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Construction productivity and global inequality

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Abstract: Two well established stylized facts of economic development are a strong correlation between investment and income, and large differences in investment rates across countries. Construction is the largest component of investment. This paper examines the implications of heterogeneity in construction productivity on cross-country income disparity. We estimate the 10:1 spread in construction productivity among 145 countries in 2005 as a factor of 61.7-fold. Based on a general equilibrium model with input–output linkages, we find that the 10:1 spread in income per capita declines by 45 per cent when the construction productivity gap is eliminated. Sectoral characterization of the aggregate effect of a change in construction productivity shows heterogeneous sectoral contributions to income convergence. Electrical equipment, metals, and transport equipment play stronger roles in transforming the effect of a change in construction productivity to the aggregate level in China compared with other countries.

Key words: productivity, construction, input–output linkages, income inequality

JEL classification: O4, O11, E01, L74

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1 Introduction

A growing body of research documents that differences in the sectoral characterization of productivity can account for large differences in income per capita across countries (Gollin et al. 2014; Herrendorf and Valentinyi 2012; Hsieh and Klenow 2007). For instance, eliminating cross-country differences in productivity in non-traditional services lowers aggregate income disparity by 58 per cent, i.e. almost an eight-fold reduction in the income gap across countries (Duarte and Restuccia 2020). In this paper, we extend this line of inquiry to examine the implications of heterogeneity in construction productivity on cross-country income disparity.

There are at least three reasons why international comparisons of construction performance are crucial. First, a strong correlation between investment rates (in PPP prices) and income is one of the robust outcomes in the empirical growth literature (Barro 1991). Large differences in investment rates across countries persist, as poor countries have low productivity in producing investment goods (Hsieh and Klenow 2007). An early literature investigated the role in long-run economic growth of investment in machinery (De Long and Summers 1993; Jones 1994; Sen 2002, 2007; Temple 1998). While construction typically accounts for more than two-thirds of investment, the role of investment in construction and the large cross-country differences in investment remain understudied.

Second, over the past three decades, construction employment and value-added share have continued to increase in many low-income countries.[1] In 2020, construction accounted for about 13 per cent of the world's GDP, which is only 3 percentage points lower than the manufacturing share (McKinsey 2020). The construction employment shares in China and India, with a combined population of close to 3 billion, are 12 and 16 per cent, respectively.

Third, due to increasing spillovers and intersectoral network effects, sectoral hubs in global value chains have gradually shifted from advanced countries to emerging markets. In 2009, the construction sector in China became the seventh-largest downstream sector globally, having not even made the top 20 list in 1997 (Frohm and Gunnella 2017). China's prominence in global value chains corresponds to the steady growth in the property sector, which alone secured a staggering 30 per cent of China's GDP in 2017 (Rogoff and Yang 2021). In short, construction is likely to play a central role in a strong recovery from the COVID pandemic in the global south; it is, however, less well understood how this complex process works.

Surprisingly, international comparisons of construction performance have received limited attention in the field of economics. An early literature on the economics of construction examined the determinants of long-term fluctuations in construction demand in advanced industrial economies (Abramovitz 1968; Kuznets 1958; Lewis 1965). This paved the way for influential works on the role of the construction sector in economic development with regard to input–output flows (Jones 1976; Schultz 1976; Straussman 1970). However, research interest in the economics of construction fell among economists from the early nineties. Notable exceptions are De Long and Summers (1993) and Hsieh and Klenow (2007), but these studies focus on the role of

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[1] Construction employment and value-added share increased in 34 out of 38 low- and middle-income countries between 2000 and 2018 (authors' estimates based on the GGDC/UNU-WIDER Economic Transformation Database). Furthermore, global construction output is predicted to grow at an annual rate of 6.7 per cent between 2020 and 2030, providing a strong recovery from the COVID pandemic for low-income countries (Oxford Economics 2021).

investment in economic performance, and not on construction per se. In more recent years, the role of construction in economic performance has become more integrated into the fields of construction engineering and management, urban studies, and housing studies (Bon 1989, 2001; Gregori and Pietroforte 2015; Ive 2005).[2]

A less productive construction sector in low-income countries can produce a larger productivity gap in construction, and consequently a larger income gap across countries. The income gap can also increase if sectors using construction intermediate inputs or sectors that supply intermediate inputs to construction are less productive due to the shorter length of their supply chain (Fadinger et al. 2022; McNerney et al. 2022). This paper is the first to examine the implications of the construction productivity gap across countries using a multisectoral general equilibrium framework that models intersectoral linkages.

We primarily use detailed data (expenditure categories, groups, and classes) from the International Comparisons Program (ICP) of the World Bank for three benchmark years (2005, 2011, and 2017), the World Input–Output Database (WIOD) (Timmer et al. 2015), and the GGDC/UNU-WIDER Economic Transformation Database (ETD) (Kruse et al. 2022). To measure the cross-country gap in construction productivity, we use available information on sectoral prices from the ICP database. We are aware that expenditure data produce a composite measure of sectoral productivity that reflects the input–output structure of an economy (Heston and Summers 1996), which makes the comparison of sectoral output productivity across countries based on the ICP data challenging. For robustness purposes, we therefore use productivity data from multiple sources. We follow Duarte and Restuccia (2020) in computing income elasticities of construction productivity from income elasticities of relative prices for construction. We also utilize total factor productivity (TFP) data for 35 sectors from Fadinger et al. (2022) and Paul and Raju (2023) based on the WIOD to perform counterfactual simulations on the aggregate implications of a change in construction productivity.

We find evidence of steady growth in construction activities in the emerging markets since the early 1990s. The shares of both employment and value added in construction increased, on average, at a higher rate in low- and middle-income countries than in high-income countries between 2000 and 2018. Like Hsieh and Klenow (2007) we observe a negative correlation between the relative price of investment (in PPP terms) and income. The negative correlation with income disappears when we consider the relative price of construction (in PPP terms). Among the sub-components of construction, income elasticity is positive and statistically significant for both residential and non-residential building, and it is negative but statistically insignificant for civil engineering work. Overall, the income elasticities of relative prices appear to be more volatile for the sub-categories of construction than for construction as a whole.

We estimate the 10:1 spread in construction productivity to be a factor of 61.7-fold in 2005 using a sample of 145 countries, falling to 49.8-fold in 2011 based on 168 counties, and 48.9-fold in 2017 based on 166 countries. The convergence in the cross-country construction productivity gap over time is primarily driven by faster growth in construction productivity in countries in the bottom five income deciles than in countries in the top five income deciles. The labour productivity measures are robust across different samples of countries. The 10:1 spread in construction productivity consistently increases as more low-income countries are covered in the sample. The heterogeneity in construction productivity using the same measure is 10 times larger with the full ICP sample of 168 countries than with the WIOD sample of 40 countries. Based on our simple

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[2] See Ive and Chang (2005) for a comprehensive discussion on the construction economics literature.

growth accounting framework, we also find a large disparity in productivity in the sub-components of construction across countries.

We extend our development accounting framework to understand the implications of input–output (IO) linkages on the construction productivity gap across countries using a sample of 40 countries that are common to both WIOD and ICP data, and for two benchmark years, 2005, and 2011. In 2005, the 10:1 spread in the construction productivity gap is lower by 57 per cent (from a factor of 6.79-fold to 2.94-fold) with IO linkages than without IO linkages. Similarly, in 2011, we estimate the 10:1 spread in the construction productivity gap to be lower by 50 per cent (from a factor of 4.08-fold to 2.04-fold) with IO linkages than the baseline results without IO linkages. As a robustness check, we compare these estimates of labour productivity in construction with the TFP in construction available from Fadinger et al. (2022). The correlation between construction TFP and construction labour productivity with intersectoral linkages (0.54) is stronger than the same between construction TFP and construction labour productivity without intersectoral linkages (0.32). This validates the implications of intersectoral linkages for construction productivity differences across countries.

Accounting frameworks are silent about the forces of the aggregate effect of the change in construction productivity. We consider a multisector general equilibrium model to examine the aggregate effect of the change in construction productivity. We apply the state-of-the-art approach on nonlinear characterization of the propagation of sectoral productivity shocks to the aggregate level (Albrizio et al. 2023; Bachmann et al. 2022; Baqaee and Farhi 2019). The aggregate effect is the sum of the first- and second-order effects of the change in construction productivity. Following Paul and Raju (2023), we derive the second-order effect from a sectoral productivity shock as a function of three factors: the variable elasticities of substitution parameters (the Morishima gross elasticity of substitution (MGES)) across sector-pairs; the elasticity parameters of sectoral productivity ratio with respect to the change in construction productivity; and the sectoral Domar weights (sectoral output-to-GDP ratio).

To quantify the aggregate effect of the change in construction productivity, we follow two steps. First, we perform some back-of-the-envelope calculations following Bachmann et al. (2022) utilising the full ICP sample of 145 countries. Second, we compute the MGES and sectoral productivity elasticities to derive the second-order effect for a smaller sample of 40 countries using the WIOD data. Based on counterfactual simulations, we find that elimination of cross-country disparity in construction productivity lowers the 10:1 spread in income in 2011 from 55.4-fold to 30.46-fold, representing a drop in cross-country income inequality of 45 per cent. Similarly, elimination of heterogeneity in construction productivity results in a drop in the 10:1 spread in income in 2017 from 48.5-fold to 21.89-fold, i.e. by 55 per cent. Elimination of the productivity gap in residential building, non-residential building, and civil engineering work produces similar outcomes, although the magnitude of the drop in income inequality is smaller due to smaller Domar weights for the sub-categories of construction than the Domar weight for construction. The quantitative results of the effect of heterogeneity in construction productivity on income disparity across countries are robust across different samples of countries.

Outcomes on variable elasticity parameters support sectoral characterization of aggregate propagation of the change in construction productivity. The estimate of MGES with respect to the change in construction productivity for nearly half of the sectors is less than one, suggesting complementarity between those sectors and construction output. On the other hand, the elasticities between construction productivity and productivity in all other sectors except water transport and household employment are positive. Since the elasticity parameters do not vary across countries, variation in the aggregate effect of the change in construction productivity largely depends on the cross-country variation in the Domar weights within each sector. Sectoral characterization provides valuable insights. For instance, the effect of the change in construction productivity is stronger in mining, metals, machinery, and electrical equipment in China than in other countries, which corroborates the rise of China's construction sector into the top 10 downstream hubs in global value chains (Frohm and Gunnella 2017). Overall, the sectoral outcomes look meaningful and reflect China's increasing predominance in global value chains.

Our paper relates to the growing literature on sectoral development accounting. It has long been established that differences in aggregate TFP account for almost half of cross-country income differences (Caselli 2005; Hall and Jones 1999). Recent research has documented larger cross-country variation in productivity in certain sectors than in aggregate productivity (Gollin et al. 2014; Herrendorf and Valentinyi 2012). Based on a sample of 145 countries, our results show that eliminating the cross-country construction productivity gap lowers the 10:1 spread in income per capita by 45 per cent. On the other hand, heterogeneity in sectoral productivity differences changes if IO linkages are modelled and IO linkages interact with sectoral productivities (Duarte and Restuccia 2020; Fadinger et al. 2022; Jones 2011; Valentinyi 2021). We find evidence of the role of IO linkages in lowering the construction productivity gap across countries.

Finally, our study relates to the literature on the propagation of sectoral productivity shocks to the aggregate level (Acemoglu et al. 2012; Baqaee and Farhi 2019; Caliendo et al. 2018; Carvalho et al. 2021). Recent advances in nonlinear characterization of the propagation of sectoral productivity shocks to the aggregate level provide deeper insights into the heterogeneous effects across sectors (Albrizio et al. 2023; Bachmann et al. 2022; Baqaee and Farhi 2019). We contribute to this growing literature by documenting how different sectors contribute to aggregate productivity growth arising from a construction productivity shock. We find a stronger role of mining, metals, machinery, and electrical equipment in the aggregate propagation of the construction productivity shock in China than in other countries.

The rest of the paper is organized as follows. In Section 2, we describe our data sources and some stylized facts related to construction employment, value added, prices, and expenditure across countries. Section 3 starts with a baseline development accounting framework and then presents a unified framework with intersectoral linkages. In Section 4, we consider a general equilibrium framework with IO linkages to quantify the aggerate implications of the heterogeneity in construction productivity. Section 5 offers some concluding remarks.

2 Data and stylized facts

In this section we describe the main data sources for our empirical analysis, following which we discuss some stylized facts related to the employment share, value added share, and prices of construction, and the sub-components of the construction sector.

2.1 Data

We primarily use sectoral expenditure and prices data from three rounds (2005, 2011, and 2017) of the World Bank's International Comparisons Program (ICP). The ICP data provide comparable price and volume measures of Gross Domestic Product (GDP) and its expenditure components for a large sample of countries (145 in 2005, 168 in 2011, and 166 in 2017). The ICP data also report information on nominal expenditure (in domestic currency) and price indices for individual expenditure categories. In Table A1 in the Appendix we show the detailed mapping of gross fixed capital formation (GFCF) into three disaggregated level classifications: group, class, and basic heading. As the ICP data are available publicly only for broad groups and categories of sectors, we obtained the sectoral data on classes and subheadings from the World Bank. We examine the expenditure share and prices in purchasing power parity (PPP) terms in both construction and its three sub-components: residential building, non-residential building, and civil engineering work.

Since the ICP data collect expenditure-based PPPs based on purchasers' prices of final goods and services, the expenditure-based PPPs need to be mapped into specific sectors for output and productivity comparisons at the sector level (van Ark and Timmer 2009).[3] We, however, directly use ICP prices for the comparison of output and expenditure in construction because expenditure-based PPPs can be a good proxy for the production-based PPPs in construction, as almost all the output of construction is for final expenditure (Inklaar and Timmer 2009). We construct real expenditure share and relative prices for GFCF, construction, and its sub-components using the ICP data.

The second dataset we use is the GGDC/UNU-WIDER Economic Transformation Database (Kruse et al. 2022),[4] which provides comprehensive (on value added, price deflators, and persons employed), long-term (time-series annual data from 1990 to 2018), and internationally comparable sectoral data (12 sectors) on employment and productivity in 51 economies in Africa, Asia, and Latin America. We use the Economic Transformation Database (ETD) to analyse the trends in employment and value added in construction for the period 2000–17.

The national input–output (IO) tables come from two sources: the World Input–Output Database (WIOD) (Timmer et al. 2015) and the OECD Inter-Country Input–Output (ICIO) Tables (OECD 2022). The WIOD contains IO tables for each year over the period 2000–14 for 43 countries. The WIOD November 2016 Release covers 28 EU countries and 15 other major countries in the world.[5] This database consists of IO tables based on a 56-sector classification. We transform the 56-sector IO tables into 10-sector IO tables for a growth accounting exercise with IO linkages. We also use the ICIO database, which contains annual IO tables for 76 countries from 1995 to 2020.

Lastly, we use sectoral productivity (TFP) measures from Fadinger et al. (2022). The authors estimate PPP-adjusted TFP for 35 sectors[6] comparable across 38 countries for the 2005 benchmark year of ICP based on the WIOD 2013 Release, which consists of IO tables with a 35-sector classification and covers 27 EU countries and 13 other major countries in the world for the

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[3] Expenditure data produce a composite measure of sectoral productivity reflecting the input–output structure of an economy (Heston and Summers 1996), which makes the comparison of sectoral productivities across countries challenging.

[4] This dataset is a joint initiative of the Groningen Growth and Development Centre (GGDC) and United Nations University World Institute for Development Economics Research (UNU-WIDER) and is publicly available here: https://www.wider.unu.edu/project/etd-economic-transformation-database.

[5] The countries covered are the EU-28 Member States (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Germany, Denmark, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Sweden, Slovakia, Slovenia, and United Kingdom) and 15 other countries for which data are available (Australia, Brazil, Canada, China, Norway, India, Indonesia, Japan, South Korea, Mexico, Russia, Switzerland, Taiwan, Turkey, USA).

[6] These 35 sectors are: (1) Agriculture, (2) Mining, (3) Food, (4) Textiles, (5) Leather, (6) Wood, (7) Paper, (8) Refining (coke), (9) Chemicals, (10) Plastics, (11) Other Non-Metallic Minerals, (12) Metals, (13) Machinery, (14) Electrical and Optical Equipment, (15) Transport Equipment, (16) Manufacturing not elsewhere classified, (17) Electricity (and other utilities), (18) Construction, (19) Retail Trade, (20) Wholesale Trade, (21) Car Retail, (22) Restaurants, (23) Inland Transport, (24) Water Transport, (25) Air Transport, (26) Transport not elsewhere classified, (27) Telecommunications, (28) Financial Services, (29) Real Estate, (30) Business Services, (31) Public Administration, (32) Education, (33) Health, (34) Social Services, (35) Household Employment.

period 1995–2011. The 2005 round of WIOD data provides PPP deflators for sector-level gross output for these 35 sectors. The TFP measures from Fadinger et al. (2022) satisfy a set of basic requirements for TFP comparisons across countries.[7] In a recent paper, Paul and Raju (2023) extend this database to another ICP benchmark year, 2011, using Socio Economic Accounts (SEA) data.[8] We use the dataset from Paul and Raju (2023) to calculate the elasticity measures based on sectoral productivity between 2005 and 2011. These elasticity measures are applied to understand the nonlinear characterization of the aggregate effects of changes in construction productivity.

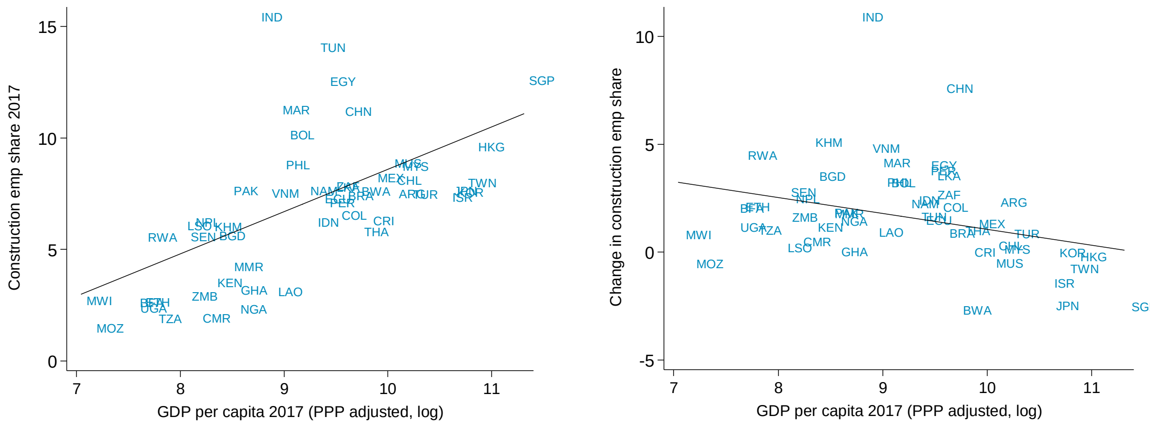
2.2 Employment and value-added shares in construction

Panel A in Figure 1 shows how the construction employment share varies with income (GDP per capita in PPP terms) in 2017. The scatterplots in Figure 1 are drawn using the ETD.

Figure 1: Construction employment and value-added shares, 2000–17

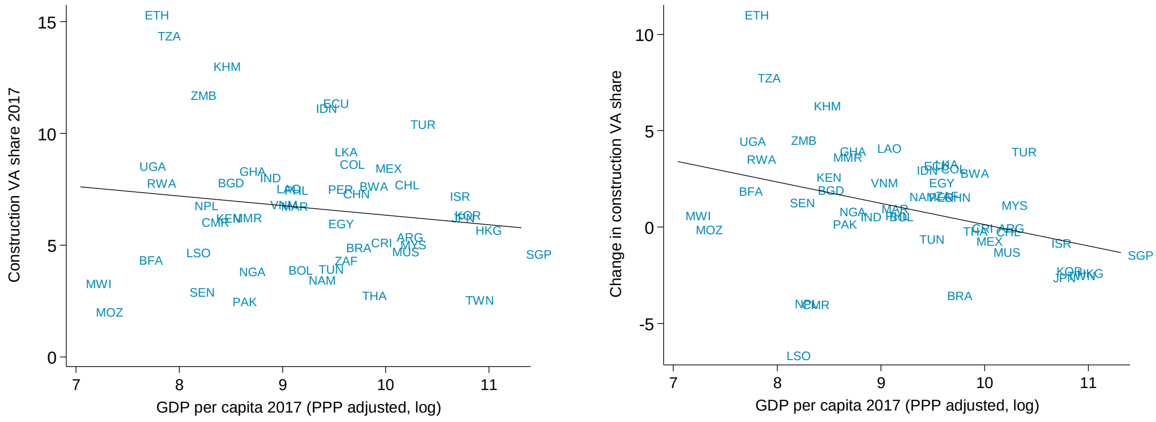
A Employment in 2017

B Change in Employment, 2000–17



C Value added in 2017

D Change in Value-added, 2000–17



Note: graphs include 51 countries. The change in the construction employment (value-added) share is the percentage points change in construction employment (value-added).

Source: authors' estimates based on the GGDC/UNU-WIDER Economic Transformation Database (ETD).

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[7] The authors use the 2005 WIOD to estimate comparable country-sector-level TFP for 35 sectors across 38 countries based on Caves et al. (1982). See Fadinger et al. (2022: 379) for further details.

[8] SEA collect industry-level data on employment, capital stocks, gross output, and value added at current and constant prices, in millions of local currencies, for the years 1995–2011.

India tops the chart, closely followed by Tunisia and Egypt. It is evident that the positive relationship between construction employment share and income level is primarily driven by middle-income countries, which on average hire almost twice the proportion of employees in construction compared with low-income and high-income countries. Panel B shows the change in the employment share in construction between 2000 and 2017. The share of employment in construction increased, on average, at a higher rate in low- and middle-income countries than in high-income countries.

Panel C of Figure 1 plots the value-added share in construction and GDP per capita. We do not observe any difference in the average value-added share in construction across low-/middle-income and high-income countries. In some of the low-income countries (Ethiopia, Tanzania, Zambia, among others), the value-added share in construction is larger than in the rest of the countries, which makes the slope of the linear fit between the value added in construction and income look slightly negative. The change in the value-added share in construction is, on average, larger in low-/middle-income countries than in high-income countries (Panel D). Overall, both in terms of employment and value added, the evidence supports growing activities in construction, especially among the low- and middle-income countries.

2.3 Relative prices of construction and income

We examine how the relative prices (in PPP terms) of construction and its sub-components vary with income using simple univariate regressions. The results are presented in Table 1.

Table 1: Development accounting: relative prices and income

	Year	Real GDP per capita	Relative price (construction to GDP)	Relative price (residential building to GDP)	Relative price (non-residential building to GDP)	Relative price (civil engineering work to GDP)
Decile 10 / Decile 1	2005	64.37	0.92	1.11	1.11	0.88
	2011	55.46	1.14	1.35	1.19	0.89
	2017	45.61	0.95			
Income elasticity	2005		0.01	0.045**	0.053**	-0.024
			(0.022)	(0.022)	(0.021)	(0.018)
	2011		0.027	0.056***	0.040**	-0.015
			(0.020)	(0.022)	(0.020)	(0.020)
	2017		-0.018			
			(0.016)			

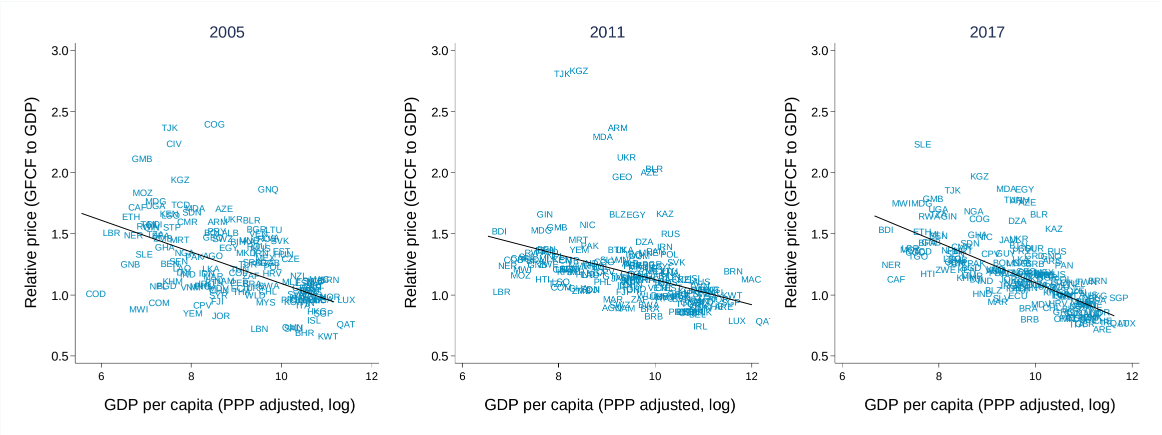
Note: 145 countries in 2005, 168 countries in 2011, and 166 countries in 2017. In each round, countries are ranked according to real GDP per capita (PPP-adjusted) and distributed among 10 income deciles. Income elasticity is measured as the slope coefficient of an OLS regression of the log of each variable on log real GDP per capita (PPP-adjusted) across countries in the sample. Standard errors are in parentheses.

Source: authors' estimates based on data from the 2005, 2011, and 2017 rounds of ICP.

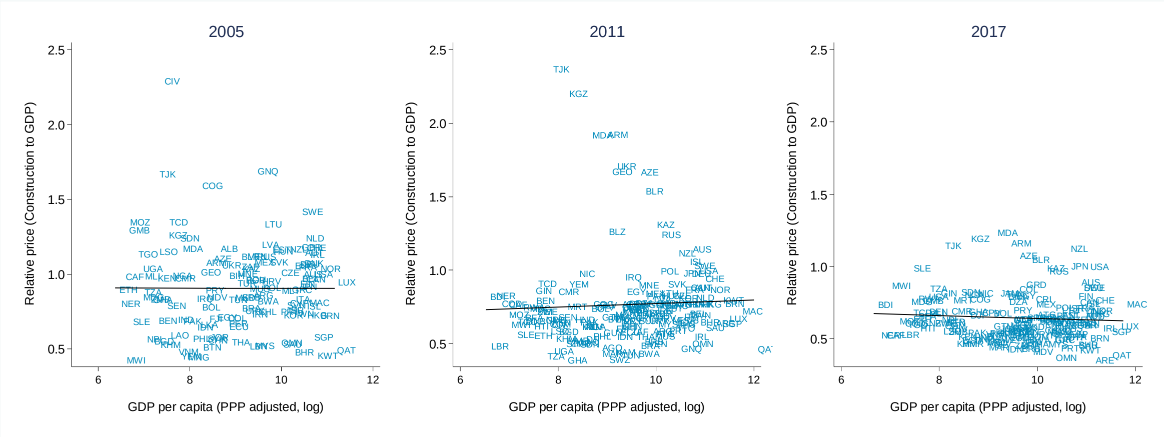
Before going over the income elasticities of relative prices, we briefly explain how the relative price of investment measured as GFCF (in PPP terms) varies with income. There is a strong negative correlation between the relative price of investment (in PPP terms) and income (Figure 2, panel A) across the three benchmark years: 2005, 2011, and 2017. However, the negative correlation with income disappears when we consider the relationship between the relative price of construction (in PPP terms) (Figure 2, panel B). Hsieh and Klenow (2007) find a similarly weak correlation between relative prices of construction and income for their benchmark years 1980 (61 countries) and 1985 (64 countries).

Figure 2: Relative prices and income: 2005, 2011, and 2017

A Relative price of investment (GFCF to GDP) and GDP per capita



B Relative price of construction (construction to GDP) and GDP per capita



Note: 145 countries in 2005, 168 countries in 2011, and 166 countries in 2017. Relative price of investment = PPP prices of GFCF / PPP prices of GDP. Relative price of construction = PPP price of construction / PPP price of GDP.

Source: authors' estimates based on data from 2005, 2011, and 2017 rounds of ICP.

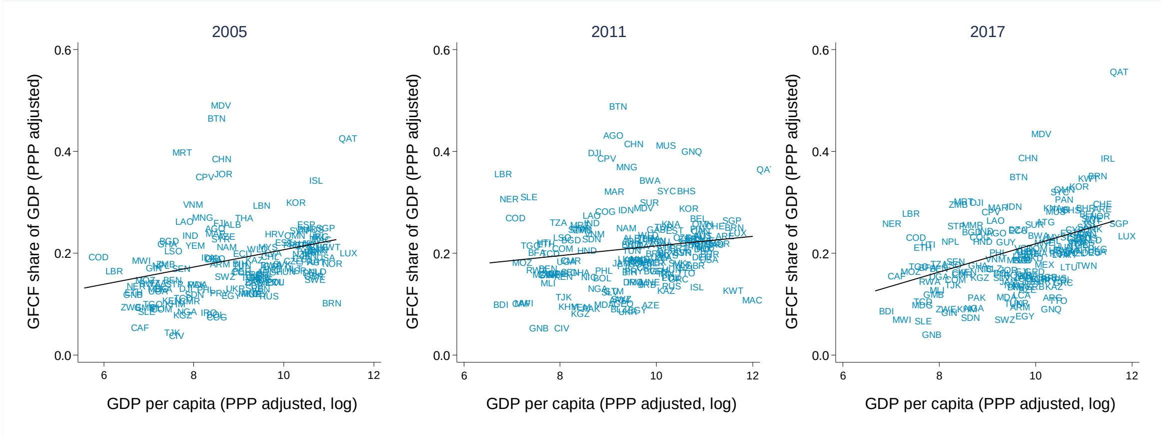
Returning to Table 1, we present the income elasticity of the relative price of construction (in PPP terms) as the slope coefficient of an OLS regression of this variable on log GDP per capita (in PPP terms). The estimated coefficients are 0.01 in 2005 (145 countries), 0.027 in 2011 (168 countries), and -0.018 in 2017 (166 countries)—all statistically insignificant at the 5 per cent level. Among the sub-components of construction, the income elasticity is positive and statistically significant for both residential and non-residential building, whereas it is negative but statistically insignificant for civil engineering work. The 10:1 spread is close to 1 for the relative price of construction, greater than 1 for residential and non-residential building, and less than 1 for civil engineering work. Overall, the income elasticities of relative prices appear to be more volatile for the sub-categories of construction than for construction itself.

2.4 Real investment rates in construction and income

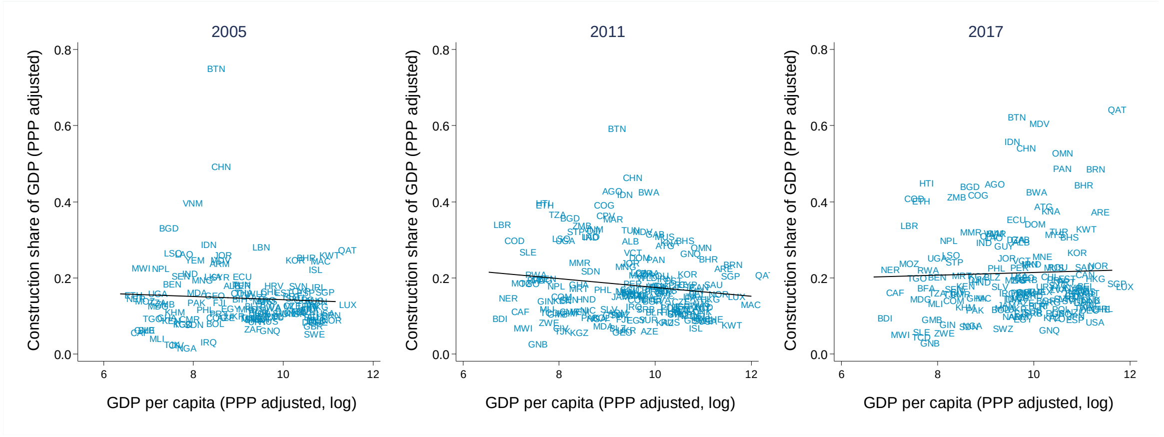
We measure the real investment rate in GFCF, construction, and the sub-components of construction as the ratio between total expenses in these expenditure categories and GDP (all in PPP terms). It is well established in the empirical growth literature that investment rates (in PPP prices) and income are strongly correlated (Barro 1991). We find similar evidence on the relationship between the investment rate in GFCF and income in 2005, 2011, and 2017 (Figure 3, panel A). One of the underlying causes of differences in the investment rate across countries is that poor countries have low productivity in the manufacture of investment goods, as documented in Hsieh and Klenow (2007).

Figure 3: Investment rates and income I: 2005, 2011, and 2017

A GFCF share of GDP and income



B Construction share of GDP and income



Note: 145 countries in 2005, 168 countries in 2011, and 166 countries in 2017.

Source: authors' estimates based on data from 2005, 2011, and 2017 rounds of ICP.

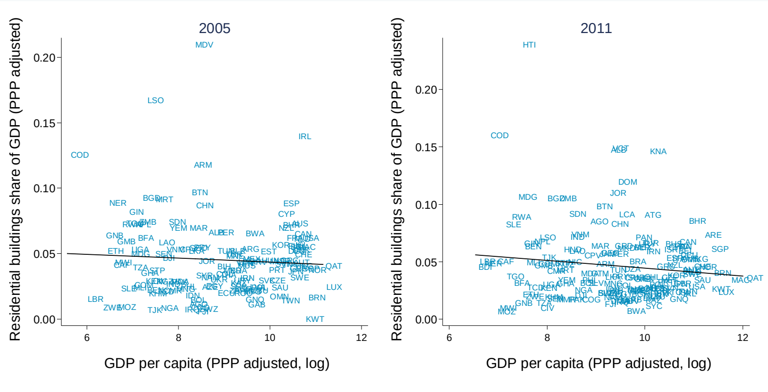
The investment rate in construction shows a somewhat different picture (Figure 3, panel B). In 2005, the linear relationship between investment rate in construction and income is almost a flat line, which becomes slightly negative in 2011; however, the relationship turns out to be slightly positive in 2017. The 10:1 spread in the investment rate in construction does not closely follow the scatterplots. It is measured as 1.32 in 2005 and 0.75 in 2011, and it goes up to only 1.1 in 2017, whereas the income elasticity of the investment rate is positive only in 2017. On the other hand, the 10:5 spread in the investment rate in construction turns out to be 0.80, 0.72, and 0.96 in 2005, 2011, and 2017, respectively. This suggests that the gap in investment rate across countries is much lower in 2017 compared with the previous benchmark years.

It is also important to note that the change in the investment rate in construction between 2005 and 2017 varies across different income groups of countries. The 10:1 spread in the rate of change in the investment rate in construction is close to 2, suggesting that construction expenses as a share of GDP in rich countries are twice as large as in poor countries. The top three countries in terms of the largest increase in the construction investment rate are Oman, Brunei Darussalam, and Qatar, while the bottom three (largest decrease) are Malawi, Armenia, and Bhutan.

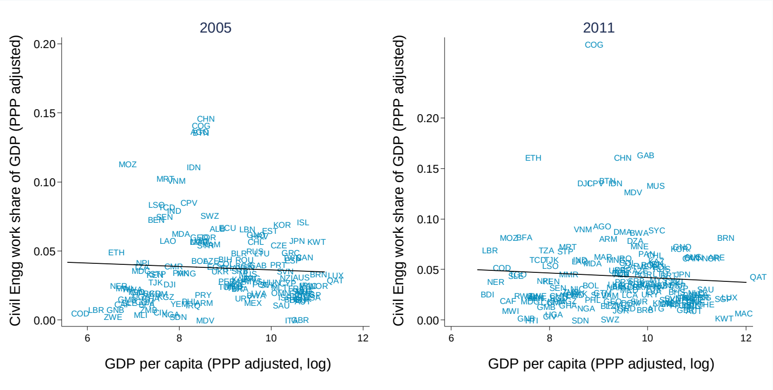
In Figure 4, we compare the relationship between the income elasticity of different sub-components of construction. The correlation between investment in residential building and income is weakly negative, whereas the expenditure share of non-residential building shows a positive correlation with income in both 2005 and 2011. The income elasticity of civil engineering work is also weakly negative. The top four countries in terms of civil engineering work's expenditure share of GDP are China, Gabon, Ethiopia, and Republic of Congo. On the other hand, Bhutan, Uganda, and Botswana are the among the top three countries in terms of the expenditure share of GDP in building. Overall, the average rate of investment in construction and its sub-components does not seem to vary much across the different income deciles of countries, even though there are outliers, especially in the middle deciles of the income distribution.

Figure 4: Investment rates and income II: 2005, 2011, and 2017

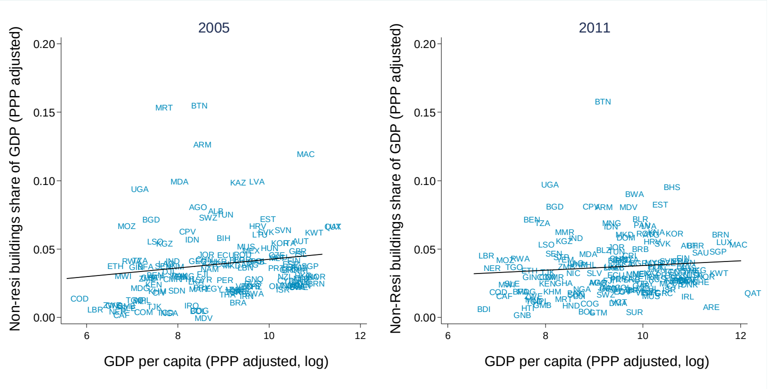
A Residential building share of GDP and income



B Non-residential building share of GDP and income



C Civil engineering work share of GDP and income



Note: 145 countries in 2005, and 168 countries in 2011.

Source: authors' estimates based on data from 2005, 2011, and 2017 rounds of ICP.

Before we conclude this section, we would like to take a quick look at how the value-added share and the expenditure share of construction compare. As only one-third of the countries in the ICP database are included in the ETD, this comparison is far from ideal. As Figure A1 shows, there is a positive correlation between these two variables. Even though the total expenditure and total value added equal the GDP of a country, expenditure data reflect the input–output structure of an economy and thus create a wedge between the sectoral share of value added and the sectoral share of expenditure (Heston and Summers 1996). Measurement issues also partly explain this discrepancy.

To conclude, we find strong evidence of growing activities in construction over time, especially in the emerging markets. Overall, the relationship of both the relative price of construction and the investment rate in construction with income remains fairly stable over time. The next step is to utilize the available information on sectoral prices, sectoral expenditure shares, and income to analyse the cross-country construction productivity gap using a growth accounting framework.

3 Construction productivity gap across countries

The purpose of this section is to analyse the cross-country productivity gap in construction. We estimate labour productivity in construction using a development accounting framework, which we later extend to incorporate the IO linkages. This allows us to examine the role of IO linkages in the cross-country construction productivity gap.

3.1 Baseline model

We adopt a simple development accounting framework similar to Herrendorf and Valentinyi (2012) and Duarte and Restuccia (2020) to compute labour productivity in construction. Output in sector i (y_i) is produced with labour (l_i) following linear technologies, $y_i = A_i l_i$, where A_i is labour productivity in sector i. In addition to linear technologies in labour, we assume competitive markets for goods and labour and free movement of labour between sectors. We assume that p_i is the price of output in sector i and w is the common wage rate across sectors. The profit-maximizing conditions can be derived from the first-order conditions for each sector i as

$$p_i A_i = w \tag{1}$$

The value of aggregate output in domestic prices can be written as $\sum_i p_i A_i = wl$, where $\sum_i l_i = l$. The nominal wage rate in this simple model is nothing but the per capita aggregate output in nominal price. Denoting the nominal price of GDP as p, we divide both sides of Equation (1) by p and then take log. Rearranging the terms, we obtain an expression for sectoral productivity, as follows:

$$log(A_i) = log(GDPpc) - log(\frac{P_i}{P}) \tag{2}$$

Differentiating Equation (2) with respect to $log(GDPpc)$, the relationship between the income elasticity of sectoral productivity (A_i) and the income elasticity of sectoral relative price $(\frac{P_i}{P})$ becomes:

$$\frac{dlog(A_i)}{dlog(GDPpc)} = 1 - \frac{dlog(\frac{P_i}{P})}{dlog(GDPpc)} \tag{3}$$

Using Equation (3), and the summary statistics presented in Table 1, we find that a 1 per cent higher GDP per capita leads to a 0.99 per cent $[= 1 - 0.09]$ higher productivity in construction in 2005, 0.97 per cent $[= 1 - 0.12]$ higher productivity in construction in 2011, and 1.02 per cent $[= 1 - (-0.18)]$ higher productivity in construction in 2017. The 10:1 spread in the construction productivity gap becomes a factor of 61.7-fold $[= \exp[0.99 \times \log(64.37)]$ in 2005, which drops to 49.8-fold $[= \exp[0.97 \times \log(55.46)]$ in 2011, and 48.9-fold $[= \exp[1.02 \times \log(45.61)]$ in 2017 (Table 2, first column). The convergence in the cross-country construction productivity gap over time is primarily driven by faster growth in average construction productivity in countries in the bottom five income deciles relative to countries in the top five income deciles.

Table 2: 10:1 Spread in construction productivity

	Construction productivity ratio between rich countries (in decile 10) and poor countries (in decile 1) becomes a factor of				
	ICP (145 countries in 2005, 168 in 2011, and 166 in 2017)	**ICP (126 countries, population >1 million)**	**ETD (51 countries)**	**ICIO (69 countries)**	**WIOD (40 countries)**
2005	61.74	54.24	44.84	10.73	6.79
2011	49.77	40.72	28.49	8.16	4.09
2017	48.86	45.57	41.70	7.72	4.05

Source: authors' elaboration based on data from ICP, ETD, ICIO, and WIOD.

The productivity gap in residential building between the rich countries (in decile 10) and the poor countries (in decile 1) becomes a factor of 53.37-fold $[= \exp[0.95 \times \log(64.37)]$ in 2005 and 44.29-fold $[= \exp[0.94 \times \log(55.46)]$ in 2011. On the other hand, the 10:1 spread in the productivity in non-residential building becomes a factor of 51.62-fold $[= \exp[0.94 \times \log(64.37)]$ in 2005, and 47.23-fold $[= \exp[0.96 \times \log(55.46)]$ in 2011. Similarly, the 10:1 spread in the productivity in civil engineering work becomes a factor of 71.13-fold $[= \exp[0.98 \times \log(64.37)]$ in 2005, and 58.91-fold $[= \exp[0.97 \times \log(55.46)]$ in 2011. Based on our simple growth accounting exercise, our results show a large disparity in construction productivity and the productivity of different components of construction across countries.

3.2 Robustness across different samples of countries

The ICP data provide comparable prices on expenditure categories for a large sample of countries, but data on IO linkages, sectoral value added, and employment are available only for a small sample of countries (40 in WIOD and 69 in ICIO). This forces us to use data from multiple sources for robustness purposes. In Table 2, we compare the 10:1 spread in construction productivity across five different samples of countries. The first column shows the outcomes for the full ICP sample of countries; in the second column we show the outcomes for a smaller ICP sample of 126 countries with a population of more than 1 million; in the third column we show the results for the ETD sample of countries; and the fourth and fifth columns show the results using the OECD ICIO sample of 69 countries and the WIOD sample of 40 countries, respectively. We find a strong correlation between the sample size of countries and the 10:1 spread in construction productivity. The 10:1 spread consistently increases with the sample size; it is 10 times larger using the full ICP sample than the WIOD sample with 40 countries.

3.3 Model with IO linkages

In this section, we extend the development accounting framework outlined in Section 3.1 to incorporate IO linkages à la Duarte and Restuccia (2020). We write the gross output production function as $y_i = B_i {l_i}^{1-\alpha_i} {h_i}^{\alpha_i}$, where B_i is the productivity level of gross output in sector i and α_i

is the share of produced inputs in each sector. h_i is the composite of intermediate inputs: $h_i = \prod_j \left(\frac{h_{ji}}{\emptyset_{ji}}\right)^{\emptyset_{ji}}$, where h_{ji} is the quantity of intermediate input j used to produce output in sector i, and $\emptyset_{ji}$ is the share of total input j in total intermediate input use. Solving for the profit maximization of sectoral output, we derive the following expression for sectoral productivity:[9]

$$log(A_i) = log(GDPpc) - log\left(\frac{P_i}{P}\right) - \frac{\alpha_i}{1-\alpha_i}\sum_j \emptyset_{ji}\left[log\left(\frac{P_i}{P}\right) - log\left(\frac{P_j}{P}\right)\right] \tag{4}$$

Equation (4) shows that the magnitude of the effect of intersectoral linkages on sectoral productivity construction lowers if the share of intermediate inputs in gross output becomes smaller, and/or the share of intermediate inputs from other sectors becomes smaller, and/or the share of intermediate inputs with different relative prices gets smaller. In the development accounting framework with IO linkages, the quantitative implications of intersectoral network depend largely on the values of α_i and $\emptyset_{ji}$.

We then estimate productivity based on the expression in Equation (4), using data from the WIOD, which include national IO tables for 43 countries for the period 2000–14 and a 56-industry classification. Since ICP data provide only expenditure prices and not output prices, however, we distinguish 10 sectors (agriculture, mining, manufacturing, public utility, construction, wholesale and retail trade, transport, business, public services, and private services), following the sectoral classification of the Gronningen Growth and Development Centre (GGDC). To minimize discrepancies and any bias arising from the comparison of output prices and expenditure prices, we construct the prices for these 10 sectors by mapping them into the ICP expenditure categories, as shown in Table A2.

To compute the parameters (α_i and $\emptyset_{ji}$) using a 10-sector IO format, we convert the 56-sector IO table from the WIOD into a 10-sector IO table, as shown in Table A3. Since the WIOD is available for the period 2000–14, our growth accounting exercise with use of the IO tables is feasible only for two benchmark years: 2005 and 2011. Figure A2 compares the average intermediate input share of construction across the income deciles of countries. We do not find any consistent pattern for the average intermediate input share of construction across the 10 income deciles. The average intermediate input share of construction output is higher for countries in the bottom, fifth, and sixth income deciles. The average intermediate input demand (as a share of construction output) to produce construction output for countries in the bottom income decile increases from 0.54 in 2005 to 0.56 in 2011, whereas it decreases for countries in the other income deciles.

Table 3 presents the construction productivity differences across countries with and without IO linkages. With intersectoral linkages, a 1 per cent higher GDP per capita is associated with 0.48 per cent higher productivity in construction in 2005, compared with 0.85 per cent in 2005 using the baseline model, and 0.42 per cent higher productivity in construction in 2011 compared with 0.83 per cent in 2011 using the baseline model. With intersectoral linkages, the 10:1 spread in the construction productivity gap reduces to a factor of 2.94-fold in 2005 compared with a factor of 6.79-fold using the baseline model in 2005. Similarly, with intersectoral linkages the 10:1 spread in construction productivity gap reduces to a factor of 2.04-fold in 2011 compared with a factor of 4.08-fold using the baseline model 2011.

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[9] See Duarte and Restuccia (2020) for the derivation of this expression.

Table 3: Development accounting: construction productivity with IO flows

	Year	Real GDP per capita	Intermediate input share in construction output	Construction productivity (without IO linkages)	Construction productivity (with IO linkages)
Decile 10 / Decile 1	2005	9.445	0.816	6.791	2.941
	2011	5.492	0.807	4.089	2.046
Income elasticity	2005			0.853	0.480
				0.039	0.103
	2011			0.827	0.420
				0.054	0.117

Note: sample includes 40 countries with a population of more than 1 million that are common between ICP and WIOD. Countries are ranked according to real GDP per capita and distributed among 10 income deciles. Construction productivity without IO linkages is calculated using Equation (3) and construction productivity with IO linkages is calculated using Equation (4) with 10 sectors.

Source: authors' estimates based on data from WIOD (Timmer et al. 2015) and from the 2005 and 2011 rounds of ICP.

We compare average construction productivity with and without IO linkages across income deciles. Panel A of Figure A3 presents the outcomes for 2005. In the presence of intersectoral linkages, countries in the bottom five deciles show a larger gain in average construction productivity than countries in the top five income deciles. Average construction productivity increases almost three-fold for countries in the bottom decile in 2005. We find similar evidence for 2011 (panel B). The role of intersectoral linkages in enhancing construction productivity is more prominent for countries in the lower income deciles. As a result, for both benchmark years, disparity in construction productivity lowers with intersectoral linkages. The 10:1 spread in construction productivity gap across income deciles declines by 57 per cent in 2005, and by 50 per cent in 2011 if IO linkages are modelled. This effect is largely driven by a substantial (two- to three-fold) increase in average construction productivity for countries in the bottom income decile (Figure A3).

Furthermore, a larger productivity gain in construction is also strongly correlated with a higher share of intermediate use of construction output for countries in the bottom income decile. Presumably, low- and middle-income countries, on average, require more construction inputs for production in other sectors than high-income countries, as more buildings, roads, and other infrastructural support are needed owing to their underdeveloped stage. The demand for construction inputs gradually diminishes as the level of income rises.

We now briefly discuss the robustness of sectoral productivity measures using IO linkages. Construction productivity in our development accounting framework is measured as labour productivity, which could be driven by factors other than IO linkages. The change in labour productivity due to intersectoral linkages is robust only when similar changes are observed in other measures of productivity, such as TFP. We compare our construction productivity estimates with the construction TFP from Fadinger et al. (2022). The authors compute PPP-adjusted TFP for 35 sectors comparable across 38 countries using the WIOD data, which satisfy a set of basic requirements for TFP comparisons across countries.[10] As shown in Figure A4, we find a much stronger correlation between construction TFP and construction labour productivity, with intersectoral linkages of 0.54 compared with the degree of fit between construction TFP and construction labour productivity without intersectoral linkages of 0.32.

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[10] See Fadinger et al. (2022: 379) for further details.

In summary, there is substantial gap in cross-country construction productivity, and the gap increases as more developing countries are included in the sample. The productivity gap in construction lowers when the growth accounting framework is modelled using IO linkages, i.e. the share of intermediate inputs in construction output and sectoral share of total intermediate inputs. As growth accounting is silent about the aggregate implications of the change in the construction productivity gap across countries, we next perform a counterfactual simulation exercise based on a general equilibrium model with IO linkages.

4 Aggregate effects of changes in construction productivity

To quantify the aggregate effects of changes in construction productivity, we consider a general equilibrium model similar to the growth accounting framework described in Section 3.3, with labour (l) as the single factor of production for N goods. Now, however, we focus on modelling the role of IO linkages in the propagation of the change in construction productivity (or productivity shock in construction) to the aggregate level. The aggregate demand in this general equilibrium framework is achieved through maximization of the constant-returns aggregator of final demand for N goods $(C_1,\ C_2,\ ..,\ C_N)$:

$$\begin{aligned} &Y = max\ \aleph(C_1,\ C_2,\ ..,\ C_N) \\ &\quad \text{subject to} \textstyle\sum_i^N P_i C_i = w\bar{l} + \sum_i^N \pi_i \end{aligned} \tag{5}$$

where C_i is the consumption good i, P_i is its price, and w is wages; labour is fixed in supply and is given by $\bar{l}$, and π_i is the profit for the producers of consumption good i ($\pi_i = P_i y_i - w_i l_i - \sum_j^N P_j\ x_{ij}$). Market clearing conditions for each sector are $y_i = \sum_j^N x_{ji} + C_i$ and $\bar{l} = \sum_i^N l_i$. Each sectoral good is produced by competitive firms:

$$y_i = A_i F_i(l_i,\ x_{i1},\ x_{i2}..,\ x_{iN}) \tag{6}$$

where A_i is a Hick-neutral technology, l_i is labour used for production of good i, and x_{ij} are intermediate inputs from sector j used for the production of sector i. The Domar weight, the proportion of output in sector i to GDP, becomes y_i/Y. For construction: y_C/Y.

4.1 Modelling IO linkages

In a production network system with multiple sectors, IO linkages are typically modelled using a two-stage set-up with a multi-input constant elasticity of substitution (CES) production function (Atalay 2017; Baqaee and Farhi 2019; Carvalho et al. 2021). For instance, in a two-sector, two-stage framework, construction (y_C) can be produced with inputs from construction (C), services (S), and labour (l), as shown in Equation (7):

$$y_C = \left[\delta_{N_1}\left[\mu_M C^{\frac{\rho-1}{\rho}} + \mu_S S^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}\frac{\sigma-1}{\sigma}} + \delta_{N_2} l^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} = N_1(C,\ S) + N_2(l) \tag{7}$$

where δ is the input cost share between N_1 and N_2, μ is the input cost share between C and S, ρ is the constant elasticity of substitution between C and S, and σ is the constant elasticity of substitution between two production sub-processes, N_1 and N_2. The sub-processes N_1 and N_2 can also be thought of as different stages of production of the construction output. If we add manufacturing (M) as an additional input for construction (y_C), the constant substitution parameter (ρ) between C and S could be different from ρ between C and M, i.e. the substitution elasticity parameter may not be constant across sector pairs, as each sector is likely to use a different mix of intermediate inputs (Lancaster 1966).

To capture variable elasticities across sector pairs in our multi-stage production process, we apply a measure of elasticity of substitution introduced by Morishima (1967), which Blackorby and Russell (1989) later termed the Morishima elasticity of substitution (MES). The MES between C and S can be written as

$$MES_{SC} = \begin{cases} \eta_{SC}{}^{[N_1]} - \eta_{CC}{}^{[N_1]}, C,\ S \in N_1 \\ \theta_C{}^{[N_1]} MES_{N_1 N_2} - \eta_{CC}{}^{[N_1]}, C \in N_1, S \in N_2 \end{cases} \tag{8}$$

where, $\eta_{SC}{}^{[N_1]}$ is the cross-price elasticity of conditional demand within N_1, $\eta_{CC}{}^{[N_1]}$ is the own-price elasticity of conditional demand within N_1, $\theta_C{}^{[N_1]}$ is the cost share of C in N_1, and $MES_{N_1 N_2}$ represents the MES between nests N_1 and N_2. In our case, the concept of the Morishima gross elasticity of substitution (MGES)—a natural extension of the MES (Davis and Shumway 1996)—is more appropriate because we are interested in understanding how the allocative efficiency of sectoral outputs, not sectoral inputs, responds to changes in sectoral productivity. The MGES is equal to the MES only when the production function is homothetic (Blackorby et al. 2007).

The MGES is a sufficient statistic to evaluate the comparative static results of the log of sectoral output shares ratio with respect to the log ratio of sectoral productivity, as follows:

$$\frac{\partial \log\left(\frac{\theta_S}{\theta_C}\right)}{\partial \log\left(\frac{A_S}{A_C}\right)} = MGES_{SC} - 1 \tag{9}$$

where $\frac{\theta_S}{\theta_C}$ is the output ratio and $\frac{A_S}{A_C}$ the productivity ratio between C and S. Inputs C and S are Morishima gross complements if $MGES_{SC} < 1$, and inputs x_i and x_j are Morishima gross substitutes if $MGES_{SC} > 1$.

4.2 First- and second-order effects of construction productivity shocks

It is well documented that the sectoral Domar weight (or the ratio of sectoral sales/output to GDP) can approximate the first-order aggregate effect of a sectoral productivity shock (Hulten 1978). In a recent study, Baqaee and Farhi (2019) show that the second-order approximation of a sectoral productivity shock is an important aspect of the shock propagation mechanism, as critical sectors can magnify a negative shock and attenuate a positive shock through disproportionate nonlinear propagation across sectors. The authors also show that nonlinearities in production can generate significantly higher welfare costs arising from business cycles than nonlinearities in risk aversion in utility (Lucas 1987).

The nonlinear characterization of the aggregate effect of a sectoral productivity shock can be formulated in terms of the reduced form structural elasticities of production, network linkages, and returns to scale at the sector level (Albrizio et al. 2023; Bachmann et al. 2022; Baqaee and Farhi 2019). Covariance in sectoral output and complementarities in sectoral outputs through structural elasticity parameters are crucial for the aggregate propagation of a sectoral productivity shock (Atalay 2017).

Baqaee and Farhi (2019) define a pseudo elasticity of substitution (ρ_{ji}) for non-homothetic functions as $\frac{1}{\rho_{ji}} = \frac{d\log\frac{f_j}{f_i}}{d\log A_i}$ (where f is a CES aggregator of sectoral outputs and A is sectoral productivity) and derive an expression for the sectoral Domar weights with respect to the log of productivity in sector i (A_i) as $\frac{d\log\frac{D_i}{D_j}}{d\log A_i} = 1 - \frac{1}{\rho_{ji}}$. The main difference between MGES and pseudo elasticity of substitution in Baqaee and Farhi (2019) is that the former is the elasticity of the ratio of marginal rates of substitution with respect to two arguments, whereas the latter is the same but with only one argument (Paul and Raju 2023). The pseudo elasticity of substitution is a generalization of the Morishima elasticity of substitution, and they are identical when the CES aggregator is homogeneous of degree one. Baqaee and Farhi (2019) define the input–output multiplier as

$$\varepsilon = \sum_{i=1}^{N} \frac{d\log Y}{d\log A_i} = \sum_{i=1}^{N} D_i \tag{10}$$

where ε captures the percentage change in aggregate output in response to a uniform change in productivity or technology in sector i. The nonlinear aggregate propagation of construction productivity shock is summarized in the following equation (Baqaee and Farhi 2019):

$$\frac{d^2\, log\, Y}{d\, log\, {A_C}^2} = \frac{dD_C}{d\, log\, A_C} = \frac{D_C}{\varepsilon} \sum_{\substack{1\le j\le N \\ C\ne j}} D_j \left(1 - \frac{1}{\rho_{jC}}\right) + D_C \frac{d\, log\, \varepsilon}{dC} \tag{11}$$

In Equation (11), ρ_{ji} is constant across sector pairs. We assume that each sector plausibly uses a different combination of sectoral outputs as intermediate inputs (Lancaster 1966); thus ρ_{ji} is likely to vary across sector pairs. Paul and Raju (2023) extend the second-order condition in Equation (11) to capture the varying degrees of substitution across sector pairs using the MGES, as follows:

$$\frac{d^2\, log\, Y}{d\, log\, {A_C}^2} = \frac{D_C}{\varepsilon} \sum_{\substack{1\le j\le N \\ C\ne j}} D_j (MGES_{jC} - 1) \left(\frac{d\, log \frac{A_j}{A_C}}{d\, log\, A_C}\right) + D_C \frac{d\, log\, \varepsilon}{dA_C} \tag{12}$$

where Y = GDP, A_C = productivity in the construction sector, $\varepsilon = \sum_i D_i$ is the input–output multiplier, $\frac{d\log\frac{A_j}{A_C}}{d\log A_C}$ is the elasticity of sectoral productivity ratio with respect to construction productivity, and $MGES_{jC}$ = Morishima gross elasticity of construction in sector j.

Equation (12) presents the nonlinear (second-order) effect characterized by the MGES and the elasticity parameters of sectoral TFPs across sector pairs. The formulation of the second-order effect in Paul and Raju (2023) differs from that in Baqaee and Farhi (2019), as the latter do not consider the elasticity parameters of sectoral productivities ($\frac{d\log\frac{A_j}{A_C}}{d\log A_C}$), which capture the effect of the change in construction productivity on the productivity ratio between sector j and construction. If $\frac{d\log\frac{A_j}{A_C}}{d\log A_C} > 1$, then the TFP of sector j increases (decreases) with an increase (decrease) in the TFP of sector i. Similarly, if $\frac{d\log\frac{A_j}{A_C}}{d\log A_C} < 1$, then the TFP of sector j decreases (increases) with an increase (decrease) in productivity of sector i. The last term in Equation (12) becomes zero because, starting at an efficient equilibrium, reallocation effects are zero-sum distributive changes only and, as such, have no aggregate consequences (Baqaee and Farhi 2019).

If $MGES_{jC} > 1$, i.e. when intermediate inputs are gross substitutes, the aggregate effect of a positive shock in construction productivity is amplified and the aggregate effect of a negative shock in construction productivity is dampened. If intermediate inputs are gross complements, i.e. when $MGES_{jC} < 1$, the aggregate effect of a positive shock in construction TFP is dampened and the aggregate effect of a negative shock in construction TFP amplified. Figure A5 presents a schematic diagram of the second-order effect.

The elasticity of sectoral productivity ratio works as a catalyst and can alter the sign of the effect of $MGES_{jC}$. If $MGES_{jC} > 1$ and $\frac{d\log\frac{A_j}{A_C}}{d\log A_C}$ >1, then a positive shock in construction TFP is amplified further through sector j. If $MGES_{jC} > 1$ and $\frac{d\log\frac{A_j}{A_C}}{d\log A_C} > 1$, then a positive shock in sectoral TFP can have a dampening effect on aggregate output through sector j. On the other hand, when $MGES_{jC} < 1$ and $\frac{d\log\frac{A_j}{A_C}}{d\log A_C} > 1$, then the aggregate effect of a positive shock in construction TFP is further attenuated through sector j. Using the same logic, the aggregate effect of a positive shock in construction TFP can be amplified through sector j even if $MGES_{jC} < 1$ if $\frac{d\log\frac{A_j}{A_C}}{d\log A_C} < 0$. To summarize, sectoral productivity ratio elasticity plays distinct roles in the propagation of construction productivity shock when its value is less than zero, between zero and one, and greater than one.

We follow Paul and Raju (2023) to measure the MGES as the sum of two elasticities of substitution measures:

$$MGES_{ij} = \frac{d\log\frac{{y_i}^V}{{y_j}^V}}{d\log\frac{{A_i}^O}{{A_j}^O}} + \frac{d\log\frac{{A_i}^V}{{A_j}^V}}{d\log\frac{{A_i}^O}{{A_j}^O}} \tag{13}$$

where ${A_i}^V$ = value added in total factor productivity (TFP); ${y_i}^V$ = value added in sector i; ${A_i}^O$ = output TFP and ${y_i}^O$ = gross output in sector i. To estimate the second-order effect, we require two sets of data. First, we need data on intersectoral linkages, which can be obtained from the IO tables. IO tables are available for only 40 countries in WIOD and 69 countries in ICIO. Second, we need sectoral productivity measures that are comparable across countries.

We have PPP-adjusted prices for three benchmark years for a large sample of 168 countries from the ICP database. So, we are constrained by the availability of IO data. Since ICIO data cover a larger sample than WIOD, the ICIO appears to be a better choice. We work with a more reliable productivity (TFP) measure available from Fadinger et al. (2022), which satisfies a set of basic requirements for productivity comparisons across countries. To construct the sector-level productivity data, Fadinger et al. (2022) used the 2005 round of WIOD data. A recent paper by Paul and Raju (2023) extends this database to another ICP benchmark year, 2011. We use two rounds of comparable sectoral productivities (2005 and 2011) to compute the MGES and productivity elasticity parameters.

We follow two methods to compute the nonlinear aggregate effect. First, we derive a set of results based on back-of-the-envelope calculations, following Bachmann et al. (2022). This simple process transforms the first- and second-order effects into a linear combination of sectoral Domar weights: $\frac{d\log Y}{d\log A_C} + \frac{d^2\log Y}{d\log {A_C}^2} = D_C + \frac{1}{2}\Delta D_C$, or $d\log Y = d\log A_C\,(D_C + \frac{1}{2}\Delta D_C)$. This method makes it feasible to use the full sample of countries in the ICP data, as we do not need IO linkages. In the second method, we use the MGES and sectoral productivity elasticities (Equation 10) to compute the second-order effect using WIOD data.

4.3 Empirical results using sectoral Domar weights

Table 4 presents the counterfactual simulation results for the full sample of countries in the ICP. We calibrate the cross-country income disparity based on the actual changes in construction productivity between 2005 and 2011, and between 2011 and 2017. The results are shown in the first row of Table 4. The 10:1 spread in income in 2011 (55.42) based on the actual change in construction productivity between 2005 and 2011 closely corresponds to the figures presented in Table 1 (55.46) based on the development accounting framework.

Table 4: Income disparity and change in construction productivity, ICP

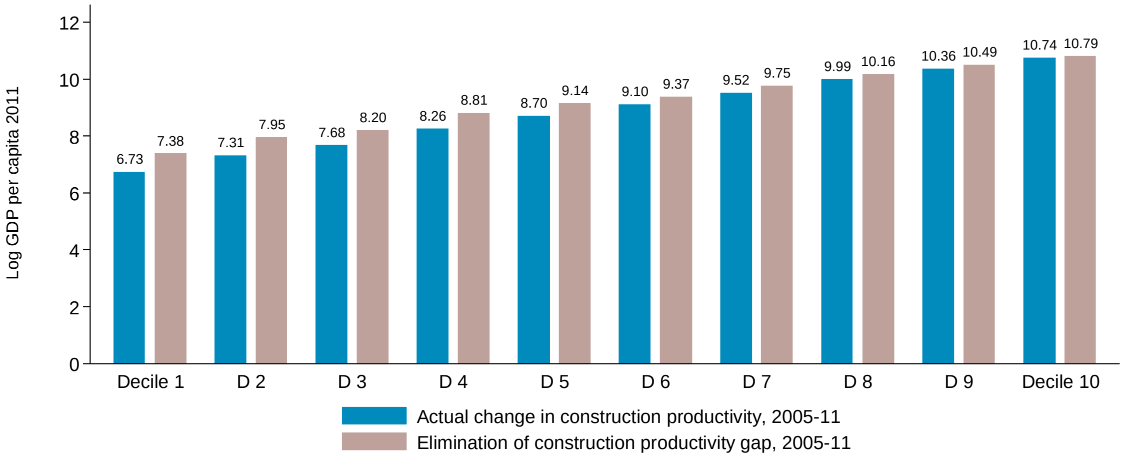
	Ratio of log GDP per capita 2011 decile 10 to decile 1				**Ratio of log GDP per capita 2017 decile 10 to decile 1**
	Due to change in labour productivity between 2005 and 2011 in				**Due to change in labour productivity between 2011 and 2017 in construction**
	Construction	**Residential building**	**Non-residential building**	**Civil engineering work**	
Actual change (baseline case)	55.42	56.93	58.34	56.86	48.50
Elimination of productivity gap	30.46	47.79	53.29	48.28	21.89
Twice the actual change in the bottom one-third of countries	48.82	54.41	57.19	55.26	46.45
Twice the actual change in the top one-third of countries	60.14	58.49	59.90	57.39	50.58

Note: 145 countries in 2005, 168 countries in 2011, and 166 countries in 2017.

Source: authors' estimates based on data from 2005, 2011, and 2017 rounds of ICP.

To understand the implications of changes in construction productivity on income disparity across countries, we consider three counterfactual scenarios. Elimination of cross-country disparity in construction productivity lowers the 10:1 spread in income in 2011 from 55.42 to 30.46, resulting in a drop in income inequality by almost 45 per cent. In Figure 5, we compare log GDP per capita between the baseline case, i.e. the actual change in construction productivity between 2005 and 2011, and the counterfactual case when the cross-country construction productivity gap is eliminated over the period from 2005 and 2011. As low-income countries predominantly have low productivity in construction (Hsieh and Klenow 2007), elimination of cross-country productivity in construction increases the rate at which less developed countries can catch up with advanced countries. The drop in income inequality is even larger in the 2017 figures. In 2017, the 10:1 spread in income drops from 48.50 to 21.89, i.e. by almost by 55 per cent.

Figure 5: Aggregate effect of construction productivity growth across income deciles



Note: 145 countries in 2005, and 168 countries in 2011.

Source: authors' estimates based on data from 2005, 2011, and 2017 rounds of ICP.

We find a smaller drop in income inequality resulting from an elimination of the productivity gap in residential building, non-residential building, and civil engineering work than from an elimination of the productivity gap in construction. This is due to smaller Domar weights for the sub-categories of construction than for construction.

On the other hand, when we allow the bottom one-third of countries to have construction productivity growth twice the actual size, the income disparity across countries is smaller than the baseline case (it drops from 55.42 to 48.82). Similarly, allowing the top one-third of countries to have construction productivity growth twice the actual size produces an opposite effect: the 10:1 spread in income increases from 55.42 to 60.14. Results are comparable when we consider similar counterfactual cases for the construction productivity gap for the period 2011–17, and the sub-components of construction for the period 2005–11.

As a robustness check, we also perform counterfactual simulations for the ICIO and WIOD samples of countries. Results are shown in Table 5. Elimination of the construction productivity gap results in a drop in the 10:1 spread in income in 2011 by almost 52 per cent (54 per cent using the ICIO and WIOD samples of countries). Similarly, an elimination of the construction productivity gap results in a drop in the 10:1 spread in income in 2017 by almost 49 per cent (53 per cent using the ICIO and WIOD samples of countries). Overall, the implications of the nonlinear propagation of construction productivity on income disparity across countries are robust across different samples of countries.

Table 5: Income disparity and change in construction productivity, ICIO and WIOD

	Ratio of log GDP per capita 2011 decile 10 to decile 1				Ratio of log GDP per capita 2017 decile 10 to decile 1
	Due to change in labour productivity between 2005 and 2011 in				Due to change in labour productivity between 2011 and 2017 in construction
	Construction	Residential building	Non-residential building	Civil engineering work	
A. ICIO					
Actual change (baseline)	18.47	19.58	19.58	18.94	12.07
Elimination of productivity gap	8.85	17.88	18.00	15.68	6.11
Twice the actual change in the bottom one-third of countries	14.86	18.78	18.86	17.92	10.64
Twice the actual change in the top one-third of countries	19.97	20.16	20.07	19.13	12.61
B. WIOD					
Actual change (baseline case)	8.28	10.33	10.21	9.78	4.76
Elimination of productivity gap	3.79	9.69	9.35	7.48	2.25
Twice the actual change in the bottom one-third of countries	6.12	9.76	9.75	9.03	3.95
Twice the actual change in the top one-third of countries	8.82	10.74	10.39	9.84	4.95

Note: 145 countries in 2005, 168 countries in 2011, and 166 countries in 2017.

Source: authors' estimates based on data from 2005, 2011, and 2017 rounds of ICP.

4.4 Empirical results using MGES and sectoral productivity elasticities

In this section, we discuss the empirical results on the non-linear propagation of changes in construction productivity using the variable elasticity of substitution parameters. The goal of this exercise is to highlight the nonlinear characterization of the aggregate propagation of construction productivity shock, albeit with a much smaller sample of countries.

Sectoral Domar weights play a crucial role in the second-order effect of a change in sectoral productivity (as shown by Equation 13). In Figure A6, we compare the Domar weights in construction for two benchmark years (2005 and 2011) across 40 countries. Countries that experienced a substantial increase in construction output as a share of GDP are China, Indonesia, Bulgaria, and Slovenia. Most of these countries are located in the bottom one-third of the income distribution. On the other hand, Spain, Ireland, and Czech Republic are among the countries that experienced a large drop in the share of construction output within GDP.

Panel A of Figure 6 plots the MGES for 34 sectors. We compute these elasticities for 40 countries, following Equation (13).[11] The changes in value added, value-added TFP, and output TFP are measured between 2005 and 2011. The estimate of MGES is less than 1 for six sectors (agriculture, textiles, leather, other non-metallic, real estate, and household employment), while outputs in the rest of the sectors are substitutes to construction output (i.e. MGES >1). Panel B of Figure 6 plots the sectoral productivity ratio elasticities with respect to changes in construction productivity. The sectoral productivity ratio elasticity with respect to construction productivity is less than 1 for all sectors, and is negative for all sectors except restaurants, air transport, financial services, real estate,

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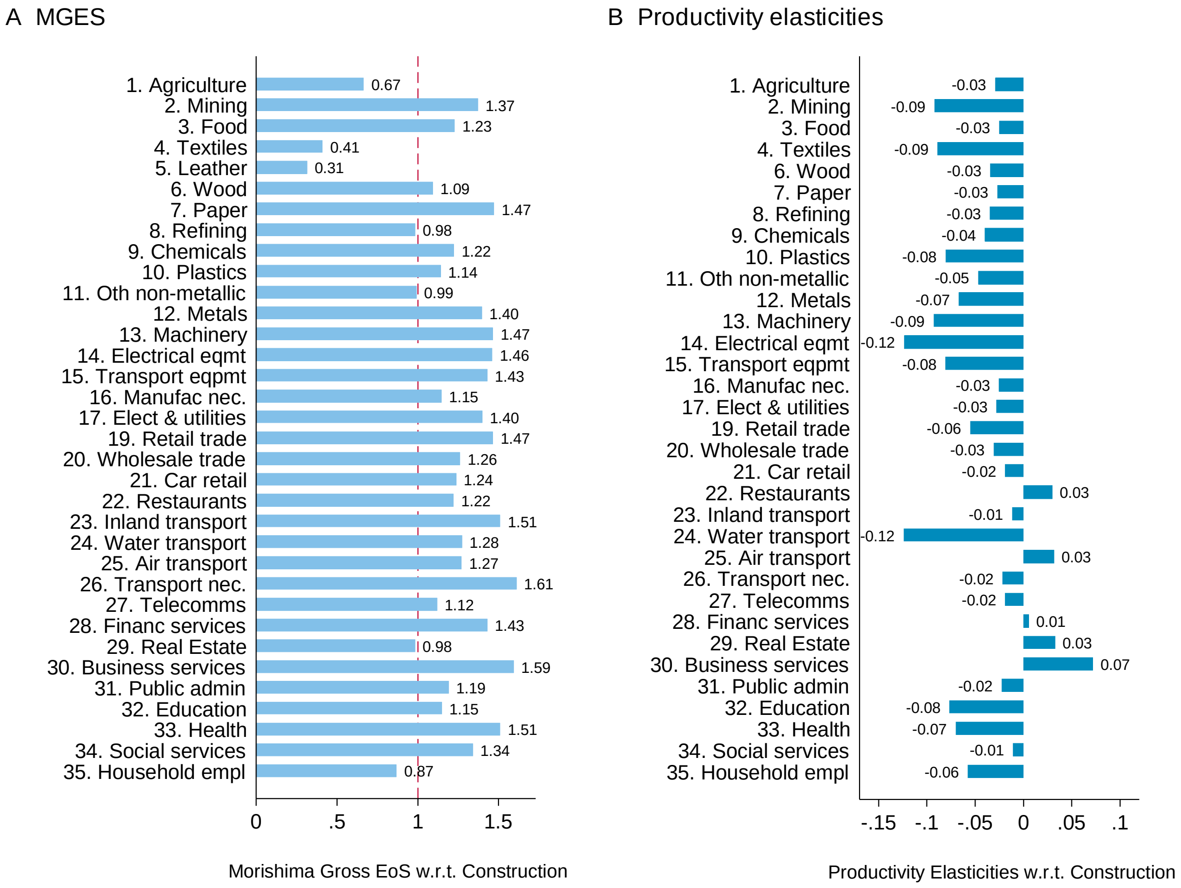
[11] See Paul and Raju (2023) for a detailed discussion of the computation of these elasticity parameters.

and business services. This suggests that, in sectors that are complementary to construction, the aggregate effect of a positive construction productivity shock can be dampened if the magnitude of productivity elasticity is less than 1. The magnitude of productivity elasticity also plays an important role in the propagation of construction productivity shock as it catalyses the effects of IO linkages.

Figure 6: MGES and sectoral productivity elasticities with respect to changes in construction productivity


A MGES

B Productivity elasticities

Note: the MGES is calculated across 34 sector pairs with respect to changes in productivity in construction between 2005 and 2011. The dotted line indicates MGES=1. The productivity elasticity for each sector is computed with respect to changes in construction productivity between 2005 and 2011.

Source: authors' elaboration based on 40 countries in WIOD (Timmer et al. 2015) and productivity data for 35 sectors from Fadinger et al. (2022).

Nonlinear characterization of the aggregate effect of sectoral productivity shocks in terms of reduced form non-parametric variable elasticities provides deeper insights into the propagation mechanisms and the individual role of each sector in it. As a final step, we compare the results based on back-of-the-envelope calculations (Section 4.3) with the outcomes from the variable elasticity of substitution parameters. We perform this exercise to check the consistency of the outcomes from these two methods. Figure A7 shows the scatterplot of income per capita generated by each method. The correlation of income from these two methods is 0.25, and it increases to 0.35 if we leave out South Korea, which appears to be the only country with negative income growth due to construction productivity shock.

The disparity between these two methods can arise for a variety of reasons, possibly including measurement errors. The back-of-the-envelope method assumes no role of IO linkages, and the differences in per capita GDP figures are mainly due to IO linkages across sectors. As highlighted by a growing literature (Acemoglu et al. 2012; Baqaee and Farhi 2019; Caliendo et al. 2018; Carvalho et al. 2021), production networks play a crucial role in propagating sectoral productivity shocks to other sectors and to the aggregate level. India, Indonesia, and Spain experienced a large negative productivity (TFP) shock in construction, and through IO linkages this propagated into an even larger negative aggregate effect. Except for this handful of countries, the linear combination of sectoral Domar weights approximates the nonlinear effect to a satisfactory level. Overall, the findings suggest the usefulness of nonlinear characterization of the aggregate effect of construction productivity shock for policy purposes.

To gather further insights into the differences in the role of different sectors in the aggregate effect across countries, we next compare the outcomes for China, India, and other countries in the WIOD data.

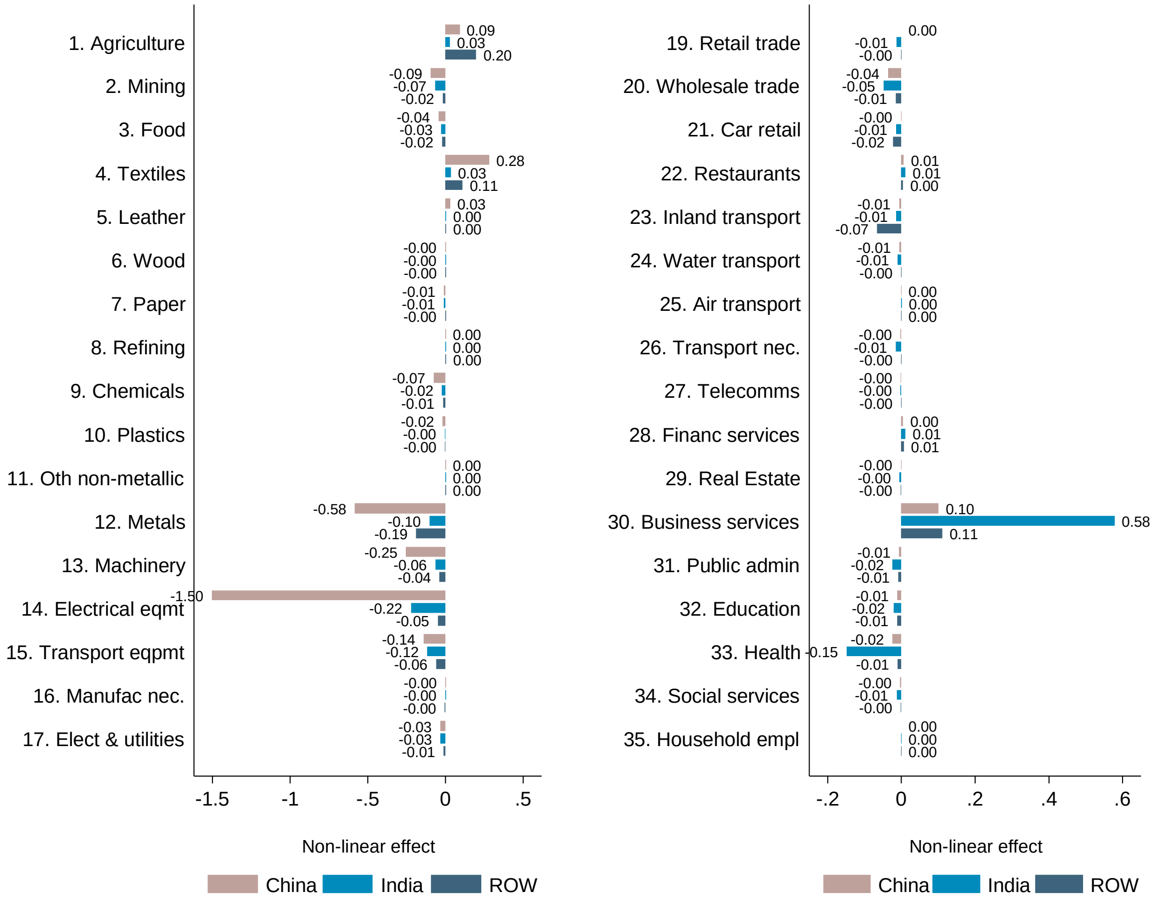
4.5 Sectoral effects: China, India, and the rest of the world

Over the past three decades, the share of employment and value added in construction has steadily increased in emerging market economies. China's construction sector has become the seventh-largest global downstream sector (Frohm and Gunnella 2017), while the largest employment share in construction among the 51 low- and middle-income countries was in India (16 per cent) in 2018. In this section, we take a closer look at the second-order aggregate effect of the change in construction productivity across 34 sectors in China, India, and the rest of the world (ROW)—where ROW represents the average productivity of 38 countries in the WIOD data.

As shown in Figure 7, the nonlinear effects are prominent in the following 13 out of 34 sectors: agriculture, mining, food, oil refining, metals, machinery, electrical equipment, transport equipment, car retail, restaurants, real estate, financial services, and telecommunication services. Among these 13 sectors, the effect of construction productivity shock is stronger in China than in other countries in the following six sectors: textiles, mining, metals, machinery, electrical, and transport equipment. This is not surprising, as the construction, basic metals, and electrical and optical equipment sectors in China rank among the top 10 downstream hubs in global value chains (Frohm and Gunnella 2017).

On the other hand, the contribution of the business sector to aggregate productivity growth is larger in India than in other countries. The prominence of business sector activities in connection with construction could be related to capital import substitution policies and their reform post-1991 (Johri and Rahman 2022; Sen 2007). The property sector alone secures a staggering 30 per cent of China's GDP (Rogoff and Yang 2021), but we find a negligible contribution of real estate to aggregate output growth arising from construction productivity shock in either China or India. Overall, the sectoral outcomes appear meaningful and reflect China's growing predominance in the global value chains through construction.

Figure 7: Sectoral effects of changes in construction productivity: China, India, and the rest of the world



Note: non-linear (second-order) effects of changes in construction productivity are calculated using Equation (10). They represent the change in log GDP per capita in each sector. We multiply the sectoral effects by 1,000 just to magnify them for the sake of comparison. ROW = rest of the world: an average of 38 countries other than China and India in the WIOD sample.

Source: authors' elaboration based on 40 countries in WIOD (Timmer et al. 2015), and productivity data for 35 sectors from Fadinger et al. (2022).

5 Conclusion

In 2020, construction accounted for 13 per cent of the world's GDP following steady growth in construction activities in many low- and middle-income countries since the early 1990s. Furthermore, that growth was accompanied by a shift of the downstream hub in construction in global value chains from advanced countries to emerging markets, particularly to China. The construction boom, alongside its new role through the production network, is expected to support many low-income countries in the global south in making a strong recovery from the COVID pandemic, as global construction output is predicted to grow at an annual rate of 6.7 per cent between 2020 and 2030 (Oxford Economics 2021).

This study aims to understand the consequences of the steady growth in construction activities on the cross-country income gap. We compare construction performance across countries and quantify the implications of heterogeneity in construction productivity on cross-country income differences. Using multiple rounds of the International Comparisons Program data and the World Input–Output Database, we find large disparity in construction productivity across countries. The

10:1 spread in construction productivity is a factor of 61.7-fold in 2005 based on 145 countries. Eliminating the cross-country disparity in construction productivity lowers income inequality by 45 per cent. The quantitative results of the heterogeneity in construction productivity on income disparity across countries are robust across different samples of countries. The nonlinear characterization of the aggregate effect of the change in construction productivity points to heterogeneous roles of sectors. For instance, we find stronger roles of metals, machinery, and electrical equipment in the aggregate propagation of the construction productivity shock in China than in other countries.

Much of the earlier empirical growth literature has focused on machinery investment, and the role it may play in increasing economic growth. Our paper highlights the growing importance of construction investment, especially in low-income countries. We show that the elimination of differences in construction productivity gaps should also be a focus of policy-makers to reduce global income inequality. Further, greater attention needs to be given to how particular sectors may amplify the positive effect of a construction productivity shock on aggregate economic growth.

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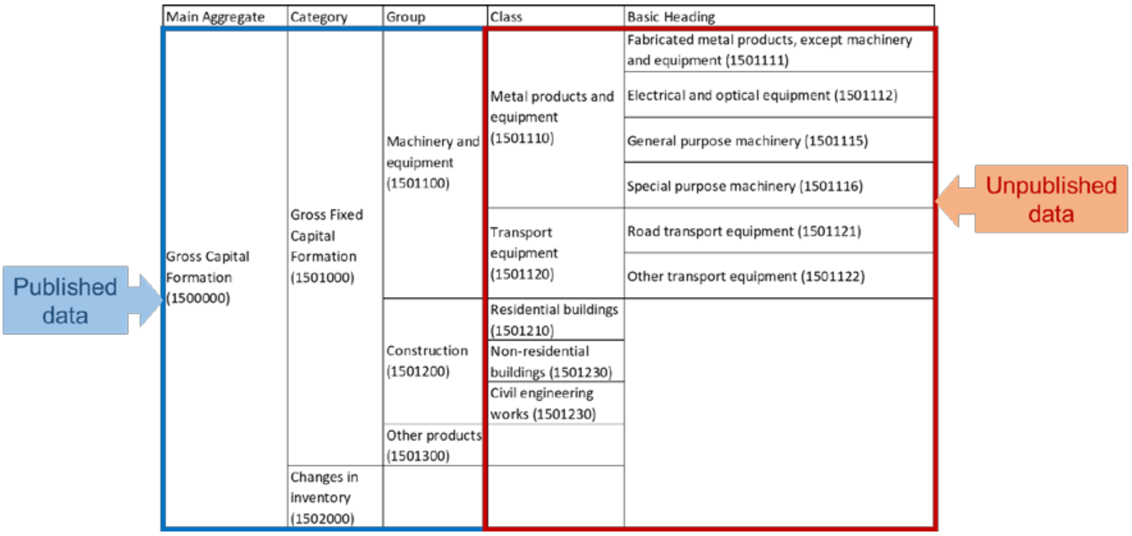
Appendix: Tables and Figures

Table A1: The International Comparisons Program database: mapping of expenditure categories



Main Aggregate	Category	Group	Class	Basic Heading
Gross Capital Formation (1500000)	Gross Fixed Capital Formation (1501000)	Machinery and equipment (1501100)	Metal products and equipment (1501110)	Fabricated metal products, except machinery and equipment (1501111)
				Electrical and optical equipment (1501112)
				General purpose machinery (1501115)
				Special purpose machinery (1501116)
			Transport equipment (1501120)	Road transport equipment (1501121)
				Other transport equipment (1501122)
		Construction (1501200)	Residential buildings (1501210)	
			Non-residential buildings (1501230)	
			Civil engineering works (1501230)	
		Other products (1501300)		
	Changes in inventory (1502000)			

Source: authors' construction based on ICP.

Table A2: Mapping of production sectors and expenditure categories

	Production sectors	ICP expenditure categories
1	Agriculture	FOOD AND NON-ALCOHOLIC BEVERAGES (1101000)
2	Mining	MACHINERY AND EQUIPMENT (1501100)
3	Manufacturing	CLOTHING AND FOOTWEAR (1103000)
4	Public utility	COLLECTIVE CONSUMPTION EXPENDITURE BY GOVERNMENT (1400000)
5	Construction	CONSTRUCTION (1501200)
6	Wholesale and retail trade	RESTAURANTS AND HOTELS (1111000)
7	Transport	TRANSPORT (1107000)
8	Business	COMMUNICATION (1108000)
9	Public services	INDIVIDUAL CONSUMPTION EXPENDITURE BY GOVERNMENT (1300000)
10	Private services	INDIVIDUAL CONSUMPTION EXPENDITURE BY HOUSEHOLDS WITHOUT HOUSING (9260000)

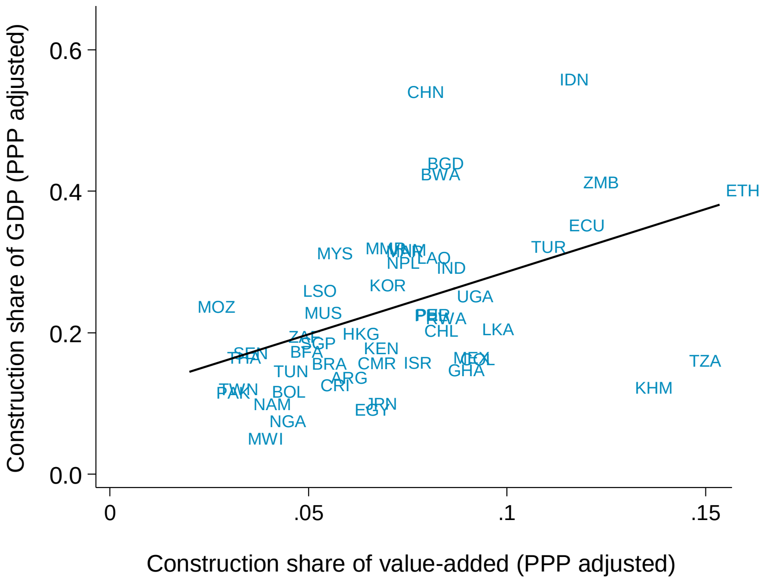
Source: authors' estimates based on data from WIOD (Timmer et al. 2015) and from the 2005, 2011, and 2017 rounds of ICP.

Table A3: Mapping of WIOD sectors to 10 sector categories

	WIOD sectors		10-sector category
1	Crop and animal production, hunting and related service activities	**c1**	Agriculture
2	Forestry and logging	**c2**	
3	Fishing and aquaculture	**c3**	
4	Mining and quarrying	**c4**	Mining
5	Manufacture of food products, beverages and tobacco products	**c5**	Manufacturing
6	Manufacture of textiles, wearing apparel and leather products	**c6**	
7	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	**c7**	
8	Manufacture of paper and paper products	**c8**	
9	Printing and reproduction of recorded media	**c9**	
10	Manufacture of coke and refined petroleum products	**c10**	
11	Manufacture of chemicals and chemical products	**c11**	
12	Manufacture of basic pharmaceutical products and pharmaceutical preparations	**c12**	
13	Manufacture of rubber and plastic products	**c13**	
14	Manufacture of other non-metallic mineral products	**c14**	
15	Manufacture of basic metals	**c15**	
16	Manufacture of fabricated metal products, except machinery and equipment	**c16**	
17	Manufacture of computer, electronic and optical products	**c17**	
18	Manufacture of electrical equipment	**c18**	
19	Manufacture of machinery and equipment n.e.c.	**c19**	
20	Manufacture of motor vehicles, trailers and semi-trailers	**c20**	
21	Manufacture of other transport equipment	**c21**	
22	Manufacture of furniture; other manufacturing	**c22**	
23	Repair and installation of machinery and equipment	**c23**	
24	Electricity, gas, steam and air conditioning supply	**c24**	Public utility
25	Water collection, treatment and supply	**c25**	
26	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	**c26**	
27	Construction	**c27**	Construction
28	Wholesale and retail trade and repair of motor vehicles and motorcycles	**c28**	Wholesale and retail trade
29	Wholesale trade, except of motor vehicles and motorcycles	**c29**	
30	Retail trade, except of motor vehicles and motorcycles	**c30**	
31	Land transport and transport via pipelines	**c31**	Transport
32	Water transport	**c32**	
33	Air transport	**c33**	
34	Warehousing and support activities for transportation	**c34**	
35	Postal and courier activities	**c35**	
36	Accommodation and food service activities	**c36**	Business
37	Publishing activities	**c37**	
38	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	**c38**	
39	Telecommunications	**c39**	
40	Computer programming, consultancy and related activities; information service activities	**c40**	
41	Financial service activities, except insurance and pension funding	**c41**	
42	Insurance, reinsurance and pension funding, except compulsory social security	**c42**	
43	Activities auxiliary to financial services and insurance activities	**c43**	
44	Real estate activities	**c44**	
45	Legal and accounting activities; activities of head offices; management consultancy activities	**c45**	
46	Architectural and engineering activities; technical testing and analysis	**c46**	
47	Scientific research and development	**c47**	
48	Advertising and market research	**c48**	
49	Other professional, scientific and technical activities; veterinary activities	**c49**	
50	Administrative and support service activities	**c50**	
51	Public administration and defence; compulsory social security	**c51**	Public services
52	Education	**c52**	
53	Human health and social work activities	**c53**	Private services
54	Other service activities	**c54**	
55	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	**c55**	
56	Activities of extraterritorial organizations and bodies	**c56**	

Source: authors' estimates based on data from WIOD (Timmer et al. 2015) and from the 2005, 2011, and 2017 rounds of ICP.

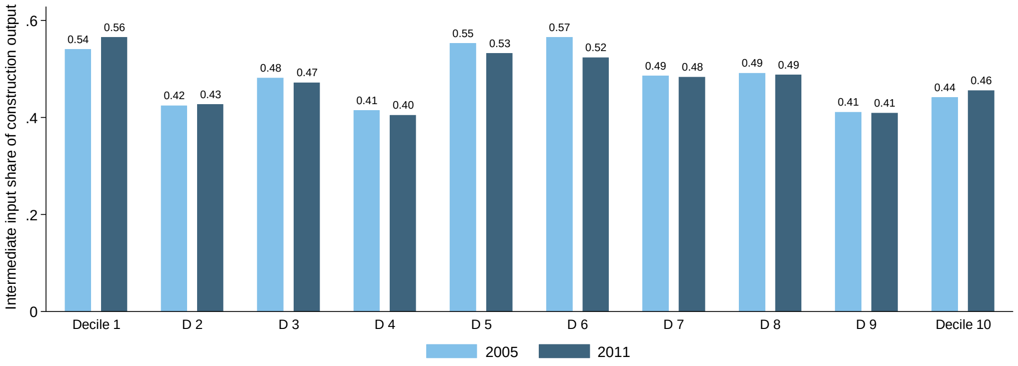
Figure A1: Construction expenditure and value-added share in 2017



Note: includes 51 countries.

Source: authors' estimates based on data from ETD and the 2005, 2011, and 2017 rounds of ICP.

Figure A2: Intermediate input share of construction output

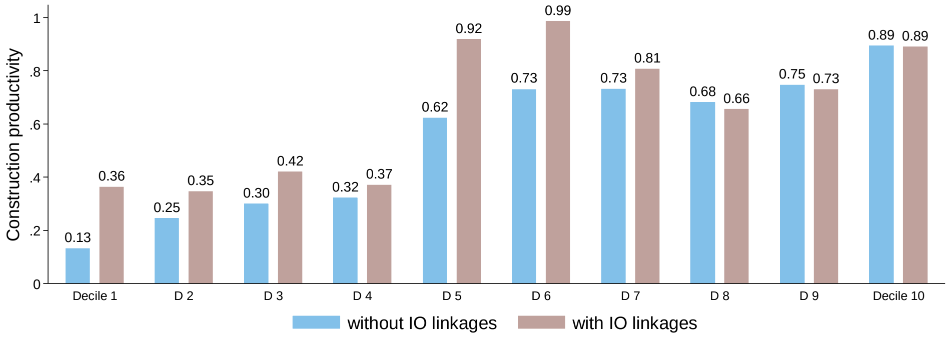


Note: sample includes 40 countries with a population of more than 1 million that are common between ICP and WIOD. Countries are ranked according to real GDP per capita and distributed among 10 income deciles. Intermediate input share of construction output = the share of produced inputs in construction output.

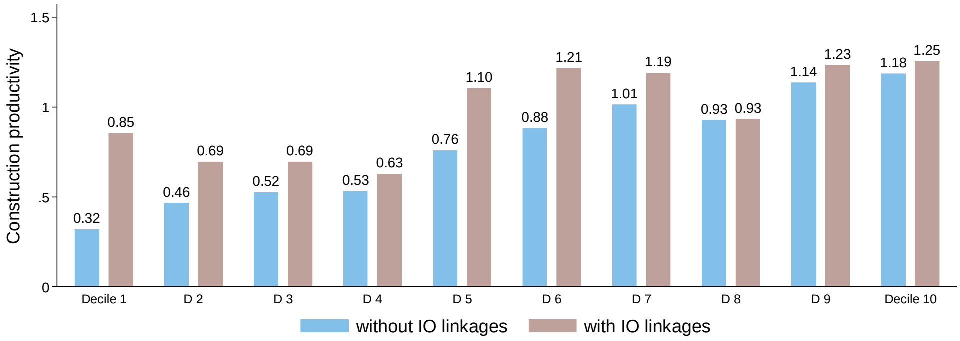
Source: authors' estimates based on data from WIOD (Timmer et al. 2015).

Figure A3: Construction productivity, with and without IO linkages

A 2005



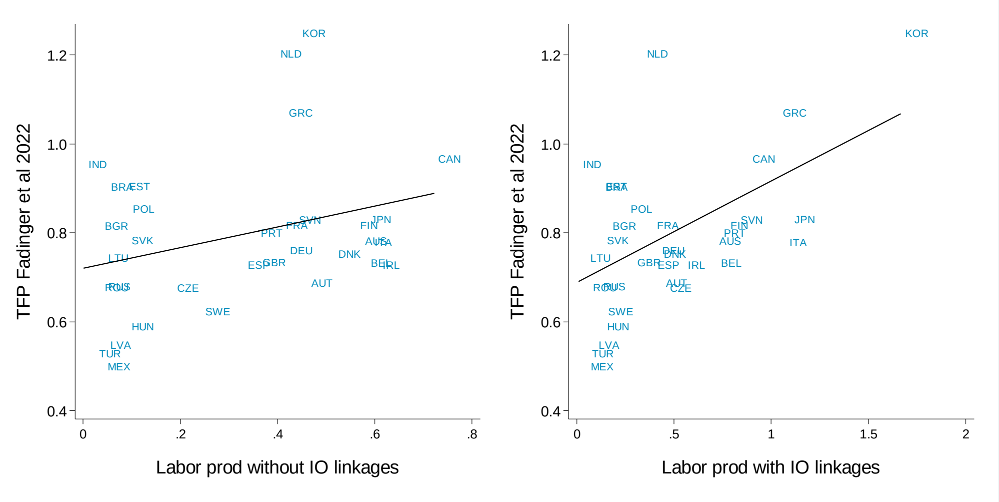
B 2011



Note: sample includes 40 countries with s population of more than 1 million that are common between ICP and WIOD. Countries are ranked according to real GDP per capita and distributed among 10 income deciles. Construction productivity without IO linkages is calculated using Equation (1), and construction productivity with IO linkages is calculated using Equation (3) with 10 sectors.

Source: authors' estimates based on data from WIOD (Timmer et al. 2015) and from the 2011 round of ICP.

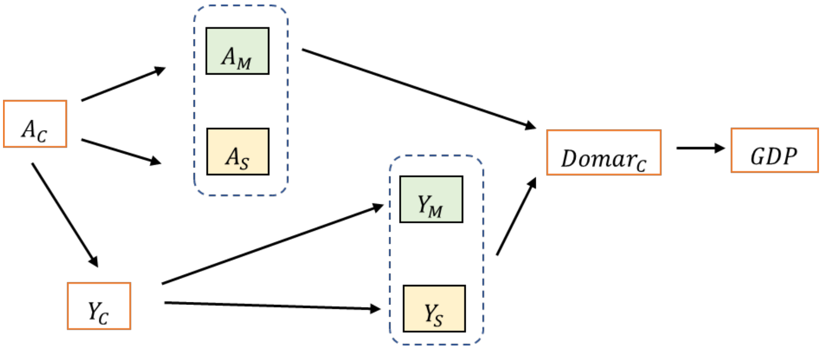
Figure A4: Labour productivity with IO linkages and TFP in construction



Note: sample includes 33 countries that are common between ICP, WIOD, and Fadinger et al. (2022). Construction labour productivity without IO linkages is calculated using Equation (1), and construction labour productivity with IO linkages is calculated using Equation (3) with 10 sectors. Construction TFP is taken from Fadinger et al. (2022).

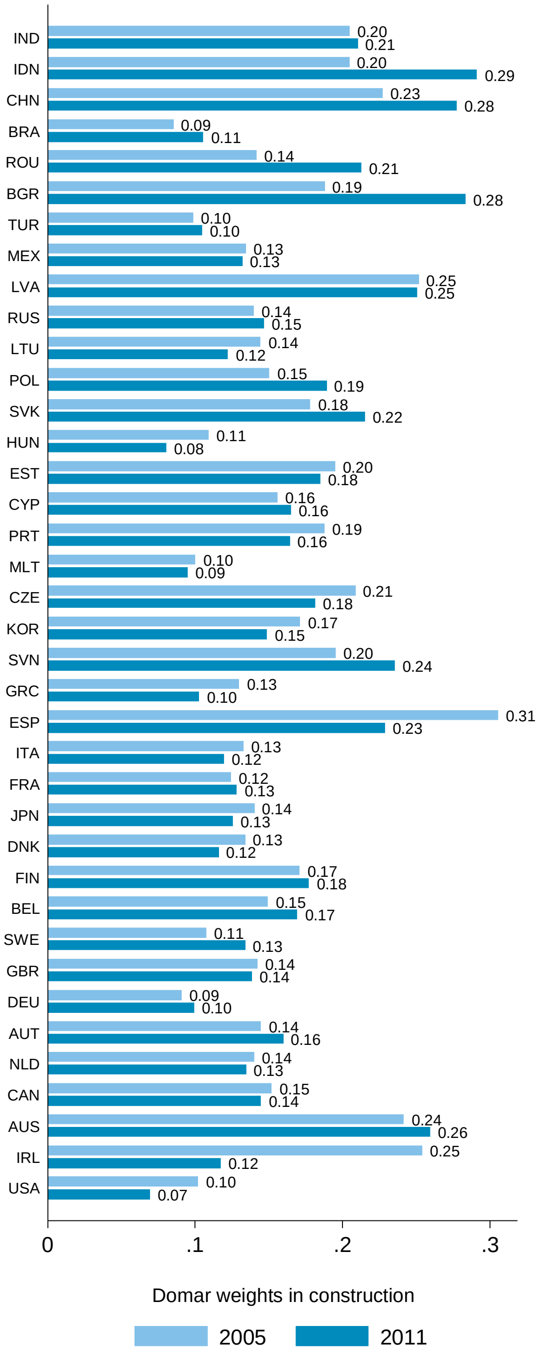
Source: authors' estimates based on data from WIOD (Timmer et al. 2015), data from 2005 round of ICP, and estimates from Fadinger et al. (2022).

Figure A5: Second-order effect of sectoral productivity shock



Source: authors' construction.

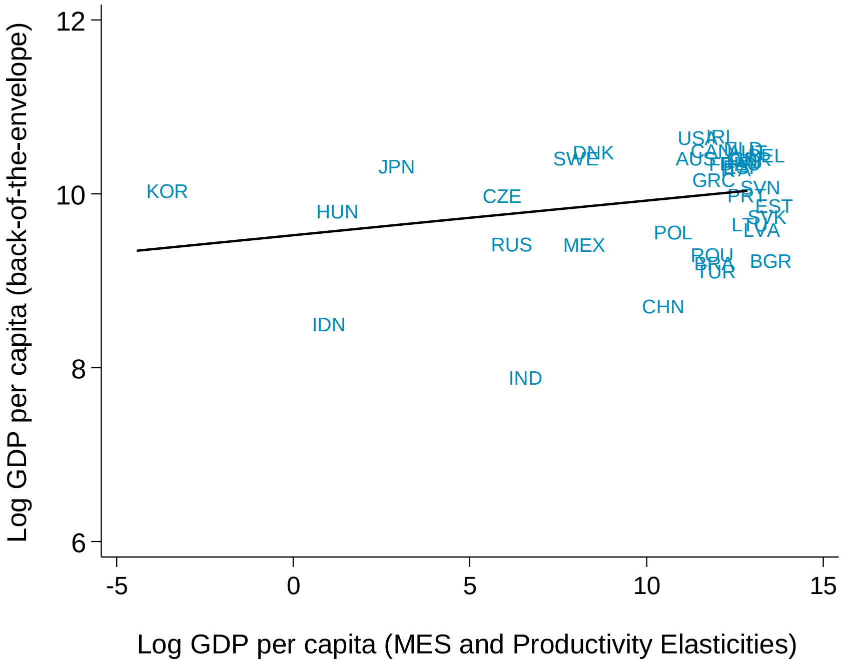
Figure A6: Domar weights in construction, 2005 and 2011



Note: countries are ranked low (top) to high (bottom) based on GDP per capita in 2005.

Source: authors' elaboration based on 40 countries from WIOD (Timmer et al. 2015) and productivity data for 35 sectors from Fadinger et al. (2022).

Figure A7: Aggregate effect of changes in construction productivity using different methods



Source: authors' elaboration based on 40 countries from WIOD (Timmer et al. 2015) and productivity data for 35 sectors from Fadinger et al. (2022).