On the Investment Network and Development*

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Preliminary

Abstract

The question of whether economic development requires a broad or focused investment strategy has long been a subject of debate among academics and policymakers alike. Through the lens of a parsimonious multisector model augmented to multiple capital types and intersectoral trade in intermediates and investment, we show that the aggregate output elasticity to sectorial productivity growth and to the terms of trade in investment producing sectors depends on the characteristics of the investment network and its interplay with the input-output structure. This paper provides novel and harmonized measures of the investment network across countries. Through income accounting exercises, we show that on average, 24% of income differences across countries can be accounted for by disparities in the investment network. At early stages of development, output elasticities to investment producing sectors are most similar across sectors, and they become more disperse at later stages of development. Importantly, the importance of different equipment types for total investment changes with income: at early stages of development, the importance of Construction is relatively high; whereas at later stages of development, ICT becomes most important. Transportation contributes similarly across the development spectrum.

JEL Codes: E23; E21; O41.

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1 Introduction

What is it required to break a country out of low-level of economic development? A coordinated broadly based investment program, a *Big Push* as in Rosenstein-Rodan (1943), or a targeted program to a handful of sectors with strong linkages, as in Hirschman (1958)? Despite the importance of providing an answer to this long-standing discussion, systematic cross-country empirical support for either of these hypothesis remains elusive.[1]

To contribute to this debate, we construct the first available measures of the investment network for multiple countries at different stages of development. The investment network rescales the capital-flow table by the total investment in each sector, so that each entry in the network corresponds to the sectorial cost share in investment of a given type within a (column) sector. Each row of the capital-flow table records the allocation of investment (new capital) for the production of different sectors, with row-sums adding to total output of a sector allocated to investment. Each column of the capital-flow table records the intensity of use of different investment by a given sector, with the column-sum adding to total investment for production in a sector. The entries in the investment network along each column summarize the intensity of use of different capital types within each sector, while the entries along each row summarize the importance of a sector as a producer of investment to the overall economy. The network is then a measure of what Hirschman (1958) refers to as forward and backward linkages of sectors producing or importing investment.

To understand the role of these linkages for aggregate economic activity, we develop a multisector model of production, where sectors produce using intermediate inputs and capital of different types at different intensities. Disparities in investment intensity drive disparities in capital-labor ratios across sectors even when markets are competitive.[2] Hence, in a close economy environment, aggregate value added depends on sectorial productivities as well as on the sectorial employment distribution, weighted by output elasticities to sectorial productivity. In an open economy, aggregate value added is also a function of the terms of trade. The impact of the terms of trade is potentially important in poor economies where capital is, for the most part, imported (Eaton and Kortum, 2001).

We use the theory to inform our measurement of aggregate output elasticities to sectorial productivity. We call the vector that summarizes these output elasticities the "influence vec-

[1]There is scattered evidence focusing on industrial policy towards heavy machinery in Korea, Choi and Levchenko (2021), shipment industry in China Barwick, Kalouptsidi and Zahur (2019), and steel rail in the US, Head (1994), among others. However, these studies are narrow in industry scope and country coverage. Another related literature entertains the "Big push", from early work of Murphy, Shleifer and Vishny (1989) to the most recent work in Buera, Hopenhayn, Shin and Trachter (2021). These studies focus on conditions that may may warrant a "big push" in policy design, either due to equilibrium multiplicity or strong complementarities in production.

[2]It is possible that disparities across sectors and countries in these intensities, i.e. the investment network, reflect distortions. For the purpose of the current analysis, we take this heterogeneity as a technological feature. Our framework can be readily extended to allow for wedges, but empirical identification would ultimately require taking a stand on the nature of technology across sectors within countries, and across countries for a given sector.

tor", following the now extensive literature that studies network properties of the economy, Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012). The influence vector summarizes the direct and indirect impact of changes in sectorial productivity and in the terms of trade for aggregate economic activity. Influence is a function of the input-output structure as well as of the investment network of the economy, through an augmented Leontief inverse. While measures of the input-output structure have become increasingly available across countries, estimates of the investment network are only available for the US (vom Lehn and Winberry, 2022) and a handful of advanced economies (Ding, 2023).[3]

We advance previous measurement efforts by providing harmonized estimates of the investment network across 22 countries at different stages of development, i.e. incomes per capita between \$1,450 and \$112,229 constant PPP dollars. For many countries, noticeably South Korea, we provide time-series estimates of the investment network that go back to 1960s. In our analysis, capital is disaggregated into multiple equipment types, including ICT, Electronics, Machinery and Transportation; as well as structures, measured through Construction investment.[4]

To create our new harmonized measures of the investment network, we exploit a methodology similar to that of the Bureau of Economic Analysis (BEA) in the US. The BEA combines the occupational composition of each industry and an allocation rule for capital to workers, to estimate investment by capital type and sector. Unfortunately, the apportioning of stocks to workers is not publicly available. Hence, to assure replicability, we opt for an allocation of capital across sectors that follows Caunedo, Jaume and Keller (2023) for equipment; and an allocation that follows intermediate inputs for construction and other sectors with positive investment in final uses. While the allocation of investment may seem arbitrary, it is reassuring that our own estimates of capital-flow tables in the US follow closely those published by the BEA.[5]

We document systematic disparities in the investment network as countries develop. Using time-series for Korea, we show that at early stages of development, overall investment relied mostly on flows produced in the Construction and the Service sectors, whereas at later stages of development, the investment network diversifies with raising importance of Machinery and Transportation.[6] A useful summary statistic to measure the relevance of sectors as providers of investment is the the *outdegree* of a sector in the network, which corresponds to the row-sum of the entries in the network. Thus, outdegrees measure forward linkages which are strongly related to "upstreamness", as defined by Antras, Chor, Fally and Hillberry (2012). On average, countries' investment diversifies as countries develop. In poorer economies such as Ghana

[3]These measures are self-reported by country offices to the OECD Statistics office, and it is unclear whether measurement is comparable across countries.

[4]Our benchmark estimates include 8 sectors but estimates for 19 sectors can be made readily available.

[5]The mean square error in the network between 1960 and 2014 is 0.04.

[6]The Service sector includes repairs of durable goods which in some accounting frameworks are capitalized and reported as investment in final uses. There is also positive investment reported as final uses from the Wholesale and Retail Sector.

and Ethiopia, the sectors with highest out-degrees are Construction and Services. In richer economies, ICT, Construction and Transportation report the highest outdegrees, but the levels of outdegrees become more similar across sectors.

So are sectors with high *outdegrees* in the investment network also sectors where changes in productivity have the strongest impact on aggregate activity? The answer is no. Our theory predicts that it is the interplay between the IO structure and the investment network, as well as the patterns of final expenditure shares that ultimately determine such a pass-through. Hence, to assess the role of changes in productivity in equipment producing sectors (or in the terms of trade) , we measure aggregate output elasticities and run an income accounting exercise.

We find that disparities in sectorial productivity explain the bulk of income disparities, consistently with the literature. An economy without IO structure of investment network generates 36% of the benchmark differences across countries. The investment network, either directly, or through interactions with the IO structure accounts for 24% of these disparities (4% directly and 20% through interactions). The contribution of the investment network is roughly a third of the contribution of disparities in the input-output structure highlighted by Fadinger, Ghiglino and Teteryatnikova, 2022, i.e. 40% on average across countries plus 20% from interactions with the investment network. A lower amplification effect from disparities in the investment network is not surprising given the magnitudes of gross output sectorial elasticities to intermediate inputs and to capital: the former is 0.58 on average while the latter is 0.10 on average across sectors and countries.

Disparities in the investment network reflect differences in the technology used for production, possibly as a consequence of distortions that shift relative prices or as a consequence of disparities in comparative advantage. To further understand the implications of disparities in investment network for income differences, we construct two exercises: we impose the investment network observed in the US in 1948 and in 2014 to the economies in our sample. We interpret the investment network in 1948 as production with relatively "old" technology, and the investment network in 2014 as production with relatively "new" technology. We show that poorer economies benefit relatively more from producing with the investment network of the US in 1948 (given their IO structure, sectorial productivities and patterns of final expenditure shares), while richer economies would benefit relatively more from producing with the investment network of the US in 2014.

Given these results, is there something one can learn in terms of the impact of investment policies? To address this question we study heterogeneity in the influence vector for countries at different stages of development.[7] We show that output elasticities are most similar across sectors in relatively poor economies, and they became more heterogeneous across sectors in rich economies. This heterogeneity is partially driven by the raise in the importance of ICT relative to other types of investment. An implication of this finding is that in poor economies, sectorial

[7] We are in the process of constructing measures of relative prices of different equipment types across countries from imported data, and we are planning to study the link between these prices and the characteristics of the investment network.

productivity improvements (or changes in the terms of trade) would generate similar impacts on value-added per worker, irrespective of the sector implementing it. In rich economies, heterogeneity in output elasticities imply that targeted policies may have heterogeneous effects depending on the sector implementing it.

Contribution to the literature. There is a growing literature studying the relevance of sectorial linkages for differences in income per capita across countries. The role of intermediate input linkages has been highlighted by Ciccone (2002); Jones (2011). This role has been quantified in Fadinger *et al.* (2022), who employs cross-country measures of input-output linkages as measured from the World Input-Output Dataset (WIOD) to show that differences in the IO structure across countries amplify the role of sectorial TFP for differences in income per capita. We show that the investment network can dampen or amplify this effect depending on the correlation between sectors' importance as providers of intermediate inputs and investment. Quantitatively, we find that disparities in the investment network amplify the role of productivity disparities for cross-country income difference.

We also contribute to this literature by allowing for dynamics in the accumulation of capital across sectors. Unitary elasticities of substitution in sectorial investment aggregators, as well as in intermediate inputs allow us to handle the empirical heterogeneity in factor intensities across sectors and the dynamics of capital-accumulation, while being consistent with balanced growth. As in Acemoglu *et al.* (2012) and Liu (2019) output elasticities to sectorial productivity are different than Domar weights. In our framework, this is the result of non-trivial dynamics in capital rather than distortions in production. Indeed, a static version of our economy with full capital depreciation eliminates this disparity.

The main empirical contribution of our paper is to construct estimates of the investment network for multiple countries. Measures of investment by sector are unavailable in many developing and developed countries, with the exception of the BEA's estimates for the US and the OECD's countries' self-reported statistics on expenses. Our estimates provide the first available measures of the composition of the capital stocks used in different sector across the development spectrum. We not only document shifts in the inputs used to produce investment (consistently with Garcia-Santana, Pijoan-Mas and Villacorta, 2021; Herrendorf, Rogerson and Valentinyi, 2021), but also shifts in the uses of capital across disaggregated sectors. Heterogeneity in the composition of the capital stock as a driver of the reallocation of economic activities is highlighted in Caunedo and Keller (2023), in an economy where technological change is embodied in capital. Distinctively from this work, we model intersectorial linkages and study an open economy framework. Highlighting the role of imported equipment for economic growth brings new relevance to the higher cost of investment relative to consumption in poorer countries, and these country's ability to generate resources to trade for these capital goods, Hsieh and Klenow (2007).[8]

[8]Gaggl, Gorry and vom Lehn (2023) and Foerster, Hornstein, Sarte and Watson (2022) study the properties of the investment network in the US within a closed economy framework. Foerster *et al.* (2022) abstract from feedback effects between imported capital, the stock of capital available in the economy and sectorial output by assuming

2 Accounting framework

We build a framework to study the impact of long-term shifts in the composition of imported investment across sectors, as well as TFP growth in sectors producing equipment and structures for aggregate GDP growth.

The economy consists of N sectors that combine capital, labor and intermediate inputs to produce output.

$$y_{nt} = \left(\frac{v_{nt}}{\gamma_{nt}}\right)^{\gamma_{nt}} \left(\frac{m_{nt}}{1-\gamma_{nt}}\right)^{1-\gamma_{nt}}, \qquad \text{for } \gamma_{nt} \in [0,1],$$

a measure of value added $v_{nt} = \exp(z_{nt}) \left(\frac{k_{nt}}{\alpha_n}\right)^{\alpha_n} \left(\frac{l_{nt}}{1-\alpha_n}\right)^{1-\alpha_n}$ that depends on productivity z_{nt}, and capital and labor allocations, k_{nt}, l_{nt}; and a constant returns to scale intermediate input aggregator $m_{nt} = \prod_{i=1}^{N} \left(\frac{m_{int}}{\mu_{int}}\right)^{\mu_{int}}$ with $\sum_i \mu_{int} = 1$. The amount of intermediate inputs from sector i used in sector n is m_{int}. This flow of intermediate inputs is summarized by an IO matrix, M_t, with typical element μ_{int}. The rows of M_t add to the importance of a sector as an intermediate inputs provider to the rest of the economy, the columns summarize the input composition of the intermediate input bundle in a sector. It will also be convenient to define $\Gamma_t = \text{diag}\{\gamma_{nt}\}$, a matrix of value added shares in production, as well as matrix of capital expenditure shares, $\alpha_t = \text{diag}\{\alpha_{nt}\}$.

The capital stock used in each sector follows the following law of motion,

$$k_{nt+1} = x_{nt+1} + (1-\delta_n) k_{nt},$$

for a composite of investment from different sectors.[9] For simplicity, we assume this composite takes a Cobb-Douglas form

$$x_{nt} = \prod_{i=1}^{N} \left(\frac{\chi_{int}}{\omega_{int}}\right)^{\omega_{int}},$$

for $\sum_{i=1}^{N} \omega_{int} = 1$, and ω_{int} the expenditure share in investment from sector n in sector j. The flow of investment is summarized by the capital flow table, Ω_t, with typical element ω_{int}. Inputs from sector i into the production of investment in other sectors, χ_{it} can be domestically produced or imported, $\chi_{int} = (\frac{\chi^d_{int}}{1-\phi_i})^{1-\phi_i} (\frac{\chi^f_{int}}{\phi_i})^{\phi_i}$, where ϕ is the expenditure share in foreign inputs.

Each sectors' output can be used for production of the final good, c, intermediate uses m, or investment, χ . Hence, feasibility requires

$$y_{nt} = c_{nt} + \sum_j m_{njt} + \sum_j \chi^d_{njt}.$$

that either the share of imported investment is small, or that there are no time-trends in the terms of trade. Neither of these assumptions is realistic for the economies that we study. Gaggl *et al.* (2023) run their quantitative analysis with a single capital good for production.

[9] A timing of investment that is contemporaneous to the stock that is being used in the period simplifies the notations without substantial changes to the analysis, because we focus on steady state allocations.

Sectorial output is combined with a homothetic aggregator into a final good

$$Y_t = \prod_{n=1}^{N} \left(\frac{c_{nt}}{\theta_n} \right)^{\theta_n}, \qquad \sum_{n=1}^{N} \theta_n = 1 \text{ and } \quad \theta_n > 0.^{10}$$

The final good can be used for consumption of the representative household, or for exports, ϵ.

$$Y_t = C_t + \epsilon_t$$

We need to define the value of next exports in the economy as the difference in the value of exports and imports

$$NX_t = \epsilon_t - p_{\epsilon^f t} \epsilon_t^f,$$

The value of imports is the product between the price index of imports and a composite import value $\epsilon_t^f = \prod_{i=1}^{N} \frac{\chi_{it}^f}{\psi_{it}^f}^{\psi_{it}^f}$, as in Basu, Fernald, Fisher and Kimball (2005).[11] Hence, the terms of trade in this economy are given by the ratio between the price of final output (and therefore of exports) and the price of imports $\tau \equiv \frac{1}{p_{\epsilon^f t}}$. The price of imported goods is exogenous to the economy, and assuming trade balance pins down the value of exports in equilibrium. The price of imported goods is a CRS aggregator of the (exogenous) prices of imported investment for production.

2.1 Equilibrium characterization. Closed economy.

We first study a closed economy. This amounts to assuming $\phi_i = 0$, or $\chi_{it}^f = 0$ in all sectors i, and no exports $\epsilon_t = 0$.

Let the Domar weight of sector n be $\eta_n \equiv \frac{p_n y_n}{pv}$, let the share of value added allocated to the production of final goods be $\zeta_n \equiv \frac{p_n c_n}{pv}$ and the value added share of each sector be $\tilde{\zeta}_n \equiv \zeta_n + \frac{p_n \chi_n^d}{pv}$.[12] Let Γ collect the vector of value added shares in production, and α collect capital intensities across sectors.

Proposition .1. *The equilibrium Domar weights are functions of sectorial investment rate.*

$$\left[I - \Gamma \alpha \Omega \frac{\mathbf{x}}{\mathbf{k}} - (1 - \Gamma) M \right]^{-1} \zeta \equiv \boldsymbol{\eta} \tag{1}$$

or in vector form

$$\eta_n = \zeta_n + \sum_{i=1}^{N} \alpha_i \gamma_i \omega_{ni} \frac{x_i}{k_i} \eta_i + \sum_{j=1}^{N} (1 - \gamma_j) \mu_{nj} \eta_j.$$

[10] The model could be readily extended to allow for non-homotheticities in preferences and therefore non-trivial income effects, as well as a homothetic aggregator with arbitrary elasticity of substitution. Then, the analysis that follows should be conducted along a constant growth path where the interest rate is constant but output shares in different sectors are changing, as in models of structural change.

[11] In general, any unitary elasticity aggregator of exports and imports would preserve the balanced growth path properties discussed in the Appendix.

[12] The share of value added allocated to final good production includes a constant expenditure share from the final output aggregator and the share of the final good in aggregate value added, $\zeta_n = \theta_n \frac{Y}{pv}$.

Investment rates affect the level of Domar weights in our economy due to the dynamic nature of capital accumulation. This channel is muted in static models of intermediate input trade, or where the investment network is treated as a succecion of static economies.

If the economy displays full depreciation $\delta_n = 1$, then $\frac{\mathbf{x}}{\mathbf{k}} = \mathbf{1}$ and the equilibrium Domar weights are independent of the investment rates. Alternatively, if depreciation is partial and the economy is in steady state, the investment rate is constant and a function of the rate of economic obsolescence, i.e. physical depreciation plus investment specific technological change, as we show the Appendix. Along the transition path, this economy displays interesting interactions between the investment rates and the Domar weights, which affect the pass through between productivity and aggregate value added, as we show next.

Proposition .2. *The equilibrium level of value added in the economy satisfies*

$$\ln(\nu) = \tilde{\boldsymbol{\eta}}'\Gamma\boldsymbol{\lambda} + \tilde{\boldsymbol{\eta}}'\boldsymbol{\epsilon} + \tilde{\boldsymbol{\eta}}'\Gamma(1-\alpha)\ln(\boldsymbol{\eta})$$

for a vector of sectorial influence $\tilde{\boldsymbol{\eta}} \equiv \tilde{\boldsymbol{\zeta}}'\Xi$, the product between sectorial value added shares, $\tilde{\boldsymbol{\zeta}}'$, and an adjusted Leontief inverse $\Xi \equiv (I - \Gamma\alpha\Omega - (1-\Gamma)M)^{-1}$. Value added is therefore a function of sectorial productivities, $\boldsymbol{\lambda}$, the employment distribution across sectors, $\boldsymbol{\epsilon}$, and the impact of the investment rates through the Domar weights of the economy, $\boldsymbol{\mu}$.

In vector form

$$\ln(\nu) = \sum_n \tilde{\eta}_n \gamma_n z_n + \sum_n \tilde{\eta}_n \ln(l_n) - \sum_n \tilde{\eta}_n \gamma_n (1-\alpha_n)\ln(\eta_n).$$

The first two terms are common to factor models of the input-output structure of the economy, where the impact of total factor productivity depends on the input-output structure. The first term showcases the impact of productivity on value added and depends on the value added shares in production through Γ, and the vector of sectorial influence $\tilde{\mu}$, similarly to Acemoglu *et al.* (2012). Distinctively from Liu (2019), a wedge between influence and Domar weights occurs even absent distortions in the economy, and due to the presence of investment. The second term showcases the impact of disparities in the employment allocation across sectors. The entire sectorial employment distribution matters for value added as a consequence of the disparities in capital-labor ratios across sectors.[13]

Domar weights are a measure of the sectorial size as summarized in the total value of production resources (i.e. the value of gross output) relative to total value added. They can be rewritten as function of sectorial value added shares (instead of consumption shares) so that they are more easily comparable to the influence vector. Then, $\boldsymbol{\eta} = \tilde{\boldsymbol{\zeta}}(I - (I-\Gamma)M)^{-1}$, and one concludes that influence is always larger than the Domar weight of the sector whenever there is a non-trivial investment network. In other words, increases in sectorial productivity augment value added through input-output linkages and investment-network linkages. Influence is the correct sectorial weight for income and growth accounting.

[13] In the current framework this is a consequence of heterogeneity in production technologies, but one could envision this feature being the consequence of distortions in factor prices across sectors or other policies.

2.2 Equilibrium characterization. Open economy.

We are now ready to extend the previous two results to an economy where final goods and investment are tradable, as in the benchmark.

Proposition .3. *The equilibrium Domar weights are functions of sectorial investment rate.*

$$\left[I - \Gamma\boldsymbol{\alpha}(1-\boldsymbol{\phi})\Omega\frac{\mathbf{x}}{\mathbf{k}} - (1-\Gamma)M\right]^{-1}\boldsymbol{\zeta} \equiv \boldsymbol{\eta} \tag{2}$$

or in vector form

$$\eta_n = \zeta_n + \sum_{i=1}^{N}\alpha_i\gamma_i\omega_{ni}(1-\phi_i)\frac{x_i}{k_i}\eta_i + \sum_{j=1}^{N}(1-\gamma_j)\mu_{nj}\eta_j.$$

Hence, the main difference to the closed economy version is that the investment network term is scaled by the importance of domestic investment, $(1-\phi) \in (0,1)$. The lower the importance of domestic investment, the closer the Domar weight is to the standard expression in a an economy with only intermediate input trade.

So is it imported capital important at all? The answer is yes, and to understand its role we turn to the expression for value added in the economy.

Proposition .4. *The equilibrium level of value added in the economy satisfies*

$$\ln(\nu) = \left(I - \Gamma\alpha\boldsymbol{\phi}'\boldsymbol{\Omega}'\right)^{-1}\left(\tilde{\boldsymbol{\eta}}'\Gamma(\boldsymbol{\lambda} + \alpha\boldsymbol{\phi}\Omega'\boldsymbol{\tau}) + \tilde{\boldsymbol{\eta}}'\boldsymbol{\epsilon} + \tilde{\boldsymbol{\eta}}'\Gamma(1-\alpha)\ln(\boldsymbol{\eta})\right)$$

or in vector form

$$\begin{aligned}\ln(\nu)(1-\sum_n\gamma_n\alpha_n\sum_j\omega_{jn}\phi_j) \quad = \quad & \sum_n\tilde{\eta}_n\gamma_n z_n + \sum_n\tilde{\eta}_n\ln(l_n) - \sum_n\tilde{\eta}_n\gamma_n(1-\alpha_n)\ln(\eta_n) + \\ & \sum_n\tilde{\eta}_n\gamma_n\alpha_n\sum_j\omega_{jn}\phi_j\ln(\tau_j).\end{aligned}$$

First, the presence of tradable investment goods induces and additional amplification (as in Jones (2011) for tradable intermediate inputs). The reason is that as productivity increases within the economy, the export capacity improves, and due to trade balance that implies higher imports of investment. The strongest the dependence on imported equipment and the intensity of use of capital, the strongest this amplification channel is. Second, the terms of trade enter as a channel directly affecting value added in the economy. Once adjusted for the role of imported investment, through the capital share and the investment network), the terms of trade affect the economy similarly to a TFP shock.

Notice that as $\phi \to 0$ the economy losses is dependence in tradable investment, and Proposition .3 and .4 boil down to their closed economy versions.

To ease the exposition, we discuss the characteristics of the BGP in Appendix A.1.1. The presence of unitary elasticity investment aggregators, as well as sectorial production technologies assures the existence of a BGP with heterogeneous rates of technological across sectors. Along the BGP, trade is balanced.

3 Investment network

A key input to the measurement of output elasticities to sectorial productivity is the investment network, which we estimate. We first describe our methodology, then the data sources and finally discuss the properties of the network across countries.

To ease the exposition and analysis, we group sectors in eight categories: four equipment types that consist of Information and Communication Technology (ICT)[14], Electronics, Machinery and Transportation Equipment, and then Construction, Agriculture, Manufacturing (other-than equipment), and Services (see Table 9 in the Appendix A.2 for details).

3.1 Methodology

An entry (i, j) of the capital flows table records total investment expenditures by column-sector j purchased from row-sector i. Summing across columns for each row in this table generates total production of investment by each sector, while summing across rows for each column generates total investment expenditures for each sector. To obtain the investment network expressed in terms of expenditure shares, we simply divide each entry of column-sector j by total expenditures in that sector.

We classify sectors between those that produce equipment, structures (construction) and other goods. Estimates of investment produced by each sector in the economy come from *Use tables*, which record the uses of output between intermediate and final uses, including consumption and investment. Next, we estimate how much of the investment flow from each sector is purchased by any other sector in the economy. To do so, we follow two different assignment rules that depend on whether the sector produces equipment or other goods, as we describe next.

Allocation of Equipment Investment Flows. We allocate investment flows following the methodology historically implemented by the BEA. This methodology exploits the occupational composition of the labor force in each sector and the types of capital that these occupations use to assign stocks to workers. BEA's allocation is ad-hoc, as outlined in their publicly available documentation. In contrast, our assignment follows the tools utilized in each occupation, as described by O*NET, and implements the methodology introduced by Caunedo *et al.* (2023) for assigning stocks to workers in the US. We cross-walk equipment categories with the corresponding tools within each SOC occupation.[15] Therefore, our identification assumption is that the relative intensity of computer use between engineers and janitors, for instance, is the same across countries. Total investment assigned to each worker in a given occupation will dif-

[14] Software is including under ICT equipment which is in turn produced by the Information and communication sector, see Table 9 for our correspondence.

[15] The methodology cross-walks equipment categories to these tools within each SOC occupation. Then we use Dingel and Neiman (2020)'s crosswalk between SOC and ISCO to map tools to harmonized cross-country occupational definitions.

fer across countries because the aggregate investment flow of computers vs. cars, for instance, is different across countries. Finally, the allocation of investment to sectors will also differ due to disparities in the occupational composition of the labor force.

Equipment producing sectors are $j = \{ICT, Electronics, Machinery, Transportation\}$. We compute the share of capital type j used by industry i as

$$share\ k_i^j = \frac{\tau_o^j n^{oi}}{\sum_o \tau_o^j n^{oi}}, \tag{3}$$

where n^{oi} is the number of workers in occupation o and industry i, and τ_o^j is the number of tools of capital type j used by a worker in occupation o at time t.

Construction and Other Sectors' Investment Flows. Given the absence of information on workers' use of investment from the construction and other sectors, we impute investment analogously to intermediate inputs flows. We use the input-output structure and assign the flow of investment from a sector proportionally to their role as intermediate goods providers of other sectors in the economy.

3.2 Data description

Investment production by sector. We obtain investment production by sector from *Use Tables* that underlie the measurement of input-ouput structures. For Ghana and Ethiopia, we exploit *Use tables* provided by Mensah and de Vries (2023). For the remaining countries, we source this information from the WIOD. Flows are reported in nominal currency, which we deflate using the price of sectorial value added from the 10 Sector Dataset for Ethiopia and Ghana, and the price deflators available at the WIOD for the remaining countries.

Employment by occupation and sector. We use the measurement available in the Living Standards Measurement Study for Ghana, IPUMS International for Ethiopia, and PIAAC's survey for the remainder countries. We favor PIAAC over IPUMS international for the occupational composition of each sector because the level of occupational disaggregation is higher in the former than the latter.[16]

Input-output structure. We compute the share of intermediate inputs purchased by each sector in the economy, such that each row of the input-output matrix sums to one. We use this production shares to allocate the production of investment for Construction, Agriculture, Manufacturing and Services.

Country Coverage. Our benchmark dataset covers 22 countries at different stages of development, with income levels ranging from 1450 and 112229 PPP GDP per capita (PPP), and through time. See Table 8 in the Appendix for a full description.

[16]See Caunedo, Keller and Shin (2021) for a comparison of the employment composition of the labor force across sources. PIAAC measurement aggregated at the 1-digit level correlates strongly with IPUMS data.

3.3 The Investment Network in the development spectrum

We start by characterizing the *outdegree* of each sector the investment network, a measure of the relevance of each sector as an investment provider to other sectors of the economy. The *outdegree* is the row sum of the entries in the investment network.

Along the development spectrum, there is an increase in the outdegree of ICT and Transportation as economies develop, see Table 1. At the same time, the role of the service sector as a provider of capital to other sectors declines with income per capita, with high-income countries exhibiting an outdegree that is half of that in low-income countries. The sectors that report the largest final output towards investment within services include repairs of durables as well as wholesale and retail trade.

Table 1: Outdegrees: investment network

	Low Income	Medium Income	High Income
Agriculture	0.11	0.09	0.07
Construction	2.41	2.90	2.42
Electronics	0.46	0.56	0.50
ICT	0.04	0.51	1.05
Machinery	1.01	1.05	0.80
Manufacturing	0.66	0.60	0.82
Services	2.60	1.06	1.26
Transportation	0.70	1.22	1.08

Notes: Low Income countries have an average per capita GDP (PPP) of 5030, Medium Income countries an average per capita GDP (PPP) of 44472, and High Income countries an average per capita GDP (PPP) of 84671 in 2005.

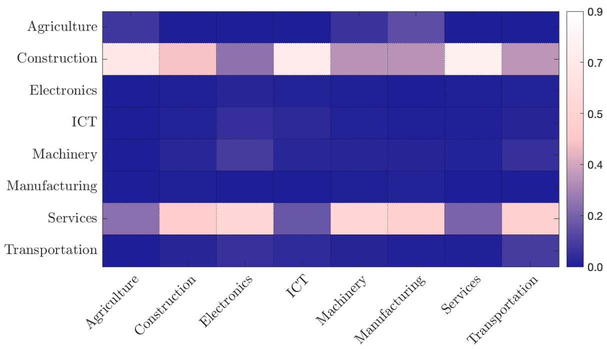
We find similar patterns when we analyze long time-series for the countries for which we have data dating back to 1960s. Figure 1 provides a graphical representation of South Korea's investment network, Ω, and shows how it changes over time. In 1965, when South Korea's GDP per capita was PPP$1450, Construction and Services sectors were star providers of investment for all sectors in the economy (Figure 1, panel a). By 2014, GDP per capita was 24.5 times higher, the role of both these sectors declines, while ICT and Transportation gain importance. Interestingly, this investment network resembles that in the USA in 1986—a period of comparable level of development (Figure 1, panel b and c)—except possibly for the role of Electronics.

If we compare de investment network of Korea at a level of GDP per capita that is 65% of the US in 2014 to the US, the most salient feature is the further raise in the importance of ICT equipment, and a decline in the importance of Construction and Machinery as providers of investment to the rest of the economy.

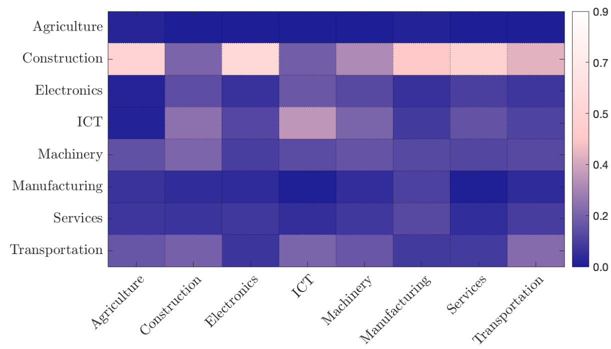
Differences in investment network across countries through time or income levels could prima facie reflect systematic disparities in technologies for production, either as a result of distortions or comparative advantage. The study of the sources of these disparities exceeds the scope of the current analysis but are nevertheless of key importance to understand the process of development. As a first step to highlight the implications of these newly uncovered patterns for income differences across countries, we now combine the structural predictions of the model with our newly constructed measures of the investment network to conduct an income accounting exercise.

Figure 1: Investment Network over time

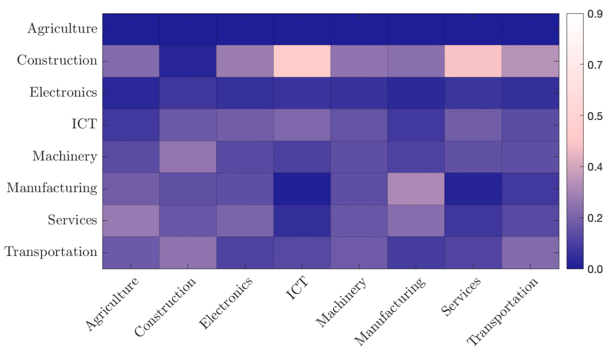
(a) South Korea: 1965
GDP per capita (PPP): 1450



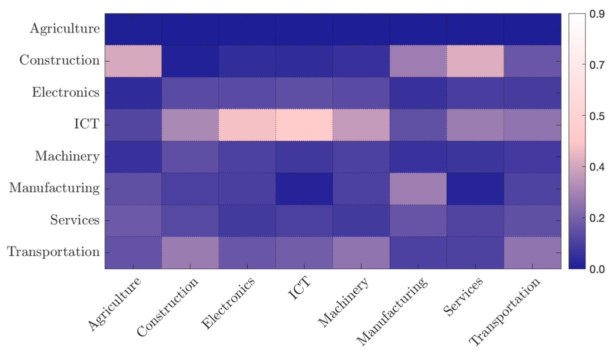
(b) South Korea: 2014
GDP per capita (PPP): 35524



(c) USA: 1986
GDP per capita (PPP): 35925



(d) USA: 2014
GDP per capita (PPP): 57116



Note: Investment-networks Ω for South Korea and USA. Rows label the sectors sourcing investment while Columns label the sectors receiving these flows. Each entry is the expenditure share in a particular investment relative to the total in the sector, column-sums add up to one.

4 Income Accounting

With our newly constructed measures of the investment network, we are now ready to quantify the influence vector, which summarizes output elasticities to sectorial productivity growth and to changes in the terms of trade. For the current version, we focus on productivity changes. We first describe the main sources for measurement of its component, and then conduct income accounting.

4.1 Data description

Input-output structure. We compute the share of intermediate inputs purchased by each sector in the economy, such that each row of the input-output matrix sums to one. The input-output structure is sourced from Mensah and de Vries (2023) and the WIOD.

Value added shares in production (Γ) and Sectorial value-added shares ($\tilde{\zeta}$). We compute sectoral value added shares in gross output and sectoral value added shares using data from Mensah and de Vries (2023) and the WIOD.

Capital share in value added. We exploit data from Penn World Tables version 10.01 to compute labor expenditure share. We estimate capital shares as residuals from labor expenditure shares, under the assumption of CRS value-added production technologies. The capital expenditure share is computed at the aggregate level, and therefore country-specific but common across sectors. For those countries with data from the WIOD, we use sector specific measures of capital expenditure shares (from 2000 onwards).

The sample of countries and time-horizon is the same as that of the investment network.

TFP. We estimate sectoral log TFP productivity in each country relative to the US as a residual between capital, labor and intermediate inputs. Recall $z_{n,c}$ represents the log TFP in sector n and country c; y_{nc} gross output in sector n and country c; $\alpha_{n,c}$ the capital expenditure share in value added and $\gamma_{n,c}$ value added share in gross output. We estimate sectoral TFP relative to US for each country c as follows:

$$\begin{aligned} z_{n,c} = & \ln(y_{n,c}) - \ln(y_{n,US}) + \gamma_{n,c}\alpha_{n,c}\ln(k_{n,c}) - \gamma_{n,US}\alpha_{s,US}\ln(k_{n,US}) \\ & + \gamma_{n,c}(1-\alpha_{n,c})\ln(l_{n,c}) - \gamma_{n,US}(1-\alpha_{s,US})\ln(l_{n,US}) \\ & + (1-\gamma_{n,c})\sum_i m_{in,c} - (1-\gamma_{n,US})\sum_i m_{in,US}. \end{aligned} \tag{4}$$

For the estimation, we obtain sectoral capital stocks and sectoral employment from the sectoral socio-economic accounts from WIOD for all countries in the sample but Ethiopia and Ghana, for which we impute sectoral capital stocks using PWT and Mensah and de Vries (2023) and retrieve sectoral employment from the 10 Sector Database and UNIDO. We source sectoral intermediate inputs use from the input-output sources described above. To ensure comparability across countries, we rely on data from WIOD in the year 2005, as it is the only year with available Purchasing Power Parity (PPP) sectoral gross output price indices that we use to convert nominal inputs to real units. For the case of Ethiopia and Ghana, as these PPP price indices are not available, we use sectoral value added price deflators from 10 Sector Database and combine them with GDP PPP price deflators from PWT.

4.2 Accounting

We are now ready to assess the sources of cross-country income disparities accounting for the direct and indirect effects of intermediate input and investment trade across sectors. First, we compute the sum across sectors of the product between sectoral multipliers and TFP levels given by $\nu_c = \sum_n \tilde{\eta}_n z_{sc,US} z_{US}$, with $z_{sc,US}$ being the productivity of sector s in country c relative to that in US, and $z_U S$ being the value-added weighted average of sectoral productivities in US (which we estimate for each sector as a residual of capital, labor and intermediate inputs use).

We begin by conducting a variance decomposition analysis of two main components: cross-country differences in TFP, $\sum_n \tilde{\eta}_n \gamma_n z_n$; and cross-country differences in the sectoral employment distribution, $\sum_n \tilde{\eta}_n \gamma_n (1-\alpha_n)(\epsilon - ln(\eta_n))$. We exploit data in 2005, for which PPP sectorial deflators are readily available.[17]

Table 3 shows the results of the income decomposition analysis for our baseline specification, given by Proposition .2. The TFP component explains almost all of the variation (96%) in income differences in our sample, while the employment distribution component explains the remaining 4%. The role of TFP disparities is heterogeneous across countries and income levels, as we show in Figure 4.

Given the quantitative importance of TFP disparities, we focus on it for the remainder of the analysis.

Table 2: Model-based Income Differences, Variance Decomposition

Channel	**Baseline**
TFP	0.960
Employment distribution	0.04

Notes: Row *TFP* refers to $\frac{\text{Cov}(\sum_n \tilde{\eta}_n \gamma_n z_n, y_{\text{model}})}{\text{Var}(y_{\text{model}})}$; Row Employment distribution refers to $\frac{\text{Cov}(\sum_n \tilde{\eta}_n \gamma_n (1-\alpha_n)(\epsilon - ln(\eta_n)), y_{\text{model}})}{\text{Var}(y_{\text{model}})}$

To study the amplification properties of the direct and indirect effects of input-output trade and the investment network, we compare the contribution of TFP differences to income differences for economies that abstract from these links. We start with a scenario where sectorial influence only reflects the direct impact of sectoral value added, $\tilde{\boldsymbol{\eta}} = \boldsymbol{\beta}'\boldsymbol{\Gamma}$; then we consider an economy with intermediate input links only; and another economy with the investment network only.

We compute the average contribution of TFP across countries (Column (1) in Table 3) and across income levels (Columns (2)-(4) in Table 3).[18] Without linkages, the TFP component can only account for 36% of the baseline income differences on average. Thus, sectorial interactions

[17] If one is willing to do away with PPP deflators, the income accounting exercise can be done for all years for which we have estimates of the investment network and sectorial TFP.

[18] The benchmark contribution here is different the average across countries, and differs from the measure in the variance decomposition exercise in table 3.

more than double the role of productivity disparities for income disparities. An economy with intermediate input interactions predicts twice as large a role for TFP disparities (40% in addition of the no-links economy). Hence, the remainder 24% should be attributed either to the direct effect of the investment network, or to interactions between the IO structure and the network. An economy with only investment network predicts 4% stronger amplification than the no links economy, so most of the role of the investment network occurs through interactions. The relative contributions of these links is similar across the income distribution. The direct effect of the investment network is highest among mid-income countries, while the direct effect of the IO structure is highest among low-income countries.

Table 3: Role of TFP across economies

log GDP per capita (PPP)	**Average**	**Low Income** <9	**Medium Income** 9-11	**High Income** >11
Benchmark	1.02 (0.99,1.13)	0.90 (0.80,0.99)	1.13 (1.03,1.25)	1.01 (0.94,1.08)
No Links	0.36 (0.30,0.42)	0.46 (0.37,0.56)	0.35 (0.30,0.51)	0.36 (0.28,0.39)
Only Intermediate Input Links	0.76 (0.72,0.81)	0.87 (0.81,0.93)	0.75 (0.72,0.87)	0.76 (0.60,0.78)
Only Investment Links	0.40 (0.38,0.45)	0.48 (0.40,0.57)	0.42 (0.34,0.55)	0.39 (0.36,0.42)

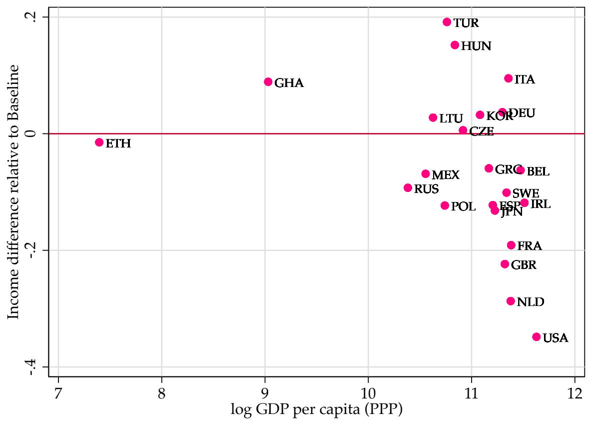
Notes: The first row shows the fraction of model-based income per capita that is explained by the TFP component $\sum_n \tilde{\eta}_n \gamma_n z_n$, for each group, i.e. a value of 1 refers to 100% of the variation. Entries in parenthesis denote the 25th and 75th percentiles. Rows 2 to 4 show the fraction of TFP component that is explained by each counterfactual scenario: No Links refers to an economy without sectorial links, Only Intermediate Links refers to an economy with an input-output structure, Only Investment Links refers to an economy with an investment network. Column "Average" reports the average across countries.

Counterfactuals Each of the accounting exercises presented above abstracts from potential interactions between intermediate and investment flows. To assess those interactions we design two counterfactual scenarios in which we substitute de investment network of an economy in 2005 by the one observed in the US in 1948 and in 2014. We interpret the network in 1948 as assigning a relatively primitive technology for production (in terms of the investment bundle in each sector), and the network in 2014 as assigning a relatively advanced technology for production.

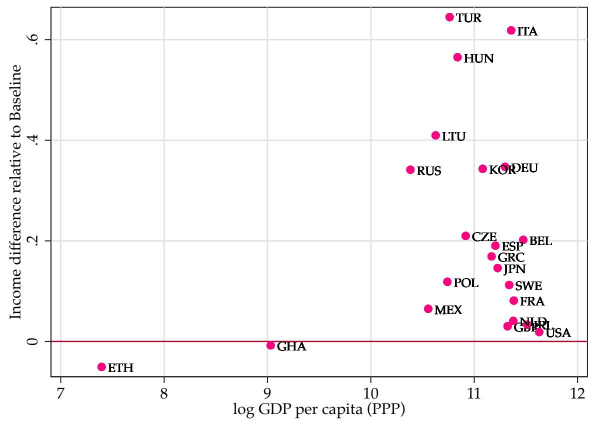
Figure 4 shows the different in income level between the model-based prediction of income per capita for each country and its counterfactual level. Hence, an outcome above 0 indicates an improvement in GDP per capita, while a negative outcome indicates a deterioration in GDP per capita. We find that poorer countries would benefit relatively more from producing with the investment network of US in 1948, whereas richer countries would benefit most from producing with the investment network of US in 2014.

Figure 2: Counterfactual analysis: USA Investment Network

(a) US Investment Network in 1948



(b) US Investment Network in 2014



4.3 The role of the Influence Vector

Disparities in amplification properties that we highlight in the income accounting exercises are summarized by the influence vector. In this section we further characterize the influence vector and compare its properties relative to the investment network and the adjusted Leontief inverse studied in vom Lehn and Winberry (2022).

Table 4 reports the magnitudes of the influence vector across countries at different stages of development. The most salient features are a steady decline in the influence of Agriculture and a steady increase in the influence of Construction, Services, ICT. Transportation, Manufacturing and Machinery (although less pronounced) display a hump-shape in the magnitude of sectorial influence. Appendix Figure 6 displays the entries in the influence vector for different equipment types across countries, whereas Appendix Figure 7 shows similar patterns for South Korea through time.

Table 4: Influence Vectors

	Low Income	Medium Income	High Income
Agriculture	0.39	0.08	0.03
Construction	0.06	0.24	0.14
Electronics	0.01	0.06	0.05
ICT	0.07	0.26	0.36
Machinery	0.03	0.08	0.05
Manufacturing	0.27	0.35	0.22
Services	0.49	0.67	0.66
Transportation	0.12	0.26	0.16

Notes: Low Income countries have an average per capita GDP (PPP) of 5030, Medium Income countries an average per capita GDP (PPP) of 44472, and High Income countries an average per capita GDP (PPP) of 84671 in 2005.

Prima facie, these patterns could be driven entirely by the sectorial shares of value added, $\tilde{\zeta}$. Hence, we separately report the outdegrees of the augmented Leontief inverse, Ξ, see Table 5. Comparing these magnitudes to those of the influence vector, it can be seen that the dynamics of influence for Services and Agriculture are mostly driven sectorial value-added shares.The reason is that the outdegrees of Leontief inverse for Services and Agriculture are relative stage along the income spectrum at levels of 3.7 and 1.4, respectively.[19] For the remainder sectors, the qualitative patterns of influence correlate with the dynamics of the outdegrees of the Leontief-inverse, although the relative magnitudes change across sectors.

Table 5: Outdegrees: adjusted-Leontief inverse

	Low Income	Medium Income	High Income
Agriculture	2.01	2.11	1.53
Construction	2.18	4.98	3.40
Electronics	1.87	3.34	2.29
ICT	1.32	3.56	5.25
Machinery	1.72	2.73	2.04
Manufacturing	7.63	10.47	6.88
Services	5.82	6.18	5.28
Transportation	2.85	4.84	3.74

Notes: Low Income countries have an average per capita GDP (PPP) of 5030, Medium Income countries an average per capita GDP (PPP) of 44472, and High Income countries an average per capita GDP (PPP) of 84671 in 2005.

One takeaway from this analysis is that the influence of Transportation, Construction and ICT increases with development, and that those are mostly driven by an increase in importance as providers of investment and intermediate inputs to the rest of the economy. To explore their role as potentially high forward-linkage sectors to the rest of the economy, we can refer again to the outdegrees of the investment network across income levels in Table 1. The outdegrees of Construction, ICT and Transportation equipment indeed increase with income levels. In other words, forward linkages from these sectors are relatively low at low-stages of development, but become more important as economies develop. Perhaps surprisingly, the role of Machinery and Manufacturing as providers of investment to the rest of the economy is relatively stable or declines with development.

So given these systematic differences in the role of sectors as providers of investment, and ultimately, in its impact on aggregate value added, is there something one can learn in terms of the impact of investment policies? We answer this question in two steps. First, by studying the correlation between the size of sectorial influence and the relative price of investment, and second, by studying heterogeneity in sectorial influence for economies at different stages of

[19] Korea in 1965 seems to be a bit of an outlier relative to Ghana and Ethiopia a low-income levels. Once we expand our sample to more countries, we will be able to see if this is an oddity or a feature.

Table 6: Relative price and influence

	Construction	Electronics	ICT	Machinery	Transportation
log_rel_price	-0.403*	-1.305***	-0.965***	-0.400	-0.0758
	(0.230)	(0.368)	(0.235)	(0.276)	(0.181)
Observations	23	23	23	23	23
R^2	0.128	0.374	0.445	0.091	0.008

Note: This sample include Korea in 1965 as a low-income country. The relative price of investment to consumption is sourced from PWT.

development.

4.4 Investment and the relative price of capital

We start by replicating the well known relationship between the relative price of investment and economic development. Unfortunately, measures of the price of capital for each equipment type are not available in our sample at the correct level of disaggregation, so we work with the aggregate price of capital. Future versions of this draft will include measures of the relative price of each equipment category constructed from trade data on imported equipment.

We first correlate the sectorial influence with a measure of the aggregate relative price of capital to consumption, see Table 6. We find a strong negative correlation across all sectors producing equipment and structures, except for Transportation and Machinery (with a negative point estimate but not statistically different from zero).[20]

But it is well known that the relative price of capital correlates negatively with development, so the negative relationship to sectorial influence could be driven by disparities in income levels. Table 7 shows the correlations between our measures of influence across salient sectors and the relative price of investment to consumption, controlling for income. We find no significant relationship between these measures after accounting for income. We also find that after controlling for the price of investment to consumption, the positive relationship between influence and income per capita is only significant for Electronics and ICT. [21] For completeness we present the correlation between influence and income per capita in the Appendix.

We interpret these result to suggest that the aggregate index for the price of investment to consumption is not informative about sectorial influence beyond countries level of development. This is not to say that the price of investment is irrelevant for the observed patterns of influence. Instead, we believe that information likely relies on sector specific prices rather than the aggregate investment price. Future versions of this draft will exploit prices of imported equipment to test such a hypothesis.

[20] Influence is hump-shaped in the relative price of capital.

[21] This result may also change as we expand our sample of countries to include more low-income economies.

Table 7: Relative price and influence, controlling by income

	Construction	Electronics	ICT	Machinery	Transportation
log_rel_price	0.202	0.194	0.406**	0.241	0.271
	(0.365)	(0.494)	(0.160)	(0.448)	(0.301)
log_gdp_pc	0.302*	0.749***	0.685***	0.320*	0.173
	(0.148)	(0.200)	(0.0647)	(0.181)	(0.122)
Observations	23	23	23	23	23
R^2	0.279	0.632	0.916	0.213	0.099

Note: This sample include Korea in 1965 as a low-income country. The relative price of investment to consumption is sourced from PWT.

4.5 Big Push and Targeted Investment.

While the economy that we study is efficient and therefore, has no role of policy intervention by construction, the empirical patterns that we uncover could be used to understand heterogeneity in returns to similar policies implemented across economies at different stages of development.

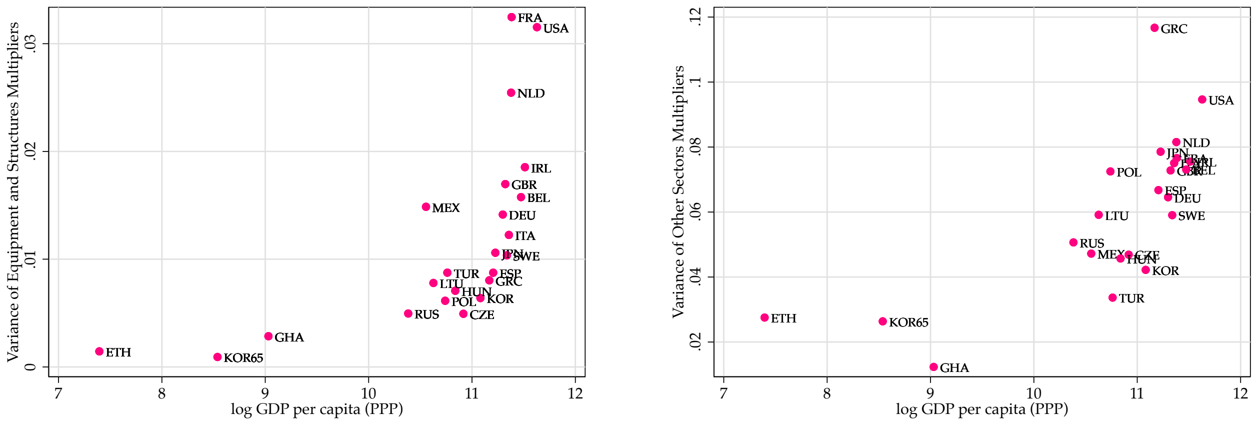
Using our measurement, one could assess the effect of improvements in productivity and the terms of trends across sectors on GDP per capita. Hirschman (1958) suggests that one should target sectors with high forward linkages, which we interpret to mean that sectors with high out-degrees in the investment network. The theory implies that the relevant measure of impact on aggregate output is influence, and hence, sectorial productivity growth has stronger effects on sectors with high influence rather than low influence. As we showed in Section 4.3, sectors with high outdegrees are not necessarily those with high influence, albeit empirically, there is a positive correlation.

Figure 3 reports the variance of influence across sectors within each country, against their level of income per worker. Two patterns emerge. First, the magnitude in the variance of influence among sectors producing equipment and structures is substantially lower than in other sectors of the economy (0.014 on average for equipment vs. 0.09 for other sectors). Second, variance in influence increases along the development spectrum. We interpret this results to suggest that productivity improvements at early stages of development have similar impacts on GDP per capita irrespective of the sector. At later stages of development, heterogeneity in influence is higher, and therefore productivity improvements in certain sectors may disproportionally affect income levels.

Indeed, the increase in variance at higher stages of development is mostly explained by the raise in the importance of ICT equipment reported in Section 4.3. Figure 5 in the Appendix shows that the variance in the influence vector is an order of magnitude smaller if we exclude ICT equipment from the sample. ICT is particularly important for relatively rich economies.

Figure 3: Variance in the Influence Vector and GDP per capita

(a) Equipment and Structure **(b)** Other sectors



5 Final Remarks

We have constructed novel measures of the investment network across the development spectrum and document systematic disparities in the importance of difference sectors as providers of investment goods as economies develop.

Through a simple framework of sectorial linkages in intermediate and investment flows we show that output elasticities to sectorial productivity depend on the interaction between the input-output structure and the investment network.

Cross-country disparities in the investment network amplify the effect of sectorial disparities in TFP for income differences by 24%. Output elasticities to improvements in the productivity of investment producing sectors are similar at earlier stages of development, and diverge as country develop and specialize. Increases in ICT intensity drive a substantial amount of this heterogeneity.

Newer versions of this paper will include a larger cross-country coverage, mostly of poorer economies.

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A Appendix

A.1 Proofs & Derivations

Proof Proposition .1. Use the optimality conditions of the firm, to rewrite the expenses in different intermediate and investment goods as a function of gross output, i.e.

$$\mu_{ni}(1-\gamma_i)p_i y_i = p_n m_{ni}$$

$$\alpha_i \gamma_i p_i y_i = r_i k_i$$

$$\omega_{ji} r_i x_i = p_j \chi_{ji}$$

Combining the optimality conditions for capital and investment, as well as the steady-state level of capital

$$\alpha_i \gamma_i p_i y_i = \frac{p_j \chi_{ji}}{\omega_{ji}} \frac{k_i}{x_i},$$

which we can use to write the feasibility constraint in each sector n,

$$p_n y_n = p_n c_n + \sum_i p_n \chi_{ni} + \sum_j p_n m_{nj}.$$

Then

$$\zeta_n \frac{y_n}{c_n} = \zeta_n + \sum_i \alpha_i \gamma_i \omega_{ni} \frac{x_i}{k_i} \zeta_i \frac{y_i}{c_i} + \sum_j (1-\gamma_j)\mu_{nj}\zeta_j \frac{y_j}{c_j}$$

The above define a system of equations across sectors that can be solved for the Domar weights $\eta_n \equiv \zeta_n \frac{y_n}{c_n}$, given investment rates in each sector $\frac{x_i}{k_i}$ which proves the result.

■

Proof Proposition (open ec) .3. Use the optimality conditions of the firm, to rewrite the expenses in different intermediate and investment goods as a function of gross output, i.e.

$$\mu_{ni}(1-\gamma_i)p_i y_i = p_n m_{ni}$$

$$\alpha_i \gamma_i p_i y_i = r_i k_i$$

$$(1-\phi_j)\omega_{ji} r_i x_i = p_j \chi^d_{ji}$$

Combining the optimality conditions for capital and investment, as well as the steady-state level of capital

$$\alpha_i \gamma_i p_i y_i = \frac{p_j \chi^d_{ji}}{(1-\phi_j)\omega_{ji}} \frac{k_i}{x_i},$$

which we can use to write the feasibility constraint in each sector n,

$$p_n y_n = p_n c_n + \sum_i p_n \chi^d_{ni} + \sum_j p_n m_{nj}.$$

Then

$$\zeta_n \frac{y_n}{c_n} = \zeta_n + \sum_i \alpha_i \gamma_i (1-\phi_n)\omega_{ni} \frac{x_i}{k_i} \zeta_i \frac{y_i}{c_i} + \sum_j (1-\gamma_j)\mu_{nj}\zeta_j \frac{y_j}{c_j}$$

The above define a system of equations across sectors that can be solved for the Domar weights $\eta_n \equiv \zeta_n \frac{y_n}{c_n}$, given investment rates in each sector $\frac{x_i}{k_i}$ which proves the result.

$$\left[I - \Gamma\alpha\Omega(1-\phi)\frac{\mathbf{x}}{\mathbf{k}} - (1-\Gamma)M\right]^{-1}\boldsymbol{\zeta} \equiv \boldsymbol{\eta}$$

■

Proof Proposition .2. Use the solution and the definition of ζ_i to solve for relative prices, given investment rates.

$$\frac{p_i}{p_j} = \frac{c_j}{c_i}\frac{\zeta_i}{\zeta_j} = \frac{\eta_i}{\eta_j}\frac{y_j}{y_i}$$

These relative prices are useful to define the demand for intermediate inputs, investment and labor, as a function of the vector of sectorial gross output. The demand for intermediate inputs follows $(1-\gamma_i)\frac{\eta_i}{\eta_n}y_n = m_{ni}$, while the demand for investment goods is $\frac{x_i}{k_i}\omega_{ji}\alpha_i\gamma_i\frac{\eta_i}{\eta_j}y_j = x_{ji}$. Total investment in sector i defines the level of the stock of capital as $x_i = \prod_j \left(\frac{x_i}{k_i}\alpha_i\gamma_i\frac{\eta_i}{\eta_j}y_j\right)^{\omega_{ji}}$, or what is the same $k_i = \prod_j \left(\alpha_i\gamma_i\frac{\eta_i}{\eta_j}y_j\right)^{\omega_{ji}}$.

Assume that the supply of labor is inelastic at 1, so the fraction of labor allocated to each sector follows Domar weights adjusted by the sectorial labor expenditure shares in gross output,

$$l_i^\star = \frac{(1-\alpha_i)\gamma_i p_i y_i}{\sum_i(1-\alpha_i)\gamma_i p_i y_i} = \frac{(1-\alpha_i)\gamma_i\eta_i}{\sum_i(1-\alpha_i)\gamma_i\eta_i}.$$

For the purpose of describing final demand, it would be useful to define $\tilde{l}_i = \frac{l_i^\star}{\gamma_i(1-\alpha_i)}$.

Final output in each sector is then

$$y_n = \left[z_n\left(\prod_i\left(\frac{\eta_n}{\eta_i}y_i\right)^{\omega_{in}}\right)^{\alpha_n}(\tilde{l}_i)^{1-\alpha_n}\right]^{\gamma_n}\left[\prod_i\left(\frac{\eta_n}{\eta_i}y_i\right)^{\mu_{in}}\right]^{1-\gamma_n}$$

Taking logs and writing output in matrix form we obtain

$$\ln(\mathbf{y}) = \Gamma\boldsymbol{\lambda} + \boldsymbol{\iota} + \Gamma\alpha\Omega'\ln(\mathbf{y}) + (1-\Gamma)M'\ln(\mathbf{y})$$

where each element of the vector $\boldsymbol{\iota}$ can be described as $\iota_n \equiv \gamma_n(1-\alpha_n)\ln(\tilde{l_n}) + \gamma_n\alpha_n\sum_i(\omega_{in})\ln(\frac{\eta_n}{\eta_i}) + (1-\gamma_n)\sum_i\mu_{in}\ln(\frac{\eta_n}{\eta_i})$. The solution for gross output is then,

$$\ln(\mathbf{y}) = \Xi\Gamma\boldsymbol{\lambda} + \Xi\boldsymbol{\iota} \tag{5}$$

where the multiplier on sectorial productivity is $\Xi \equiv (I - \Gamma\alpha_d\Omega' - (1-\Gamma)M')^{-1}$. Let the price level of the economy be normalized to $p = 1$, then aggregate value added is $\nu = \frac{p_n y_n}{\eta_n}$ for any n. We can compute a geometric average of each of the terms using the expenditure shares consumption and investment $\tilde{\zeta}_n \equiv \zeta_n + \frac{p_n\sum_i x_{ni}}{\nu}$ as weights (since these weights add up to 1).

$$\ln(\nu) = \sum_n\tilde{\zeta}_n\ln(p_n) + \sum_n\tilde{\zeta}_n\ln(y_n) - \sum_n\tilde{\zeta}_n\ln(\eta_n)$$

Given a CRS aggregator of sectorial output, the price index for final goods satisfies, $\ln(p) = \sum_n\zeta_n\ln(p_n)$. Because final output is the numeraire, the log of the price index equals zero, and therefore the first term in the expression for value added drops up. The weighting of the terms in the sum also include investment shares in value added. Investment shares are proportional to consumption shares in value added whenever sectorial value added shares are proportional to consumption shares across sectors. This is by construction the assumption in canonical models of input-output linkages without capital and we assume that feature here.[22]

We have already characterized the solution to each of the last two terms, in equations 2 and 6.

$$\ln(\boldsymbol{\nu}) = \tilde{\boldsymbol{\zeta}}'\Xi(\Gamma\boldsymbol{\lambda} + \boldsymbol{\iota}) - \sum_n \tilde{\zeta}_n \ln(\eta_n)$$

where we can define the elasticity of value to sectorial TFP as $\tilde{\eta} \equiv \tilde{\boldsymbol{\zeta}}'\Xi$. Unlike the Domar weight, these elasticities are not adjusted by the investment rate. At the same time, the investment rate enters into the measure of the expenditure share, $\tilde{\zeta}$ through the Domar weight because $(I - (1-\Gamma)M')^{-1}\tilde{\zeta} = \eta$.

Unpacking the vectors, $\tilde{\zeta}_j = \tilde{\eta}_j - \sum_n \gamma_n\alpha_n\omega_{jn}\tilde{\eta}_n - \sum_n (1-\gamma_n)\mu_{jn}\tilde{\eta}_n$

$$\sum_j \tilde{\zeta}_j ln(\mu_j) = \sum_j \tilde{\eta}_j \ln(\eta_j) - \sum_j\sum_i \gamma_n\alpha_n\omega_{ji}\tilde{\eta}_i \ln(\mu_j) - \sum_j\sum_i (1-\gamma_n)\mu_{ji}\tilde{\eta}_i ln(\mu_j)$$

Now consider the term, $\tilde{\eta}\iota$

$$\sum_n \tilde{\eta}_n\iota_n = \sum_n \tilde{\eta}_n\gamma_n(1-\alpha_n)\ln(\tilde{l}_n) + \tilde{\eta}_n\gamma_n\alpha_n \sum_j \omega_{jn} \ln(\frac{\eta_n}{\eta_j}) + \tilde{\eta}_n(1-\gamma_n)\sum_j \mu_{jn}\ln(\frac{\eta_n}{\eta_j}))$$

which can be rewritten as

$$\begin{aligned}\sum_n \tilde{\eta}_n\iota_n &= \sum_n \tilde{\eta}_n\gamma_n(1-\alpha_n)\ln(\tilde{l}_n) + \sum_n \tilde{\eta}_n(\gamma_n\alpha_n + 1 - \gamma_n)\ln(\eta_n) \\ &\quad - \sum_n \tilde{\eta}_n\gamma_n\alpha_n \sum_j \omega_{jn}\ln(\eta_j) - \sum_n \tilde{\eta}_n(1-\gamma_n)\sum_j \mu_{jn}\ln(\eta_j).\end{aligned}$$

Therefore the difference in the last two terms of the expression for value added are

$$\sum_n \tilde{\eta}_n\iota_n - \sum_n \tilde{\zeta}_n \ln(\eta_n) \quad = \quad \sum_n \tilde{\eta}_n\gamma_n(1-\alpha_n)(\ln(\tilde{l}_n) - \ln(\eta_n))$$

which proves our result. ■

Proof Proposition .4. Use the solution and the definition of ζ_i to solve for relative prices, given investment rates.

$$\frac{p_i}{p_j} = \frac{c_j}{c_i}\frac{\zeta_i}{\zeta_j} = \frac{\eta_i}{\eta_j}\frac{y_j}{y_i}$$

[22]Alternatively, one can set up the economy so that investment in different capital types is produced through the final good. This economy would also allows us to define the price of value added as a function of sectorial prices in a way that they drop out from the expression above, while allowing for investment shares that need not be proportional to consumption shares. The undesirable feature of this economy is that sector producing for final production and intermediate inputs are decoupled from those producing investment.

These relative prices are useful to define the demand for intermediate inputs, investment and labor, as a function of the vector of sectorial gross output. The demand for intermediate inputs follows $(1-\gamma_i)\frac{\eta_i}{\eta_n}y_n = m_{ni}$, while the demand for domestic investment goods is $\frac{x_i}{k_i}(1-\phi_j)\omega_{ji}\alpha_i\gamma_i\frac{\eta_i}{\eta_j}y_j = \chi_{ji}$. The demand for imported investment satisfies $\frac{x_i}{k_i}(\phi_j)\omega_{ji}\alpha_i\gamma_i\frac{\eta_i}{p_j^f}\nu = \chi_{ji}^f$.

Total investment in sector i defines the level of the stock of capital as

$$x_i = \prod_j \left(\left(\frac{x_i}{k_i}\alpha_i\gamma_i\frac{\eta_i}{\eta_j}y_j \right)^{1-\phi_j} \left(\frac{x_i}{k_i}\alpha_i\gamma_i\frac{\eta_i}{p_j^f}\nu \right)^{\phi_j} \right)^{\omega_{ji}},$$

or what is the same $k_i = \prod_j \left(\left(\alpha_i\gamma_i\frac{\eta_i}{\eta_j}y_j \right)^{1-\phi_j} \left(\alpha_i\gamma_i\frac{\eta_i}{p_j^f}\nu \right)^{\phi_j} \right)^{\omega_{ji}}$.

Assume that the supply of labor is inelastic at 1, so the fraction of labor allocated to each sector follows Domar weights adjusted by the sectorial labor expenditure shares in gross output,

$$l_i^\star = \frac{(1-\alpha_i)\gamma_i p_i y_i}{\sum_i (1-\alpha_i)\gamma_i p_i y_i} = \frac{(1-\alpha_i)\gamma_i\eta_i}{\sum_i (1-\alpha_i)\gamma_i\eta_i}.$$

For the purpose of describing final demand, it would be useful to define $\tilde{l}_i = \frac{l_i^\star}{\gamma_i(1-\alpha_i)}$.

Final output in each sector is then

$$y_n = \left[z_n \left(\prod_i \left(\left(\frac{\eta_n}{\eta_i}y_i\right)^{1-\phi_i} \left(\frac{\eta_n}{p_i^f}\nu\right)^{\phi_i} \right)^{\omega_{in}} \right)^{\alpha_n} (\tilde{l}_i)^{1-\alpha_n} \right]^{\gamma_n} \left[\prod_i \left(\frac{\eta_n}{\eta_i}y_i \right)^{\mu_{in}} \right]^{1-\gamma_n}$$

Taking logs and writing output in matrix form we obtain

$$\ln(\mathbf{y}) = \Gamma\boldsymbol{\lambda} + \boldsymbol{\iota} + \Gamma\alpha\boldsymbol{\phi}'\boldsymbol{\Omega}'\nu + \Gamma\alpha(1-\boldsymbol{\phi})'\Omega'\ln(\mathbf{y}) + (1-\Gamma)M'\ln(\mathbf{y})$$

where each element of the vector $\boldsymbol{\iota}$ can be described as $\iota_n \equiv \gamma_n(1-\alpha_n)\ln(\tilde{l}_n) + \gamma_n\alpha_n\sum_i(1-\phi_i)\omega_{in}\ln(\frac{\eta_n}{\eta_i}) + \gamma_n\alpha_n\sum_i\phi_i\omega_{in}\ln(\frac{\eta_n}{p_i^f}) + (1-\gamma_n)\sum_i\mu_{in}\ln(\frac{\eta_n}{\eta_i})$. The solution for gross output is then,

$$\ln(\mathbf{y}) = \Xi\Gamma\boldsymbol{\lambda} + \Xi\boldsymbol{\iota} + \Xi\Gamma\alpha\boldsymbol{\phi}'\boldsymbol{\Omega}'\nu \tag{6}$$

where the multiplier on sectorial productivity is $\Xi \equiv (I - \Gamma\alpha\boldsymbol{\phi}'\Omega' - (1-\Gamma)M')^{-1}$. Let the price level of the economy be normalized to $p = 1$, then aggregate value added is $\nu = \frac{p_n y_n}{\eta_n}$ for any n. We can compute a geometric average of each of the terms using the expenditure shares consumption and investment $\tilde{\zeta}_n \equiv \zeta_n + \frac{p_n x_n}{\nu}$ as weights (since these weights add up to 1 and trade is balanced),

$$\ln(\boldsymbol{\nu}) = \sum_n \tilde{\zeta}_n\ln(p_n) + \sum_n \tilde{\zeta}_n\ln(y_n) - \sum_n \tilde{\zeta}_n\ln(\eta_n).$$

Given a CRS aggregator of sectorial output, the price index for final goods satisfies, $\ln(p) = \sum_n \zeta_n\ln(p_n)$. Because final output is the numeraire, the log of the price index equals zero, and therefore the first term in the expression for value added drops up. The weighting of the terms in the sum also include investment shares in value added. Investment shares are proportional to consumption shares in value added whenever sectorial value added shares are proportional to consumption shares across sectors. This is by construction the assumption in canonical models of input-output linkages without capital and we assume that feature here.[23]

We have already characterized the solution to each of the last two terms, in equations 2 and 6.

$$\ln(\nu) = \tilde{\boldsymbol{\zeta}}'\Xi(\Gamma\boldsymbol{\lambda} + \boldsymbol{\iota} + \Gamma\alpha\boldsymbol{\phi}'\boldsymbol{\Omega}'\nu) - \sum_n \tilde{\zeta}_n \ln(\eta_n)$$

where we can define the elasticity of value to sectorial TFP as $\tilde{\eta} \equiv \tilde{\boldsymbol{\zeta}}'\Xi$. Unlike the Domar weight, these elasticities are not adjusted by the investment rate. At the same time, the investment rate enters into the measure of the expenditure share, $\tilde{\zeta}$ through the Domar weight because $(I-(1-\Gamma)M')^{-1}\tilde{\zeta} = \eta$..

Because of the presence of tradable investment goods we obtain an additional amplification (as in Jones (2011) for tradable intermediate inputs). The reason is that as productivity increases within the economy, the export capacity improves, and due to trade balance that implies higher imports of investment. The strongest the dependence on imported equipment and the intensity of use of capital, the strongest is this amplification channel.

$$\ln(\nu) = \left(I - \Gamma\alpha\boldsymbol{\phi}'\boldsymbol{\Omega}'\right)^{-1}\left[\tilde{\boldsymbol{\zeta}}'\Xi(\Gamma\boldsymbol{\lambda} + \boldsymbol{\iota}) - \sum_n \tilde{\zeta}_n \ln(\eta_n)\right]$$

Unpacking the vectors, $\tilde{\zeta}_n = \tilde{\eta}_n - \sum_j \gamma_j\alpha_j(1-\phi_j)\omega_{nj}\tilde{\eta}_j - \sum_j(1-\gamma_j)\mu_{nj}\tilde{\eta}_j$

$$\sum_n \tilde{\zeta}_n ln(\mu_n) = \sum_n \tilde{\eta}_n \ln(\eta_n) - \sum_n\sum_j \gamma_n\alpha_n(1-\phi_n)\omega_{nj}\tilde{\eta}_j \ln(\mu_n) - \sum_n\sum_j (1-\gamma_n)\mu_{nj}\tilde{\eta}_j \ln(\mu_n)$$

Now consider the term, $\tilde{\eta}\iota$

$$\begin{aligned}\sum_n \tilde{\eta}_n \iota_n &= \sum_n (\tilde{\eta}_n\gamma_n(1-\alpha_n)\ln(\tilde{l}_n) + \tilde{\eta}_n\gamma_n\alpha_n \sum_j (1-\phi_j)\omega_{jn}\ln(\frac{\eta_n}{\eta_j}) + \gamma_n\alpha_n\sum_j \phi_j\omega_{jn}\ln(\frac{\eta_n}{p_j^f}) \\ &\quad + \tilde{\eta}_n(1-\gamma_n)\sum_j \mu_{jn}\ln(\frac{\eta_n}{\eta_j}))\end{aligned}$$

which can be rewritten as

$$\begin{aligned}\sum_n \tilde{\eta}_n \iota_n &= \sum_n \tilde{\eta}_n\gamma_n(1-\alpha_n)\ln(\tilde{l}_n) + \sum_n \tilde{\eta}_n(\gamma_n\alpha_n + 1 - \gamma_n)\ln(\eta_n) \\ &\quad - \sum_n \tilde{\eta}_n\gamma_n\alpha_n\sum_j \omega_{jn}\left((1-\phi_j)\ln(\eta_j) + \phi_j\ln(p_j^f)\right) - \sum_n \tilde{\eta}_n(1-\gamma_n)\sum_j \mu_{jn}\ln(\eta_j)\end{aligned}$$

Therefore the difference in the last two terms of the expression for value added are

$$\sum_n \tilde{\eta}_n \iota_n - \sum_n \tilde{\zeta}_n \ln(\eta_n) = \sum_n \tilde{\eta}_n\gamma_n(1-\alpha_n)(\ln(\tilde{l}_n) - \ln(\eta_n)) - \sum_n \tilde{\eta}_n\gamma_n\alpha_n\sum_j \omega_{jn}\phi_j\ln(p_j^f)$$

[23] Alternatively, one can set up the economy so that investment in different capital types is produced through the final good. This economy would also allows us to define the price of value added as a function of sectorial prices in a way that they drop out from the expression above, while allowing for investment shares that need not be proportional to consumption shares. The undesirable feature of this economy is that sector producing for final production and intermediate inputs are decoupled from those producing investment.

The last term can be written as a function of the terms of trade for imported equipment j, $\ln(\tau_j) = \ln(p) - \ln(p_j^f)$. Because the final good is the numeraire, p=1. Hence,

$$\sum_n \tilde{\eta}_n \iota_n - \sum_n \tilde{\zeta}_n \ln(\eta_n) = \sum_n \tilde{\eta}_n \gamma_n (1-\alpha_n)(\ln(\tilde{l}_n) - \ln(\eta_n)) + \sum_n \tilde{\eta}_n \gamma_n \alpha_n \sum_j \omega_{jn} \phi_j \ln(\tau_j)$$

which proves our result. ■

A.1.1 Balanced growth path

Let us start by defining GDP in the economy, ν as the value of consumption and investment expenses plus net exports, $C + \sum p_n x_n + NX = \nu$, in units of consumption.

Definition: *A balanced growth path is an allocation where output, consumption, investment and capital in each sector grow at a constant, possibly different, growth rate.*

Along the BGP

$$g^\nu = g^c = g^{p^x} + g^x = g^{NX},$$

The growth rate of net exports is

$$g^{NX} = g^\epsilon = g^{p^f} + g^{x^f}.$$

It follows that the growth rate of the terms of trade (considered exogenous) determines the relative growth of real exports and imports whenever trade is balanced.

$$g^\tau \equiv -g^{p^f} = g^{x^f} - g^\epsilon. \tag{7}$$

Define g^y as the vector collecting the growth rates of gross output across sectors $g^y = (g^{y_1}, ..., g^{y_N})$. We define g^ν, g^m, g^k and g^x analogously. The growth rate of output in each sector grows at a constant rate equal to growth rate of its uses, including consumption, investment and intermediate goods. Feasibility then implies that $g^{m_{in}} = g^{y_i}$, and therefore, given the aggregator of intermediate inputs in sector n, $g^{m_n} = \sum_{i=0}^N \mu_{in} g^{y_i}$. In other words, $g^{m_n} = M' g^y$.

Along the BGP, the law of motion for capital requires $g^x = g^k$, where investment includes domestically and foreign sourced investment. Hence,

$$g^k = g^x = (1-\phi)\Omega' g^{x^d} + \phi \Omega' g^{x^f}$$

$$g^k = g^x = (1-\phi)\Omega' g^{x^d} + \phi \Omega' g^\epsilon + \phi \Omega' g^\tau$$

Note that because of trade balance the amount of exports in equilibrium equals the amount of imported equipment.

Finally, the production technology implies $g^y = \Gamma g^\nu + (1-\Gamma) g^m$, and by definition, $g^\nu = g^z + \alpha g^k + (1-\alpha) g^l$. But aggregate labor supply is fixed and along a BGP the share of labor allocated to each sector is constant (because relative sectorial output is constant). Using the growth rate of capital and collecting the terms with the growth rate of gross output yields

$g^y = \Gamma g^z + \Gamma\alpha(1-\phi)\Omega' g^y + \Gamma\alpha\phi\Omega' g^\nu + \Gamma\alpha\phi\Omega' g^\tau) + (1-\Gamma)M' g^y$. The third term in the RHS of this expression corresponds to the growth rate of exports.

$$g^y = \Xi'\Gamma(g^z + \alpha\phi\Omega' g^{\underline{\tau}} + \alpha\phi\Omega' g^\nu).$$

Hence, the growth rate of gross output in the economy depends on the productivity growth in each sector, the terms of trade and the growth rate of exports, proportional to value added, with a multiplier $\Xi' \equiv (I - \Gamma\alpha(1-\phi)\Omega' - (1-\Gamma)M')^{-1}$. The matrix Ξ is the generalized Leontief inverse.

$$g^\nu = (I - \alpha\phi\Omega'(I + \alpha(1-\phi)\Omega'\Xi'\Gamma))^{-1}(I + \alpha(1-\phi)\Omega'\Xi'\Gamma)[g^z + \alpha\phi g^\tau]$$

Hence, the growth rate of value added follows from the factor structure of the economy, as in Long and Plosser (1983).

A.2 Data appendix

Table 8: Country Sample and Data Sources

Country	GDP per capita (PPP, 2005)	Use-Tables; Input-Output Matrix; Value Added Share in Gross Output;		Employment by Occupation and Industry		Capital Expenditure Share in Value Added	
		Source	*Available Years*	*Source*	*Available Years*	*Source*	*Available Years*
Ethiopia	1628	MDV	1990-2019	IPUMS International	1994	PWT*	1960-2019
Ghana	8357	MDV	1990-2019	LSMS	2009	PWT*	1950-2019
Czechia	55101	WIOD	2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
Hungary	50934	WIOD	2000-2014	PIAAC	2017	PWT, WIOD	1970-2019
Lithuania	41234	WIOD	2000-2014	PIAAC	2015	PWT, WIOD	1970-2019
Mexico	38368	WIOD	1965-2000; 2000-2014	PIAAC	2017	PWT, WIOD	1950-2019
Polonia	46192	WIOD	2000-2014	PIAAC	2012	PWT, WIOD	1970-2019
Russia	32305	WIOD	2000-2014	PIAAC	2012	PWT, WIOD	1970-2019
Turkey	47174	WIOD	2000-2014	PIAAC	2015	PWT, WIOD	1950-2019
Belgium	96193	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
Germany	80663	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
Spain	73499	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
France	87810	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
United Kingdom	82649	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
Greece	70791	WIOD	1965-2000; 2000-2014	PIAAC	2015	PWT, WIOD	1951-2019
Ireland	99918	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
Italy	85574	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
Japan	75050	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
South Korea	64971	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1953-2019
Netherlands	87396	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
Sweden	83982	WIOD	1965-2000; 2000-2014	PIAAC	2012	PWT, WIOD	1950-2019
United States	112229	WIOD	1965-2000; 2000-2014	PIAAC	2017	PWT, WIOD	1950-2019

*Note: Ethiopia's and Ghana's expenditure share statistics are unavailable so we impute the expenditure share using data from Rwanda for Ethiopia and Kenya for Ghana respectively, countries with a similar level of GDP per capita.

Table 9: Aggregate Sectors Definition

GGDC Sector	GGDC Sector Description	Aggregate Sector
A	Agriculture, forestry and fishing	Agriculture
C10t12	Manufacture of food products and beverages, tobacco products	Manufacturing
C13t15	Manufacture of textiles; wearing apparel; leather and related products	Manufacturing
C16t18	Manufacture of wood and of products, except furniture; articles of straw and plaiting materials; paper and paper products; Printing and reproduction of recorded media	Manufacturing
C19t22	Manufacture of coke and refined petroleum products; chemicals and chemical products; basic pharmaceutical products and pharmaceutical preparations; rubber and plastics products	Manufacturing
C23t25	Manufacture of other non-metallic mineral products; basic metals; fabricated metal products, except machinery and equipment	Manufacturing
C26t27	Manufacture of computer, electronic and optical products; electrical equipment	Electronics
C28	Manufacture of machinery and equipment n.e.c.	Machinery
C29t30	Manufacture of motor vehicles, trailers and semi-trailers; other transport equipment; Transportation and storage services	Transportation
C31t33	Manufacture of furniture; Other manufacturing; Repair and installation of machinery and equipment	Machinery
DtE	Electricity, gas, steam and air conditioning supply; Water supply; sewerage, waste management and remediation activities	Services
F	Construction	Construction
GnI	Wholesale and retail trade; repair of motor vehicles and motorcycles; Accommodation and food service activities	Services
JnMN	Information and communication; Professional, scientific and technical activities; Administrative and support service activities	ICT
K	Financial and insurance activities	Services
L	Real estate activities	Services
OtQ	Public administration and defence; compulsory social security; Education; Human health and social work activities	Services
RtU	Arts, entertainment and recreation; Other service activities; Activities of households as employers; goods- and services-producing activities of households for own use; Activities of extraterritorial organizations and bodies	Services

B Additional Tables & Pictures

Figure 4: TFP Component Contribution vs Observed GDP per capita

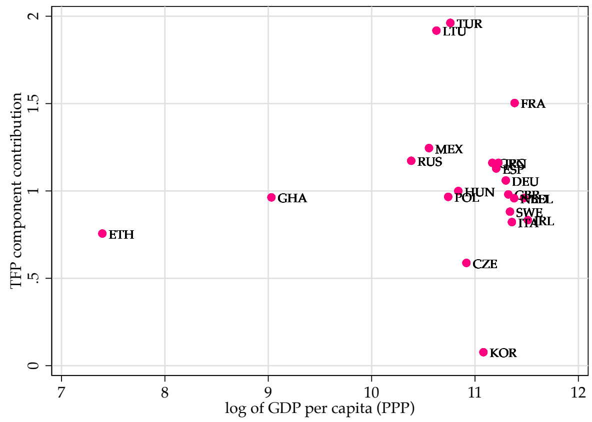
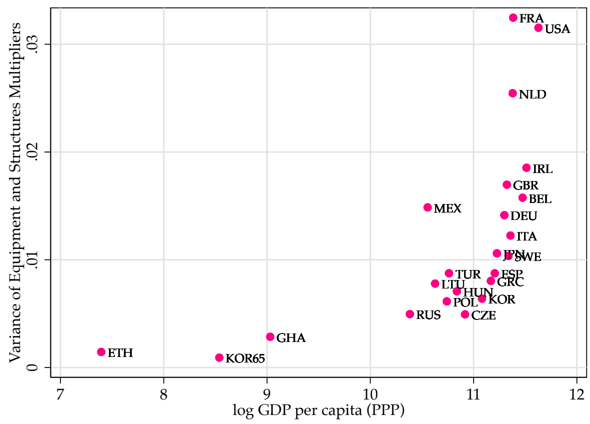
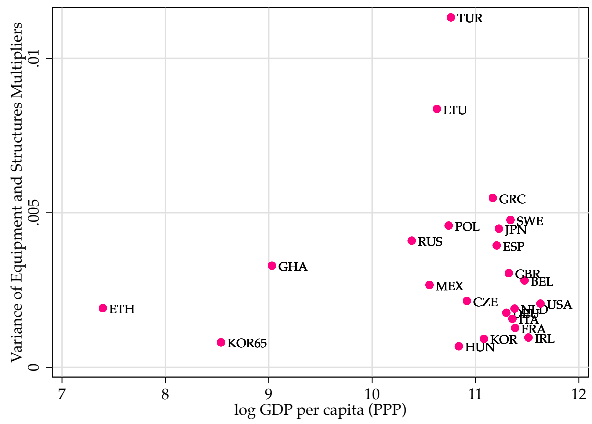


Figure 5: Variance of (...) with and without ICT

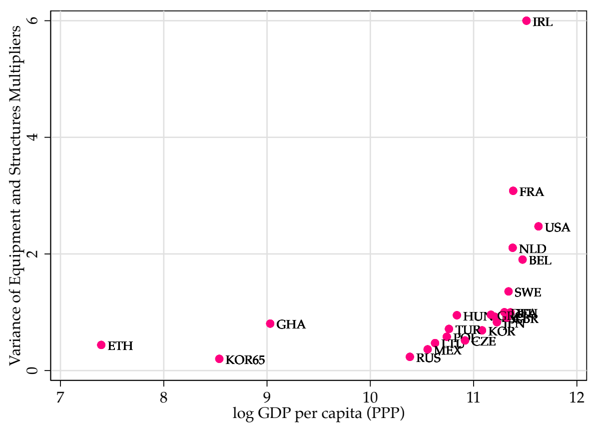
(a) Influence vector



(b) Influence vector, w/o ICT



(c) Outdegree of Augmented Leontief Inverse



(d) Outdegree of Augmented Leontief Inverse, w/o ICT

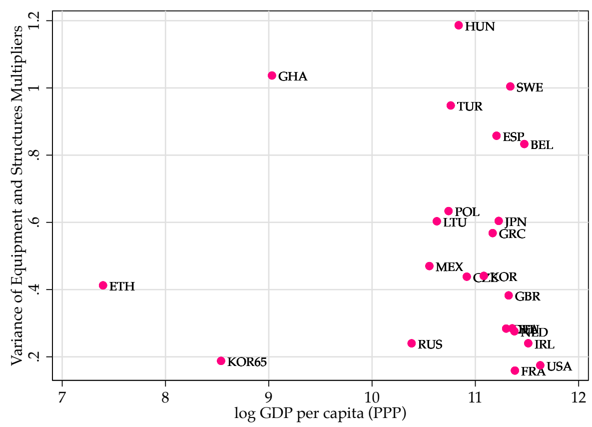
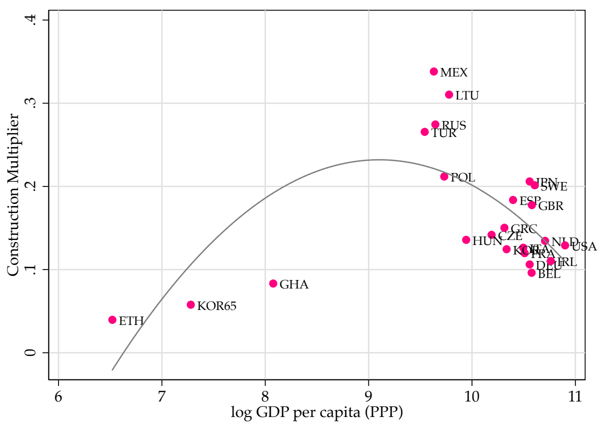
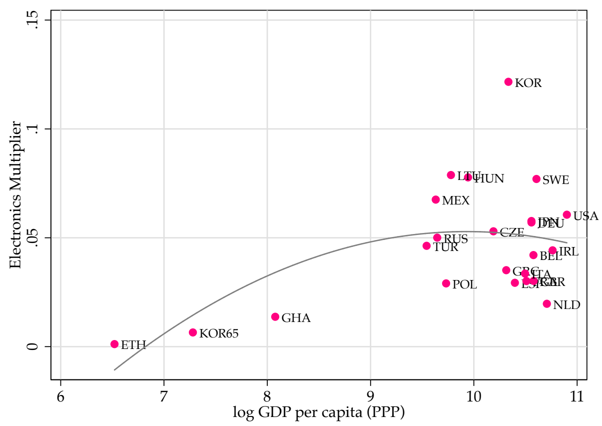


Figure 6: Influence and GDP per capita – Cross Country, 2005

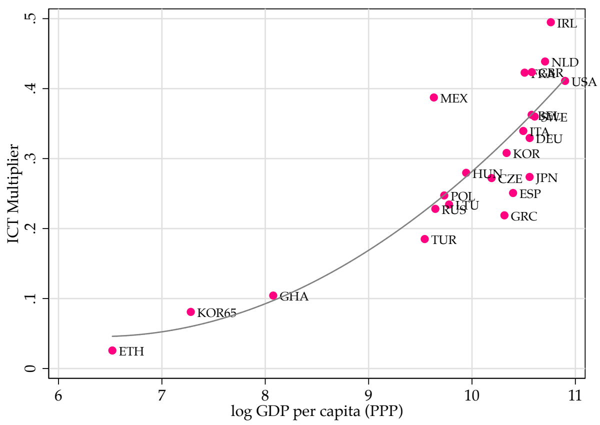
(a) Construction



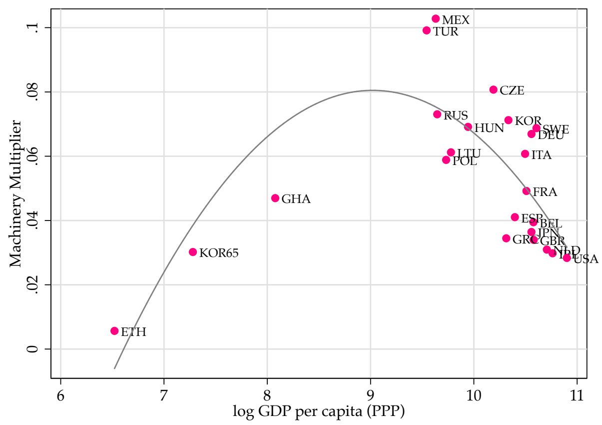
(b) Electronics



(c) ICT



(d) Machinery



(e) Transportation

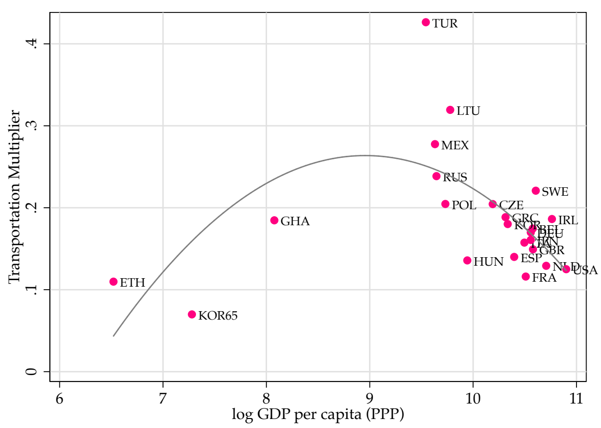
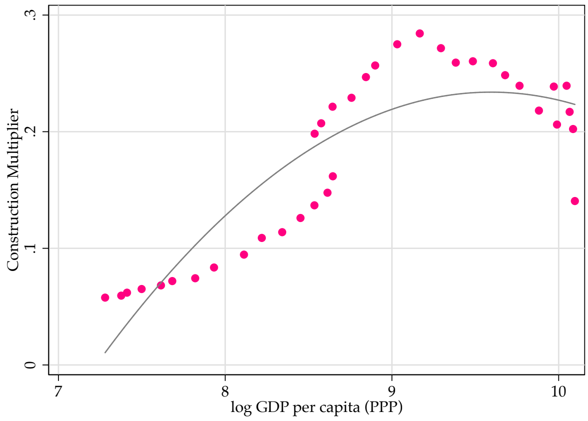
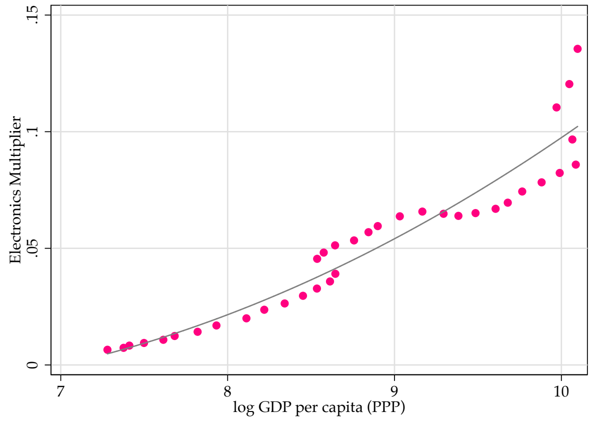


Figure 7: Influence and GDP per capita – South Korea, 1965-2000

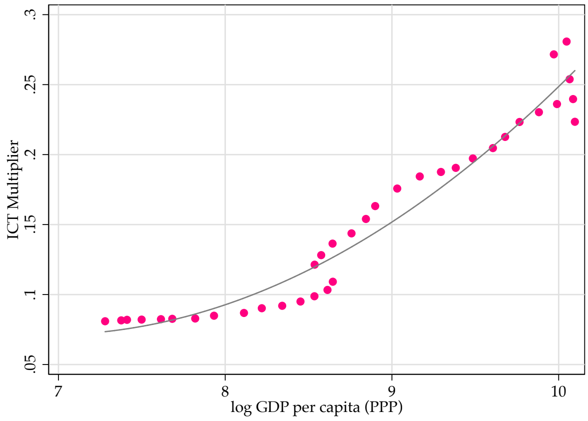
(a) Construction



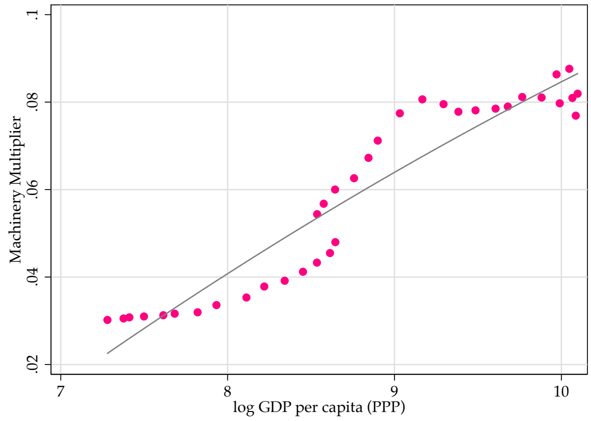
(b) Electronics



(c) ICT



(d) Machinery



(e) Transportation

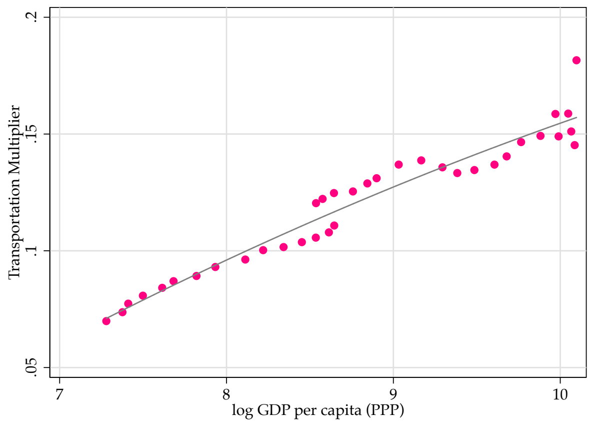


Table 10: GDP per capita and influence

	Construction	Electronics	ICT	Machinery	Transportation
log_gdp_pc	0.236**	0.685***	0.552***	0.241**	0.0844
	(0.0852)	(0.115)	(0.0426)	(0.105)	(0.0710)
Observations	23	23	23	23	23
R^2	0.268	0.629	0.889	0.202	0.063