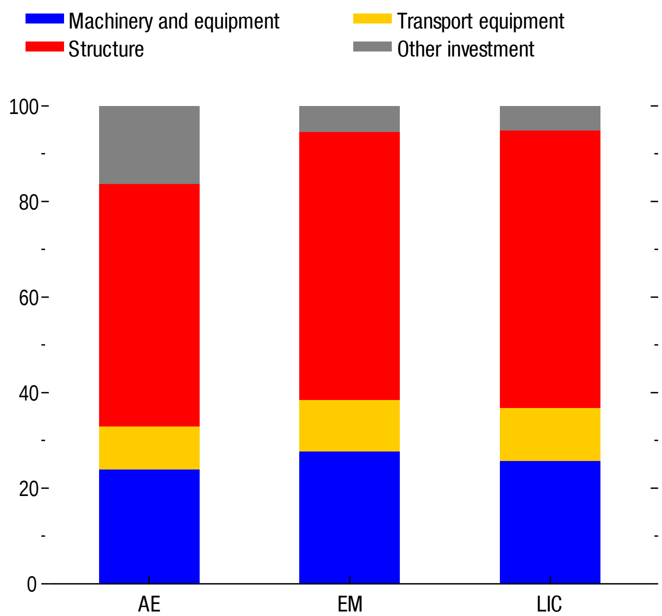
*(Percent, median and interquartile range)*




Sources: Penn World Table 9.0; and IMF staff calculations.
Note: AE = advanced economy; EMDE = emerging market and developing economy.

Finally, annex Figure 3.2.4 provides a breakdown of average nominal investment shares across broad assets classes for advanced, emerging market and low-income countries in 2014, the latest year in the PWT 9.0. About 60 percent of gross fixed capital formation in low income countries is accounted for by investment in structures, compared to about 50 percent in advanced economies. Interestingly, investment in machinery and equipment (including transport) comprises a very similar share of overall investment in all economies, roughly 35 percent. As expected, advanced economies devote a significantly large fraction of their investment budget to "other investment," such as intellectual property products.

**Annex Figure 3.2.4. Composition of Gross Fixed Capital Formation by Broad Country Groups in 2014**
*(Percent)*



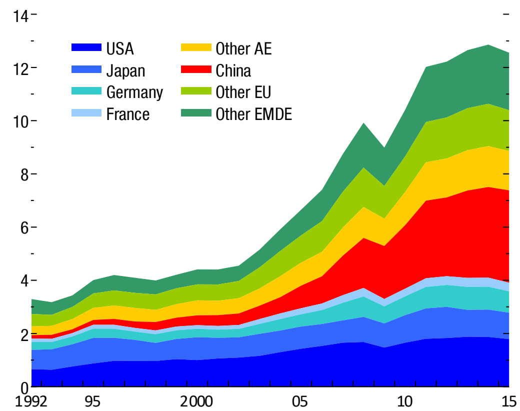

Source: Penn World Table 9.0; and IMF staff calculations.
Note: Each type of investment is expressed as a share of nominal total investment (gross fixed capital formation) in local currency for each country. Shares are then averaged over broad country groups. Other investment mostly includes intellectual property investment, such as research and development. AE= advanced economy; EM= emerging market economy; LIC = low-income country.

## Annex 3.3. 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. The analysis builds 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 (see Annex Figure 3.3.1.) and therefore most countries rely on importing capital goods. Imported capital good 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.

**Annex Figure 3.3.1. Capital Goods Production**

*(Trillions of U.S. dollars)*




Sources: Eora MRIO database; and IMF staff calculations.
Note: AE = advanced economy; EMDE = emerging market and developing economy; EU = European Union.

Detailed export data from the following five large capital goods exporters is obtained: the US, China, France, Germany and Japan. For each product, destination and exporting country, the unit value is calculated by dividing the overall export value by the reported quantity. The specification that is estimated 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. Product*exporting country*year fixed effects are included to make a within product-exporting country comparison to minimize 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, exports at the 10-digit HS codes for 1989–2005 are obtained 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 6-digit product level data for 1992–2017 is used from COMTRADE; for Germany and France 8-digit HS export data for 1988–2017 is taken from Eurostat.[1] To assess whether patterns of correlation may vary depending on the exporting country, the regression is also estimated separately for each exporting country.[2]

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

[2] 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.

Annex Table 3.3.1 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).

**Annex Table 3.3.1. Unit Values of Capital Goods Across Countries: Evidence from Trade Data**

| Dependent Variable: Log Unit Value | (1)<br>Top 5 | (2)<br>US | (3)<br>China | (4)<br>France | (5)<br>Germany | (6)<br>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: IMF staff 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.

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

However, the coefficient exhibits substantial heterogeneity across exporting countries. When the sample is restricted to exports only from the US (column 2) and 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 1978–2011. The estimated correlation suggests that US and Chinese firms charge importers from poorer countries higher prices for the same product. The opposite result is found 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.

In an alternative exploration of the trade data, Annex Table 3.3.2 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 3.3.1, 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.

**Annex Table 3.3.2. Unit Values of Capital Goods by Broad Country Group: Evidence from Trade Data**

| Dependent Variable: Log Unit Value | (1)<br>Top 5 | (2)<br>US | (3)<br>China | (4)<br>France | (5)<br>Germany | (6)<br>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: IMF staff 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.

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

Following Manova and Zhang (2012), in Annex Table 3.3.3, the baseline specification is augmented 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.[3]

**Annex Table 3.3.3. 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: IMF staff 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.

The price index in Figure 3.3 is computed 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.

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

[3] 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 chapter's focus on capital goods.

## Annex 3.4. 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, the following equation is estimated using ordinary least squares. The standard errors are 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.

The trade costs considered are as follows: (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 3.4.1 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 (these are also depicted in Figure 3.6, Panel 1).

**Annex Table 3.4.1. Absolute Price of Capital Goods**

| Dependent Variable: | Measure of Trade Barrier | | | | | |
|---|---|---|---|---|---|---|
| Absolute Price of Capital Goods | 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: IMF staff calculations.

Note: Robust standard errors in parentheses.

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

As outlined in the simple conceptual framework in the chapter, the relative price of capital goods is shaped by a number of factors. Of prime importance is the efficiency with which the economy can produce machinery and equipment (or other tradable goods that it could exchange for investment goods) relative to the efficiency in other (non-tradable) sectors. In countries where a significant fraction of investment goods is imported, as is the case in many emerging market and developing economies, the relative price of machinery and equipment also reflects the prices international suppliers charge for these goods and other factors that drive a wedge between international and domestic prices, such as transport costs, import tariffs, customs regulations, time and cost associated with the logistical process of importing goods. Tax policies, such as accelerated depreciation, investment tax credits and subsidies, also bear on the relative investment price.[1] To summarize:

$$\frac{P_I}{P_C} = f\left( \frac{a_T}{a_{NT}},\ P_I^*,\ trade\ costs\right)$$

where $\frac{P_I}{P_C}$ is the relative price of capital goods, and $\frac{a_T}{a_{NT}}$ is the productivity in the tradable goods sector relative to the productivity in the non-tradable goods and services sectors of the economy.

Taking this reduced form relationship to the data, the analysis examines the contribution of the efficiency in the production of capital goods relative to the efficiency in the overall economy, and alternative measures of trade costs to the cross-country variation in the relative prices of capital goods.[2] The following equation is estimated using ordinary least squares. The standard errors are adjusted for heteroskedasticity.

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

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 3.4.2 provides the estimated coefficients. The regression-based decomposition, depicted in Figure 3.6, Panel 2, 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

[1] 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.

[2] Given the high correlation among different components of trade costs, including all the measures in the same regression does not significantly increase the share of variation in relative prices that can be explained by trade costs. The fraction of cross-country variation in relative prices that can be explained by the "most powerful" measure of trade costs (time to import) is 41 percent. If all trade costs are included together, they can explain 45 percent of the variation.

of the independent variable and (ii) the dependent variable, divided by the variance of the dependent variable.

### Annex Table 3.4.2. 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: IMF staff 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.

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

## Annex 3.5. Drivers of Relative Investment Prices: Over Time

This annex provides technical details for the analysis that examines the over-time change in relative producer prices, relying on sectoral data from WIOD. The analysis follows a two-step approach. First, sectoral producer price data across 40 advanced and emerging market economies and 33 sectors over 1995–2011 are analyzed to estimate the elasticity of producer prices to changes in sectoral labor productivity and exposure to international trade (as measured by the ratio of imports to domestic output), while controlling 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.[1] Second, the estimated elasticities are combined with the change in the relative labor productivity and trade exposure of the capital goods sector to obtain an estimate of how much each potential factor can account for in the decline of the relative prices of machinery and equipment over 2000–11.

This approach faces two main challenges. Conceptually, 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 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.[2] Second, exposure to foreign competition affects relative domestic prices indirectly, through its impact on sectoral labor productivity as documented in numerous studies. 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, the analysis quantifies the changes in labor productivity that can be attributed to changes in import penetration, and, in the second step, distinguishes 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.

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[1] The sectors in the WIOD table are as follows: AtB: Agriculture, Hunting, Forestry and Fishing; C: Mining and Quarrying; 15t16: Food, Beverage and Tobacco; 17t18: Textiles and Textile Products; 19: Leather, Leather and Footwear; 20: Wood and Products of Wood and Cork; 21t22: Pulp, Paper, Printing and Publishing; 23: Coke, Refined Petroleum and Nuclear Fuel; 24 Chemicals and Chemical Products; 25: Rubber and Plastics; 26: Other Non-Metallic Mineral; 27t28: Basic Metals and Fabricated Metal; 29: Machinery, NEC; 30to33 Electrical and Optical Equipment; 34t35: Transport Equipment; 36t37: Manufacturing, NEC; Recycling; E: Electricity, Gas and Water Supply; F: Construction; 50: Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel; 51: Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles; 52: Retail Trade, Except of Motor Vehicles; Repair of Household Goods; 60: Inland Transport; 61: Water Transport; 62: Air Transport; 63: Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies; 64: Post and Telecommunications; 70: Real Estate Activities; 71t74: Renting of Machinery and Equipment and Other Business Activities; H: Hotels and Restaurants; J: Financial Intermediation; L: Public Admin and Defense; Compulsory Social Security; M: Education; N: Health and Social Work; O: Other Community, Social and Personal Services; P: Private Households with Employed Persons.

[2] 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.

## Regression Framework

Two separate regressions are estimated to understand relative contributions of global integration and relative productivity growth to the decline in the relative price of machinery and equipment in the past decades.

First, the impact of global integration and relative labor productivity on relative producer price is estimated through 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).[3]

$\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\overline{VA}_{i,t}}\right)$ 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

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

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, the impact of trade liberalization on relative labor productivity is estimated through the following equation:

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

where $\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\overline{VA}_{i,t}}\right)$ 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 oversea. The estimation results in Annex Table 3.5.3 confirm the need to address this endogeneity issue: the OLS coefficient is much smaller than what the instrumental variable estimation finds.

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

Import tariffs are assumed to satisfy the exogeneity conditions:

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

Annex Table 3.5.1 suggests that the first-stage relationship between import tariff and import penetration (the endogenous variable) is very strong, suggesting that import tariff is a good instrument. The second column of the table, which contains the reduced form relationship between the instrument and the dependent variable of interest, suggests that lower import tariff leads to a decline in producer price, after controlling for labor productivity. This suggests that deepening trade integration directly affects producer prices, beyond its impact on labor productivity.

**Annex Table 3.5.1. First-Stage Relationship, Effects of Import Tariff on Producer Prices**

| Dependent Variables: | Relative Import Penetration OLS (1) | Relative Producer Prices OLS (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: IMF staff calculations.

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

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

Robustness tests let $\beta$, $\gamma$ and $\beta^{LP}$ vary across advanced economies and emerging market and developing economies, and their results are presented in the Annex Tables 3.5.2 and 3.5.3.

**Annex Table 3.5.2. Relative Producer Prices, Trade Integration and Relative Productivity**

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

Source: IMF staff 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$_{t-1}$ .

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

**Annex Table 3.5.3. 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: IMF staff calculations.

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

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

## Decomposing Changes in Relative Producer Prices of Capital Goods Producing Sectors

The decomposition chart is presented in Figure 3.7. The details of its construction are as follows. Using the coefficients in column (3) of Annex Table 3.5.2 and column (4) of Annex Table 3.5.3, the change in relative price of investment from 2000 to 2011 can be decomposed into four components: (i) the direct effect of deepening trade integration, defined as the weighted 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; (ii) the effect of trade integration through higher labor productivity, defined as the weighted 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; (iii) the effect of higher labor productivity, which is not due to deepening trade integration, defined as the weighted 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; (iv) the contributions of other factors, i.e., the residual term.

In the calculation of (i) - (iii), all country-sectors have the same weight.

## Annex 3.6. Empirical Evidence on the Impact of Relative Investment Prices on Investment-to-GDP Ratios at the Country-Level

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 as a share of real output in order to keep up with capital stock's depreciation.[1]

The general regression relates the log of the real investment-to-GDP ratio in machinery and transport equipment and the log of the price of machinery and transport equipment relative to the price of consumption,[2] controlling for all time-invariant differences across countries ($\mu_i$) and year fixed effects ($\theta_t$) 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,[3] 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 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 affecting the estimates of the effect of relative prices on investment-to-GDP ratios. The full list of data sources can be found in Annex Table 3.1.1.

Estimation results are reported in Annex Table 3.6.1. The main estimates based on instrumental variable (IV) regression as presented in the chapter are given in column 5. Other columns use alternative estimation methods or sub-samples as robustness checks. Across all specifications, the coefficient on the relative price of machinery and transport equipment is

[1] Of course, the growth rate of capital in the steady state only depends on population growth and technological progress.

[2] 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:

$$P_{M\&E} = \frac{I_{Machinery}}{I_{M\&E}} P_{Machinery} + \frac{I_{Transport}}{I_{M\&E}} P_{Transport}.$$

[3] 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.

significant and negative; suggesting that—similar to the GIMF model simulations presented in the chapter—a decline in the relative price is associated with higher investment rates.

The regressions are estimated on five-year non-overlapping window averaged data, except for column 4 where the results are based on annual data. This approach aims to smooth the influence of short-term fluctuations, and to capture the potential medium-run relationship.

Columns 1–4 are estimated using OLS regressions. Column 1 presents the baseline specification, which includes only the relative price of machinery and transport equipment. The full specification with controls for other determinants of investment-to-GDP ratios and the sample starting from 1985 is given in column 2. In column 3 the relative price of investment is lagged to minimize potential endogeneity concerns. In column 4 the relationship is also examined with annual data, where the relative price, as well as the institutional and structural variables, are likewise lagged. 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 of -0.410***, closer to the five-year average regressions and the long-run results of the GIMF model.

In columns 5–10 the relationship is estimated using instrumental variable (IV) regressions, where 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.[4] Across all IV specifications, the first stage regression is significant with F-statistic above 10. Column 5 gives the main estimates that are presented in the chapter. Columns 6–9 are estimated for sub-samples: post 1990, emerging market and developing economies, advanced economies, and capital importing countries, respectively.

Columns 10–12 present additional robustness checks. In column 10, the relative price of investment is defined relative to the overall GDP price level, instead of the price level of consumption. To account for the dynamic nature of the regression, the bias arising from the lagged dependent variable, and potential endogeneity of some of the control variables, the regression in column 11 is performed using the system generalized method of moments (GMM) estimator, where endogenous variables are instrumented with a set of lagged levels and differences of the regressors.[5] This approach gives smaller, but still statistically significant, coefficient on the relative price of investment. Column 12 is based on an IV regression where the relative price is instrumented with the average relative price of all other countries except the

[4] 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.

[5] The Im-Pesaran-Shin test for a unit-root in all panels is rejected for the log real investment-to-GDP ratio and for the log relative price with a non-stochastic deterministic trend. The five-year averaging of the data and year fixed effects further mitigate concerns of non-stationarity. The system GMM specification follows 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. The validity of the set of instruments is confirmed with the Hansen test. The absence of serial correlation in the residuals is confirmed using the AR(2) test, while the AR(1) test, as expected, suggest first-order serial correlation.

country's own 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, again allowing to minimize the measurement error bias as measurement error in country's own prices is unlikely to be correlated with measurement error in other countries' prices.

The coefficients on the control variables are in line with economic theory and previous literature. The availability and cost of finance measures are in general not significant, with negative coefficient expected on real interest rate and positive coefficients on capital account openness and credit-to-GDP ratio. Trade openness is significantly and positively correlated with investment-to-GDP ratios. An increase in export commodity prices is associated with higher investment rates, but the relationship is not statistically distinguishable from zero. Finally, institutional quality, mitigation of political risks, and the overall quality of infrastructure are likewise positively associated with investment-to-GDP ratios.

The empirical analysis in Annex Table 3.6.1 suggests a robust negative relationship between relative prices and real investment-to-GDP ratios. Indeed, the big decline in the relative prices of machinery and transport equipment over the past decades, as shown in the chapter Figure 3.2, has been a significant contributor to the rise in investment-to-GDP ratios. Figure 3.9 shows the decomposition of average contributions to changes in machinery and equipment investment rates between 1990–94 and 2010–14: based on the coefficients estimated with the five-year window average data (column 5) for a sample of 75 countries for which data is available in both time periods. Over this period, machinery and transport equipment investment rates grew by more than 60 percent, increasing from 5 percent to over 8 percent in EMDEs (Annex Figure 3.2.2). A significant portion of the total change in investment rates across different country groups can be attributed to the decline in relative prices of machinery and transport equipment.

## Annex Table 3.6.1. Real Investment Rate and Relative Price of Machinery and Equipment: Country-Level

| Dependent Variable: Log Real Investment-to-GDP Ratio | OLS | OLS | OLS Lagged | OLS Annual | IV | IV | IV | IV | IV | IV $P_I/P_{GDP}$ | GMM | IV Excluding Own |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Log Relative Price | −0.624*** | −0.413*** | −0.221*** | −0.092*** | −0.377*** | −0.292* | −0.491*** | −0.558*** | −0.418*** | −0.450*** | −0.191** | −0.481*** |
| | (0.075) | (0.101) | (0.079) | (0.030) | (0.116) | (0.171) | (0.161) | (0.136) | (0.132) | (0.117) | (0.088) | (0.086) |
| Log Investment $Rate_{t-1}$ | | 0.412*** | 0.434*** | 0.776*** | 0.419*** | 0.388*** | 0.378*** | 0.436*** | 0.409*** | 0.382*** | 0.534*** | 0.398*** |
| | | (0.085) | (0.086) | (0.026) | (0.078) | (0.094) | (0.086) | (0.063) | (0.081) | (0.081) | (0.064) | (0.074) |
| Log GDP per $Capita_{t-1}$ | | −0.173** | −0.118 | −0.052** | −0.164** | −0.199** | −0.192** | −0.248** | −0.141 | −0.149** | −0.067 | −0.190** |
| | | (0.085) | (0.087) | (0.023) | (0.079) | (0.095) | (0.088) | (0.114) | (0.086) | (0.068) | (0.049) | (0.076) |
| GDP per Capita $Growth_{t-1}$ | | −0.396 | −0.310 | 0.091 | −0.400 | −0.492 | −0.616* | −0.438 | −0.494* | −0.232 | −0.072 | −0.390 |
| | | (0.323) | (0.327) | (0.070) | (0.282) | (0.323) | (0.325) | (0.385) | (0.300) | (0.288) | (0.357) | (0.286) |
| Real Interest Rate | | −0.028 | −0.030 | −0.071* | −0.030 | −0.103* | −0.027 | −0.448 | −0.029 | −0.022 | −0.052 | −0.025 |
| | | (0.065) | (0.076) | (0.039) | (0.060) | (0.055) | (0.063) | (0.419) | (0.059) | (0.053) | (0.072) | (0.054) |
| Log Credit-to-GDP | | 0.043 | 0.047 | 0.008 | 0.043 | 0.073 | 0.042 | 0.007 | 0.033 | 0.025 | 0.013 | 0.042 |
| | | (0.053) | (0.052) | (0.010) | (0.046) | (0.063) | (0.062) | (0.031) | (0.050) | (0.044) | (0.045) | (0.047) |
| Capital Account Openness | | 0.087 | 0.094 | 0.022 | 0.088 | 0.085 | 0.101 | 0.149** | 0.053 | 0.082 | −0.153*** | 0.086 |
| | | (0.079) | (0.082) | (0.023) | (0.069) | (0.082) | (0.091) | (0.067) | (0.084) | (0.070) | (0.057) | (0.070) |
| Log Export Commodity Price | | 0.561 | 0.383 | 0.161 | 0.537 | 0.475 | 0.517 | 0.153 | 0.499 | 0.227 | 0.024 | 0.605* |
| | | (0.366) | (0.370) | (0.100) | (0.336) | (0.402) | (0.378) | (0.221) | (0.354) | (0.256) | (0.334) | (0.323) |
| Log Trade Openness | | 0.252* | 0.210* | 0.136*** | 0.245** | 0.204 | 0.321** | 0.090 | 0.276** | 0.269** | 0.114 | 0.265** |
| | | (0.134) | (0.126) | (0.038) | (0.116) | (0.151) | (0.141) | (0.078) | (0.128) | (0.105) | (0.110) | (0.118) |
| Institutional Quality and Political Risk | | 0.009*** | 0.007** | 0.002** | 0.008*** | 0.008* | 0.010*** | 0.010** | 0.009*** | 0.009*** | 0.006* | 0.009*** |
| | | (0.003) | (0.003) | (0.001) | (0.003) | (0.004) | (0.004) | (0.004) | (0.003) | (0.003) | (0.004) | (0.003) |
| Log Paved Roads per Capita | | 0.078 | 0.087 | 0.051** | 0.081 | 0.165** | 0.079 | −0.074 | 0.088 | 0.089 | 0.006 | 0.072 |
| | | (0.069) | (0.068) | (0.021) | (0.060) | (0.077) | (0.082) | (0.053) | (0.076) | (0.057) | (0.028) | (0.061) |
| Long-Run Effect | | | | −0.410*** | | | | | | | | |
| | | | | (0.125) | | | | | | | | |
| Number of Observations | 1,688 | 658 | 658 | 2,944 | 658 | 553 | 457 | 201 | 542 | 658 | 658 | 658 |
| Number of Countries | 173 | 127 | 127 | 126 | 127 | 127 | 93 | 34 | 108 | 127 | 127 | 127 |
| $R^2$ | 0.76 | 0.86 | 0.85 | 0.91 | 0.41 | 0.36 | 0.38 | 0.72 | 0.41 | 0.46 | | 0.40 |
| First Stage F-Statistic | | | | | 118.80 | 81.81 | 64.04 | 87.17 | 96.87 | 169.20 | | 134.70 |
| AR(1) Test P-Value | | | | | | | | | | | 0.00 | |
| AR(2) Test P-Value | | | | | | | | | | | 0.42 | |
| Hansen Test P-Value | | | | | | | | | | | 0.18 | |
| Number of Instruments | | | | | | | | | | | 114 | |
| Sample | All | All | All | All | All | Post 1990 | EMDE | AE | Capital Goods Importers[1] | All | All | All |

Source: IMF staff 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. 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 clustered at the country level in parentheses.

[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.

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

## Annex 3.7. Empirical Evidence on the Impact of Relative Investment Prices on Investment Rates at the Sector Level

This annex provides additional details on the analysis carried out in the subsection "Empirical Analysis: Sector level." First, it describes the data and construction of variables, followed by a technical overview of the main specification and robustness checks.

This section uses data from EU KLEMS and World KLEMS, which have two main advantages over other data sources used in the chapter. First, sector-level variation allows the introduction of various sets of fixed effects that can alleviate concerns of omitted variable bias, which exists at the country level. Second, KLEMS 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.[1] 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. A range of possible estimates using slightly different specifications are presented in Annex Table 3.7.1.

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

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, Annex table 3.7.1). Annex table 3.7.2 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

[1] The broad sectors included in the analysis are: A: Agriculture, forestry and fishing; B: Mining and quarrying; C: Total manufacturing; D-E: Electricity, gas and water supply; F: Construction; G: Wholesale and retail trade, repair of motor vehicles and motorcycles; H: Transportation and storage; I: Accommodation and food service activities; J: Information and communication; K: Financial and insurance activities; L: Real estate activities; M-N: Professional, scientific, technical, administrative and support service activities; O: Public administration and defense, compulsory social security; P: Education; Q: Health and social work.

and equipment investment rate, followed by machinery and equipment investment, value added, and output per worker.

As a robustness check, Annex Table 3.7.3 presents all the regressions presented in Annex Table 3.7.2 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.

**Annex Table 3.7.1. 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: IMF staff 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.

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

**Annex Table 3.7.2. Relative Prices of Machinery and Equipment and Sectoral Outcomes: Five-Year Averages**

| Dependent Variables: | Log Real Investment-to-GDP (1) | Log Real Investment (2) | Log Value Added (3) | Log Value Added per Worker (4) | Log Real Investment-to-GDP (5) | Log Real Investment (6) | Log Value Added (7) | Log Value Added per Worker (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: IMF staff 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.

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

**Annex Table 3.7.3. Relative Prices of Machinery and Equipment and Sectoral Outcomes: Annual**

| Dependent Variables: | Log Real Investment-to-GDP (1) | Log Real Investment (2) | Log Value Added (3) | Log Value Added per Worker (4) | Log Real Investment-to-GDP (5) | Log Real Investment (6) | Log Value Added (7) | Log Value Added per Worker (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: IMF staff 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.

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