CHAPTER 3

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

Online Annex

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 authors of the chapter are Weicheng Lian, Natalija Novta, Evgenia Pugacheva, Yannick Timmer, and Petia Topalova (lead), with support from Jilun Xing and Candice Zhao.

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, Consumption, 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
Economy-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

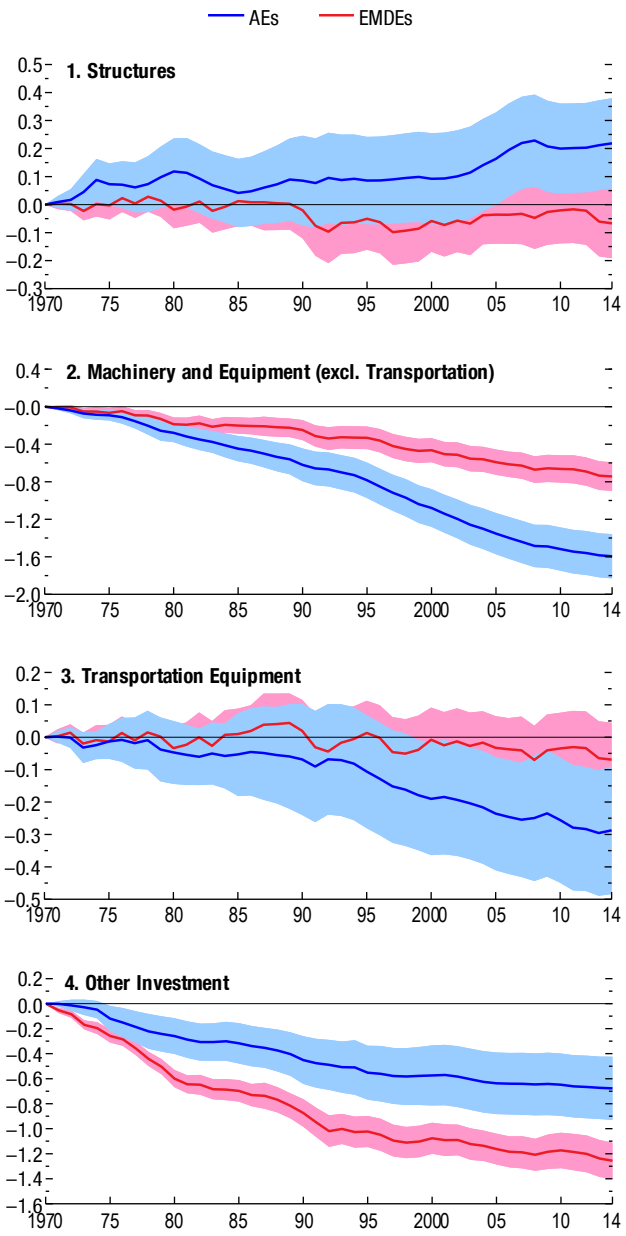
This annex provides additional stylized facts on the evolution of relative prices of capital goods, the composition of investment across capital types, and nominal and real investment rates, based on the PWT 9.0, and other data sources.

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 period 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 percent change relative to 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 coincided with the pickup in real investment rates in emerging market and developing economies.

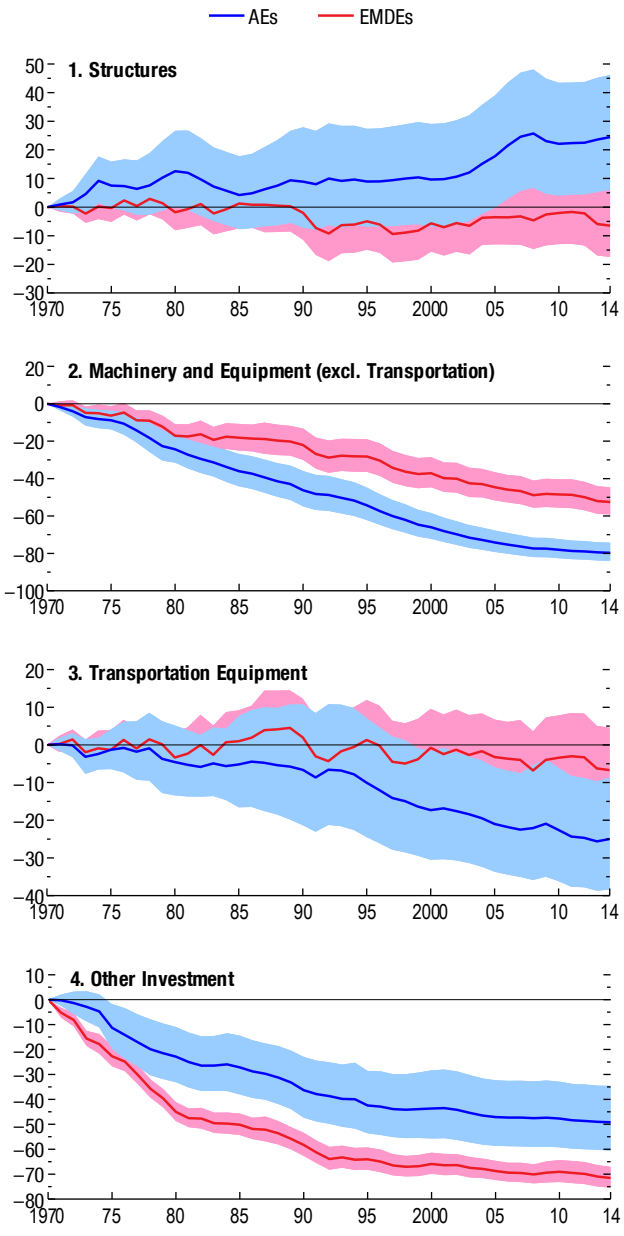
[1] Using log differences to capture the change in the relative prices over time is preferable as it facilitates visually detecting changes in the pace of decline once the cumulative decline relative to the reference point become very large, as is the case with the declines in the prices of some types 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 period 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. Other investment mostly includes intellectual property investment, such as research and development. AEs = advanced economies; EMDEs = emerging market and developing economies.

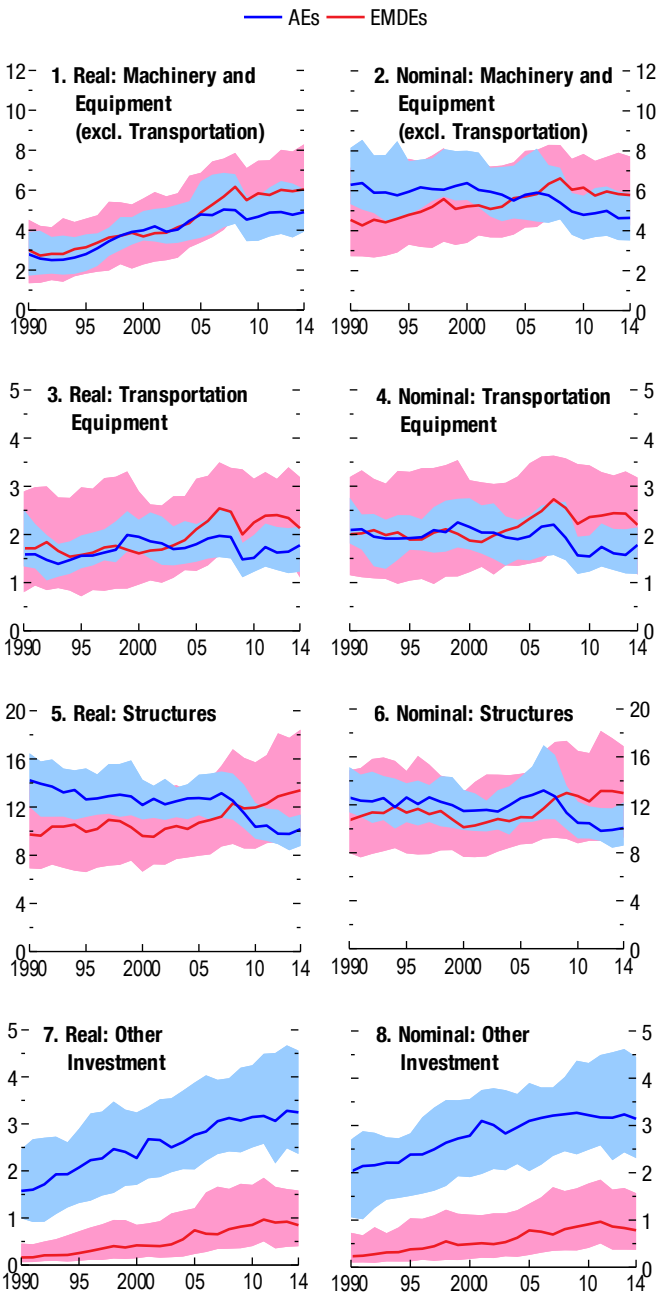
Annex Figure 3.2.2. Dynamics of Relative Prices across Types of Capital Goods and Broad Country Groups: 1970–2014
(Percent change relative to 1970)



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 period 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. Other investment mostly includes intellectual property investment, such as research and development. AEs = advanced economies; EMDEs = emerging market

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 measured 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 Figure 3.2.3. Real and Nominal Investment-to-GDP Ratios
(Percent, median and interquartile range)

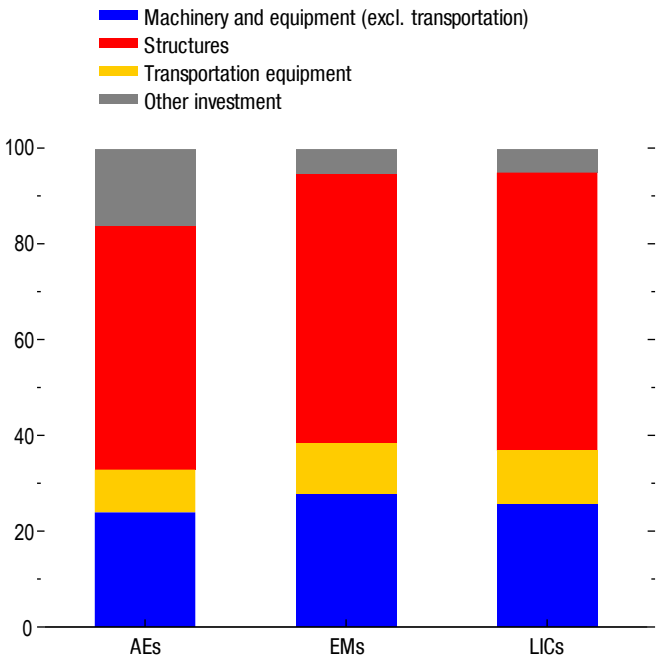


Sources: Penn World Table 9.0; and IMF staff calculations.
Note: Other investment mostly includes intellectual property investment, such as research and development. AEs = advanced economies; EMDEs = emerging market and developing economies.

Finally, Annex Figure 3.2.4 provides a breakdown of average nominal investment shares across broad asset 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)

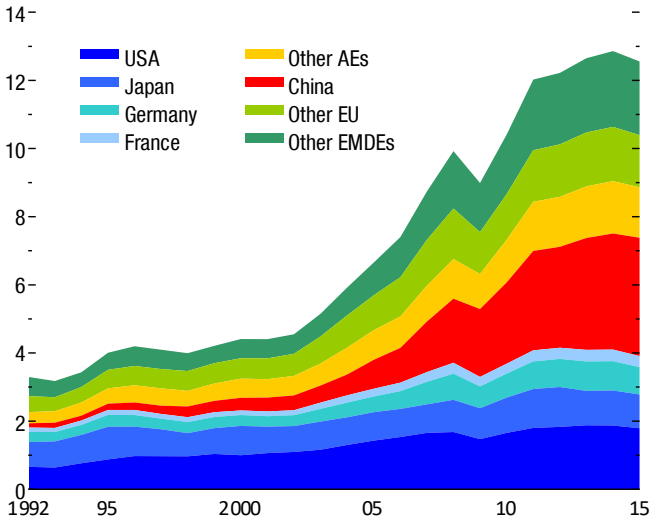


Sources: Penn World Table 9.0; and IMF staff calculations.
Note: Each type of investment is expressed as a share of nominal total investment (gross fixed capital formation) in local currency for each country. Shares are then averaged over broad country groups. Other investment mostly includes intellectual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

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's 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 goods prices may exhibit variation either due to mark-ups or trade costs. The advantage of using export-level data is that the value of the exports is reported free-on-board (FOB), which excludes trade costs.

Annex Figure 3.3.1. Capital Goods Production
(Trillions of US dollars)



Sources: Eora MRIO database; and IMF staff calculations.
Note: AEs = advanced economies; EMDEs = emerging market and developing economies; 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:

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

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 are obtained from COMTRADE; for Germany and France 8-digit HS export data for 1988–2017 is taken from Eurostat.[1] To assess whether patterns of

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

correlation may vary depending on the exporting country, the regression is also estimated separately for each exporting country.[2]

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

Source: IMF staff calculations.

Note: Regression for Top 5 exporting countries in column 1 includes product*exporting country*year fixed effects. Regressions for individual exporting countries in columns 2–6 include product*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. It is unclear which factors may explain this negative coefficient in the case of U.S. and Chinese exports, and this would be a fruitful topic for future research. 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 markets (EMs) and low-income countries (LICs). 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.

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

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

Source: IMF staff calculations.

Note: Regression for Top 5 exporting countries in column 1 includes product*exporting country*year fixed effects. Regressions for individual exporting countries in columns 2–6 include product*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 the 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 Values 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 product*exporting country*year fixed effects. Regressions for individual exporting countries in columns 3–7 include product*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 pay lower prices. One explanation could be

[3] The finding of a robust negative correlation between unit values and importer's 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.

that their quality of imports is lower because they must import even low-quality products from faraway 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 capital good domestically.

The price index in panel 3 of Figure 3.4 is computed by aggregating the unit values from the trade data described above for the year 2011. First, for each importing country (*i*), exporting country (*x*), product pair (*p*), we compute the deviation of the log unit value paid by the importing country *i* from the log of the average of the unit values charged by the exporting country *x* for this product *p* 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 sample.

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

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.

$$\ln(P_I)_i = \alpha + \beta \cdot \ln(\text{TradeCost})_i + \epsilon_i$$

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 the country's port(s); (3) the Fraser Institute's Freedom to Trade Internationally, which is based on four different types of trade restrictions: tariffs, quotas, hidden administrative restraints, and controls on exchange rate and the movement of 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, are from the World Bank, Doing Business Indicators database.

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

Source: 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 nontradable goods and services sectors of the economy.

Taking this reduced form relationship to the data, the analysis examines the contribution of the relative efficiency of capital goods production 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 value added of the tradable goods producing sectors divided by their total employment, and the value added of all nontradable 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 (i) the product of the estimated coefficient and the value of the independent variable and (ii) the dependent variable, divided by the variance of the dependent variable.

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[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.

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 producing sector to obtain an estimate of how much each potential factor can account for 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:

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

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; $\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\bar{VA}_{i,t}}\right)$ is the relative import penetration (measured as the value of goods produced by sector j that are imported by country i divided by the value added of sector j in country i); and $\frac{LP_{i,j,t}}{\bar{LP}_{i,t}}$ is the relative productivity of labor (measured as real value-added per employee).

$\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\bar{VA}_{i,t}}\right)$ is instrumented by relative import tariff, defined as $\tau_{i,j,t} - \bar{\tau}_{i,t}$. The tariff of sector j 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). The average tariff $\bar{\tau}_{i,t}$ is simply defined as the average across all sectors: $\bar{\tau}_{i,t} = \frac{\sum_{j=1}^{J}\tau_{i,j,t}}{J}$.

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

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

where $\ln\left(\frac{M_{i,j,t}}{VA_{i,j,t}}\right) - \ln\left(\frac{\bar{M}_{i,t}}{\bar{VA}_{i,t}}\right)$ 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. Here, import tariffs are assumed to satisfy the exogeneity conditions:

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

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 confirms the idea 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 several coefficients in the relative price and relative productivity equations, including those of import penetration β and β^{LP} and that of relative labor productivity γ, depend on whether a country is an advanced economy or an emerging market and developing economy, 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.

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

A. 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 is decomposed into four components: (i) the direct effect of deepening trade integration, defined as the simple average of $\beta \times \{\left[\ln\left(\frac{M_{i,j,2011}}{VA_{i,j,2011}}\right) - \ln\left(\frac{\bar{M}_{i,2011}}{\bar{VA}_{i,2011}}\right)\right] - \left[\ln\left(\frac{M_{i,j,2000}}{VA_{i,j,2000}}\right) - \ln\left(\frac{\bar{M}_{i,2000}}{\bar{VA}_{i,2000}}\right)\right]\}$ across countries and sectors; (ii) the effect of trade integration through higher labor productivity, defined as the simple average of $\gamma \times \beta^{LP} \times \{\left[\ln\left(\frac{M_{i,j,2011}}{VA_{i,j,2011}}\right) - \ln\left(\frac{\bar{M}_{i,2011}}{\bar{VA}_{i,2011}}\right)\right] - \left[\ln\left(\frac{M_{i,j,2000}}{VA_{i,j,2000}}\right) - \ln\left(\frac{\bar{M}_{i,2000}}{\bar{VA}_{i,2000}}\right)\right]\}$ across countries and sectors; (iii) the effect of higher labor productivity, which is not due to deepening trade integration, defined as the simple average of $\gamma \times \{\left[\ln\left(\frac{LP_{i,j,2011}}{\bar{LP}_{i,2011}}\right) - \ln\left(\frac{LP_{i,j,2000}}{\bar{LP}_{i,2000}}\right)\right] - \beta^{LP} \times \{\left[\ln\left(\frac{M_{i,j,2011}}{VA_{i,j,2011}}\right) - \ln\left(\frac{\bar{M}_{i,2011}}{\bar{VA}_{i,2011}}\right)\right] - \left[\ln\left(\frac{M_{i,j,2000}}{VA_{i,j,2000}}\right) - \ln\left(\frac{\bar{M}_{i,2000}}{\bar{VA}_{i,2000}}\right)\right]\}$ across countries and sectors; (iv) the contributions of other factors, i.e., the residual term.

Annex 3.6. Empirical Evidence on the Impact of Relative Investment Prices on Investment Rates 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-producing 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 equipment and the log of the price of machinery and equipment relative to the price of consumption,[2] controlling for all time-invariant differences across countries (μ_i) and year fixed effects (θ_t) to capture common global shocks:

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

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 effects, 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 preferred 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 equipment is significant and

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[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.

negative; suggesting that—similar to the GIMF model simulations presented in the chapter and Box 3.3—a decline in the relative price of investment is associated with higher real 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 ordinary least squares. 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 rates 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 from 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, in which the sample period is restricted to be post-1990, and the sample countries are restricted to be 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,

[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.

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 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 rates. 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 rates. Indeed, the big decline in the relative prices of machinery and equipment over the past decades, as shown in 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 equipment investment rates grew by more than 60 percent, increasing from 5 percent to over 8 percent in EMDEs (panel 1 of Figure 3.1). 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 equipment.

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

Dependent Variable:	OLS	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV	GMM	IV
Log Real Investment-to-GDP Ratio			Lagged	Annual						P_I/P_{GDP}		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. The weight is the share of each type of capital asset in the total investment of machinery and equipment of the sector.

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

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 its lagged value. A range of possible estimates using slightly different specifications are presented in Annex Table 3.7.1.

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

The baseline specification includes country-period and country-sector fixed effects, where the period refers to five-year non-overlapping windows. However, country-period fixed effects may absorb too much variation, for example if there is an aggregate effect of the relative price of investment on real investment rate that is common to all sectors within a country-period. For that reason, an alternative specification includes country-sector and 5-year period (or year) fixed effects, to address this issue (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: machinery and

[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.

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. Given annual changes may be dampened by adjustment cost of investment compared with variation in the long run, the estimated coefficients are smaller in magnitude when annual data are used instead of five-year averages. However, all the results have the expected sign, 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:	IV	OLS	OLS	IV	IV	OLS	OLS	IV
Log Real Investment-to-GDP Ratio			Lagged	P_I/P_{VA}			Lagged	P_I/P_{VA}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(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	Log Real Investment	Log Value Added	Log Value Added per Worker	Log Real Investment-to-GDP	Log Real Investment	Log Value Added	Log Value Added per Worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Relative Price	−0.326***	−0.192**	−0.061***	−0.016	−0.528***	−0.444***	−0.058***	−0.033
	(0.078)	(0.079)	(0.018)	(0.025)	(0.068)	(0.071)	(0.015)	(0.021)
Number of Observations	971	1,046	972	747	971	1,046	972	747
R^2	0.94	0.99	0.99	0.99	0.93	0.98	0.99	0.99
First Stage F-Statistic	645	456	991	378	729	500	1339	434
Period Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
Country-Period Fixed Effects	Yes	Yes	Yes	Yes	No	No	No	No
Country-Sector Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: 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	Log Real Investment	Log Value Added	Log Value Added per Worker	Log Real Investment-to-GDP	Log Real Investment	Log Value Added	Log Value Added per Worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Relative Price	−0.170***	−0.264***	−0.013***	−0.005	−0.203***	−0.279***	−0.011***	−0.007*
	(0.018)	(0.018)	(0.003)	(0.004)	(0.017)	(0.017)	(0.003)	(0.004)
Number of Observations	5,629	6,004	5,644	4,430	5,629	6,004	5,644	4,430
R^2	0.96	0.99	0.99	0.99	0.95	0.99	0.99	0.99
First Stage F-Statistic	20,770	18,595	26,232	12,603	23,442	20,477	33,690	14,700
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.

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$