Essays on Aggregate Productivity

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I would like to dedicate this thesis to my parents Vesna and Bojan for teaching me the value of knowledge.

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Needless to say, the work involved in a thesis cannot come about without the proper emotional stability. I draw my inspiration from Gaja. Hvala ti Piki za to, da te imam, za najino Zweisamkeit.

Contents

Introduction

This thesis is concerned with differences in aggregate labor productivity across economies. Much of the income disparities that we observe across countries today are related to productivity differences. It follows that much human suffering could be alleviated by raising the efficiency of production. This requires an idea of the qualitative and quantitative significance of potential barriers. Unsurprisingly, productivity has been studied by economists for as long as economics has been around but despite its importance - or perhaps rather because of it - this research area applied to the *aggregate* economy still offers a huge field open to exploration. In the following chapters I tackle the issue at hand from several distinct angles and using a variety of techniques, but always with the same aim.

The first chapter, entitled *Development Accounting with Intermediate Goods*, asks whether intermediate goods help explain relative and aggregate productivity differences across countries. Three observations suggest they do: (i) intermediates are relatively expensive in poor countries; (ii) goods industries demand intermediates more intensively than service industries; (iii) goods industries are more prominent intermediate suppliers in poor countries. I build a standard multisector growth model accommodating these features to show that inefficient intermediate production strongly depresses aggregate productivity and increases the price ratio of final goods to services. Applying the model to data for middle and high income countries, I find that poorer countries are only modestly less efficient at producing goods than services, but substantially less efficient at producing intermediate relative to final goods and services. If all countries had the intermediate production efficiency of the US, the aggregate productivity gap between the lowest and highest income countries in the sample is predicted to shrink by roughly two thirds while cross-country differences in the final price ratio would virtually vanish.

The second chapter, entitled *Managerial Delegation and Aggregate Productivity*, proposes a novel mechanism to answer why firms in low income countries are badly managed, and quantifies the resulting productivity loss. First, I present empirical evidence on a significant positive correlation between the share of managerial workers and contract enforcement across countries. Second, I construct a tractable model that captures benefits to managerial delegation in large organizations. The model also features an agency problem between the owner of a firm and its middle management. Ineffective contract enforcement, allowing middle managers to steal from the firm, constrains firm size by limiting the efficient delegation of managerial authority. Third, I use a calibrated version of the model to measure the effect of lowering contract enforcement. Compared to the benchmark of US contract enforcement, no enforcement decreases the aggregate share of managerial workers by about 10 percentage points, typical of countries with income levels of about one-tenth of the US. The associated loss in aggregate labor productivity is roughly 18 percentage points. Auxiliary statistics on the mean firm size, self-employment and productivity dispersion offer additional empirical validation of these results.

The third chapter, entitled *Progressive Income Taxation and Aggregate Productivity* and co-authored with Tomaz Cajner, offers a theory on how the progressivity of the labor tax may affect individuals' decision to manage firms or work as production workers. Managers must be matched to firms in an environment featuring search frictions and the pair bargain over the surplus from the match. A higher tax progressivity makes it less lucrative to create and improve risky projects as it compresses the right tail of outcomes. The model is used to link three prominent macroeconomic phenomena occurring over the last two to three decades in the developed world: the lowering of the top marginal labor taxes, the rise in inequality and the renewed opening of the aggregate labor productivity gap between Europe and the US. A parameterized version of the model is capable of delivering the concomitant occurrence of the latter two phenomena as a result of the lowering of top labor income taxes. The quantitative effects predicted by the model, however, cannot match the data.

Chapter 1

DEVELOPMENT ACCOUNTING WITH INTERMEDIATE GOODS

The value of intermediate production as a ratio of total output in a typical economy is about one half. Despite their quantitative importance, intermediate goods have so far received little attention in development accounting. This should *per se* not be of any concern if the efficiency of intermediate relative to final good production were not systematically different across countries and if the structure of input-output relations were not asymmetric across broadly-defined industries. My concern in this paper is threefold. First, I document that the above conditions for intermediate good-neutrality do not hold up in the data. Second, I develop a simple growth model featuring two industries and two specializations (intermediate and final production) and propose some analytical qualitative results based on a plausible input-output structure. Third, I use the model to back out efficiency levels across countries to identify which industry-specializations pairs are particularly inefficient in poor countries.

Two observations are key for the paper's motivation. First, different broadly-defined sectors have systematically distinct technological requirements as regards the use of intermediates and vary systematically in their importance as suppliers of intermediates. More to the point, when the economy is subdivided into goods and service industries, the former consume more intermediate value per unit of output, approximately 0.57 versus 0.36. Goods industries also supply a relatively larger share of intermediates in poor compared to rich countries. This issue has been, to the best of my knowledge, largely overlooked in the recent literature on development accounting, but proves significant in interaction with another set of empirical regularities. This is the fact that for the same industry, intermediate goods, relative to final goods, appear to be relatively expensive in poor countries. It motivates the additional dichotomy between firms specializing in either final or intermediate production.

The main theoretical results are the following. First, it is shown that the price of final goods relative to final services is expected to be lower in less efficient economies even if their efficiency in the goods industry is no lower relative to the one in the service industry. Rather, because the goods industry is a more intensive intermediate input user than the service industry, low efficiency in all industry-specialization pairs renders the goods industry relatively less productive than the service industry as intermediate resources are relatively scarce compared to labor. Second, it is shown that if relative to poor countries, rich countries were particularly more efficient at producing intermediate goods and services, then all specialization-industry pairs except for specialized intermediate goods (as opposed to service) producers are likely to increase their *real* intensity use of intermediates. This happens despite the fact that intensity is by construction identical in value terms. Third, compared to percent increases in the efficiency of final good production, a percent increase in the efficiency of intermediate input production has a relatively stronger impact on theoretical aggregate productivity in poor countries than in rich countries. This is because poor countries not only have higher final expenditure shares on goods than services, they also spend larger fractions of intermediate consumption on goods than on services. In turn, goods - in both specializations - are more sensitive to increases in intermediate production efficiency than services. In other words, observed complementarities in the production of intermediate goods strongly leverage inefficiencies of intermediate input production.

For the quantitative part I employ the EU Klems dataset for a sample of middle and high income countries which features comparable intermediate and final prices and quantities. The results suggest that compared to rich countries, poor countries are less efficient across the board in all industry-specialization pairs. More interestingly, poorer countries are only modestly less efficient at producing (final or intermediate) goods than services. Moreover, poorer countries are particularly less efficient at producing intermediate rather than final goods and services. The fact that final goods are relatively more expensive in poor countries than final services hence does not result so much from the fact that these countries are particularly worse at producing goods compared to services. Rather, it is due to the fact that poor countries are relatively inefficient at producing *intermediates*.

The model offers a straightforward method to gauge the separate effects created by the input-output structure and by efficiency differences across specializations. I find that ignoring the fact that intermediate and final good production is done at different efficiency levels substantially increases the perceived efficiency gap that poor countries have in producing goods rather than services. Also, poor countries in this context appear much less efficient at producing both final goods and services than in the benchmark case. In a similar fashion, ignoring the intermediate input demand asymmetry between goods and services also strongly exaggerates the poor countries' efficiency gap between the production of goods and services. Ignoring the supply asymmetry creates an analogous effect, though it is quantitatively less important. A development accounting exercise ignoring these features is therefore likely to underestimate poor countries' efficiency in producing final goods and services and is furthermore likely to exaggerate especially their inefficiency in creating goods vis-à-vis services.

A simple counterfactual exercise stresses the impact of intermediate inputs in the accounting framework. If middle income countries were somehow able to adopt the US efficiency of intermediate good production, their aggregate productivity (compared to the richest countries) is predicted to increase from about 0.47% to 0.84%. Also, such a move would almost equalize the final good price ratios across poor and high income countries. This finding is important. It states that the efficiency of intermediate good production is responsible for the bulk of the aggregate and relative productivity differences across countries.

The paper is closely related to the literature on sectoral development accounting. Based on final expenditure price data, Herrendorf and Valentinyi (forthcoming) compute that poor countries are particularly bad at producing goods as compared to services. On the other hand, Duarte and Restuccia (2010) present evidence, based on industry growth accounting and the pattern of structural transformation, that poorer countries are particularly unproductive in the agriculture and services sectors, but not so much in manufacturing. My aim is to shed light on these conflicting pieces of evidence by stressing the importance of input-output patterns in determining relative sectoral productivities. Ngai and Samaniego (2009) similarly stress the importance of the composition of intermediate goods for productivity inferences, though their focus is on investment-specific technical change.[1]

[1] The classical theoretical contributions on growth accounting with intermediate goods include amongst others

The literature offers some support for the notion that the production of intermediate goods is particularly inefficient in poor countries. On the theoretical front, Acemoglu, Antràs and Helpman (2007) apply the incomplete contracts framework of Grossman and Hart (1986) and Hart and Moore (1990) to the analysis of contracts between producers and their specialized input suppliers. They find that a higher degree of contract incompleteness lowers the suppliers' incentive to invest and hence leads to underprovision of intermediate inputs. This fits well with empirical evidence provided by Nunn (2008) who argues that countries with more efficient contractual institutions tend to be richer and specialize in the production of goods that require special relationships with suppliers. An alternative reason for poor countries' low performance in producing intermediates is a lower degree of competitive pressure. Amiti and Konings (2007) provide empirical support that the lowering of trade barriers in developing countries boosts productivity by increasing import competition in the market for intermediate goods. That foreign competitive pressures strongly boost productivity in a prominent intermediate good producing sector such as mining is also empirically documented in Galdón-Sánchez and Schmitz (2002).

As intermediates are essential factors of production, a strand of the literature has focused on their underprovision as a substantial barrier to development. Jones (forthcoming) shows theoretically how generic wedges that disperse the marginal productivity of intermediate goods, coupled with these goods' complementarity in production, leads to substantial leverage effects on productivity.[2] His model builds on the seminal contribution of Mirrlees (1971) on the negative welfare effect of taxing intermediate inputs and the one of Kremer (1993) on the problem of complementarity in production. Ciccone (2002) is also a theoretical treatment of the process of industrialization as the deepening of intermediate good use intensity, based on some evidence to that effect reported in Chenery, Robinson and Syrquin (1986). Restuccia, Yan and Zhu (2008), based on producer price data of the Food and Agriculture Organization (FAO), find that farms in poor countries face substantially higher relative prices for intermediate goods. This lowers their agricultural productivity, which in turn strongly diminishes aggregate productivity as due to the negative income effect most resources are channeled into agriculture. Finally, the interest in (real) physical intermediate input intensity as opposed to value intensity is very similar in spirit to Hsieh and Klenow (2007). They stress that poorer countries have lower investment rates in physical capital when measured at internationally comparable prices, but not at local prices. Here I highlight a similar phenomenon by claiming that a portion of poor countries' low productivity can be 'explained' by their low investment rates in the production factor intermediate goods.

The organization of the paper is as follows. Section 1 presents the empirical evidence. Section 2 proposes the model environment. The theoretical results of the model are summarized in section 3 while section 4 explores the data implications following the calibration of the model. Section 5 concludes.

1.1 Empirical motivation

1.1.1 Relative prices

One of the most salient stylized features in development accounting is that at the level of final expenditure, goods (agricultural, industrial consumption and investment goods) are rela-

Melvin (1969) and Hulten (1978).

[2]The dispersion of productivities *within* sectors as a source of large aggregate productivity differences has recently received a lot of attention as well. See for instance Banerjee and Duflo (2005), Guner, Ventura and Yi (2008), Restuccia and Rogerson (2008) and Hsieh and Klenow (2009).

tively more expensive than services in poorer countries. Figure (1.1) reproduces the data to that effect from the World Bank's International Comparisons Program.[3] These relative price differences are presumably informative about which are the 'problem sectors' in poor countries if one is interested in growth accounting at the final expenditure level. Herrendorf and Valentinyi (forthcoming) use similar data to construct production functions for different sectors to back out sectoral TFP series. They find that the poorest countries are particularly inefficient at producing agricultural and investment goods, and also inefficient at producing consumption goods, while much less inefficient at producing services.

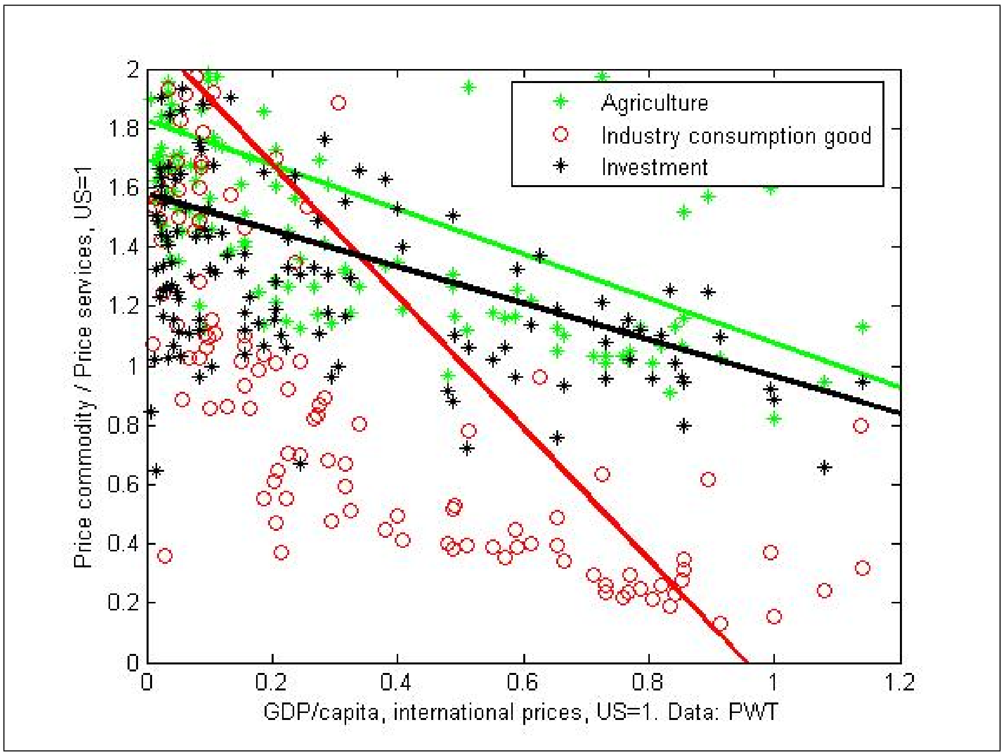

Figure 1.1: Relative price of expenditure items

The trouble with such an approach is that it does not directly imply relative productivity differences at the industry level. This information, however, would be more valuable for researchers trying to micro-found productivity differences across countries and sectors that is related to inefficiencies at the level of the production unit. To circumvent this problem, Duarte and Restuccia (2009) use a structural transformation model to measure cross-country sectoral productivity differences for OECD countries and a smaller sample of middle income countries. They infer level differences from relative employment shares at a given moment in time and then use industry-based productivity growth data to measure productivity growth and hence productivity levels through time. Interestingly, and in stark contrast, they find that rich compared to poor countries have much higher productivity levels in the production of agricultural goods and services but not so much in manufacturing.

The difference in the two results may of course only be due to the fact that Herrendorf and Valentinyi (forthcoming) measure TFP while Duarte and Restuccia (2010) infer productivity, but since the sectoral physical and human capital factor shares used by Herrendorf and Valentinyi (forthcoming) do not vary much between manufacturing and services, this seems

[3]The construction of all the series in the following Figures is described in the Appendix.

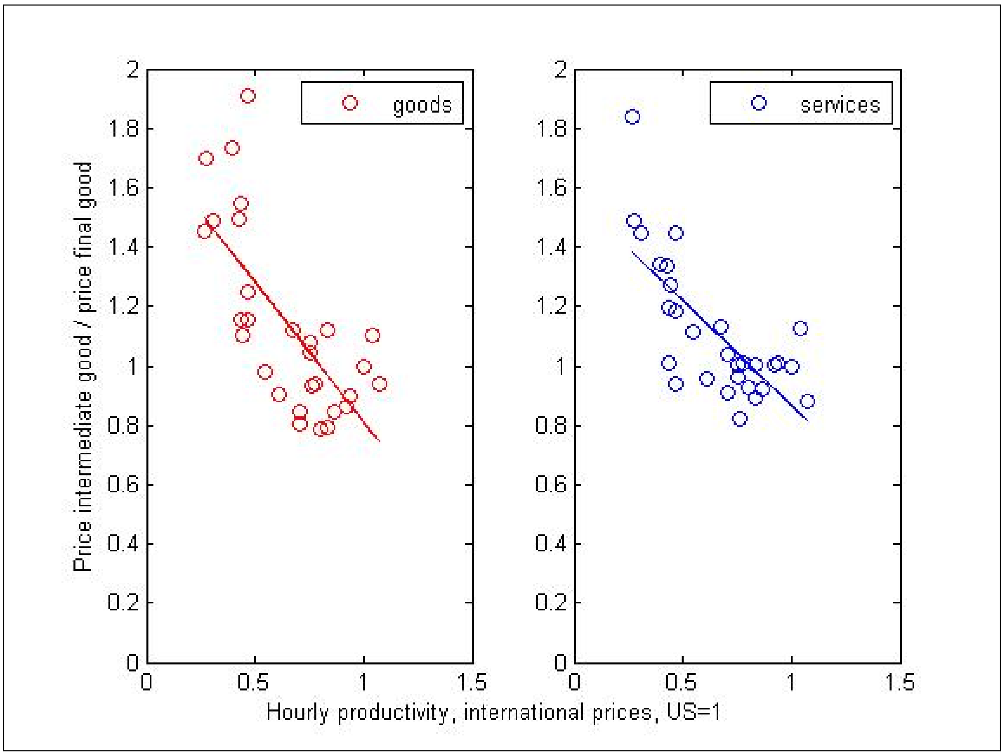

Figure 1.2: Relative cost of intermediate to final goods

unlikely. Rather, the conflicting evidence calls for an analysis that explicitly takes into account the input-output pattern in the economy in determining the relative sectoral productivity levels. Such an analysis could explain why in poor countries sectors producing goods appear to be relatively less productive than service sectors measured at final expenditure level, while the result is partially reversed at the industry level.

One indicator that intermediate goods play an essential role in development accounting is the fact that they appear to be relatively expensive in poor countries. This observation comes out of the only dataset on internationally comparable relative prices at the industry level, provided by EU Klems and covering most OECD countries and several Central and Eastern European countries (for further discussion see O'Mahony and Timmer (2009)). Figure (1.2) plots data for each sample country on the price of intermediate goods (services) relative to the price of final goods (services) against data on aggregate hourly productivity. The downward-sloping shape of the series suggests that in both industries - goods and services - intermediates are particularly expensive compared to final goods in poor countries.

1.1.2 Intermediate consumption and supply shares

Figure (1.3) summarizes the intermediate consumption factors (value of an industry's intermediate good consumption needed for one unit of output value - the difference to one is the industry's value-added) across countries from internationally comparable input-output tables (for further details see Ahmad and Yamano (2006)). Each dot represents the ratio of country-year pairs for broadly defined industries, plotted against the country's GDP per capita in that year.[4]

[4]The sample includes OECD as well as several non-OECD countries. GDP per capita values are taken from the Penn World Tables. The years are 1995, 2000 and 2005.

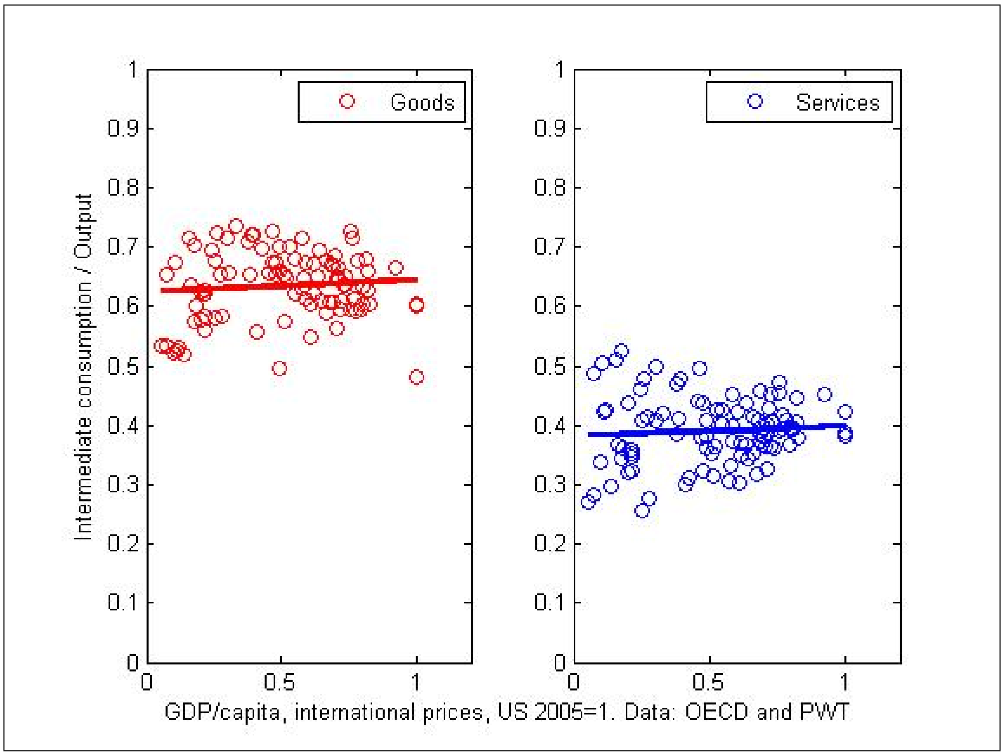

Figure 1.3: Intermediate factor shares

Two apparent trends stand out. First, for both sectors the ratios seem rather uncorrelated with GDP per capita. This fact has been previously pointed out elsewhere for the overall intermediate consumption ratio in the economy (e.g. Jones (forthcoming)). It runs counter, however, to the argument expressed in Chenery, Robinson and Syrquin (1986), according to which input-output ratios may have increased during industrialization in several developing countries, possibly due to the adoption of different technological practices.[5] In this paper I will abstract from arguments involving changes in technology and treat the input-output ratio of an industry as depending exclusively on a time-invariant factor share of inputs in the production function. Rather, I wish to highlight the other feature that emerges from Figure (1.3), namely that industries vary substantially in their requirement of intermediate goods. In particular, the figure shows that the production of goods uses up relatively larger values of intermediate goods than the production of services. I claim that this is an aspect that may not have received sufficient attention in the latest literature on aggregate productivity across countries.

The constancy of aggregate intermediate factor shares across countries and industries does not, however, extend to a finer breakdown of intermediate goods by types. Figure (1.4) shows that as countries grow richer, industries producing goods tend to use rather less intermediates deriving from their own sector, as a share of their total intermediate good consumption, while service industries tend to use rather more intermediates deriving from their own sector. Goods intermediates are therefore relatively more prevalent in poorer countries.

[5]This study is related to the analysis of the economy by means of the Leontieff matrix and has its roots in the identification of optimal demand stimulus. In particular, the concern there is with the 'technical coefficients', i.e. the multiplier value of demand in upstream sectors due to a percentage increase in a final demand sector.

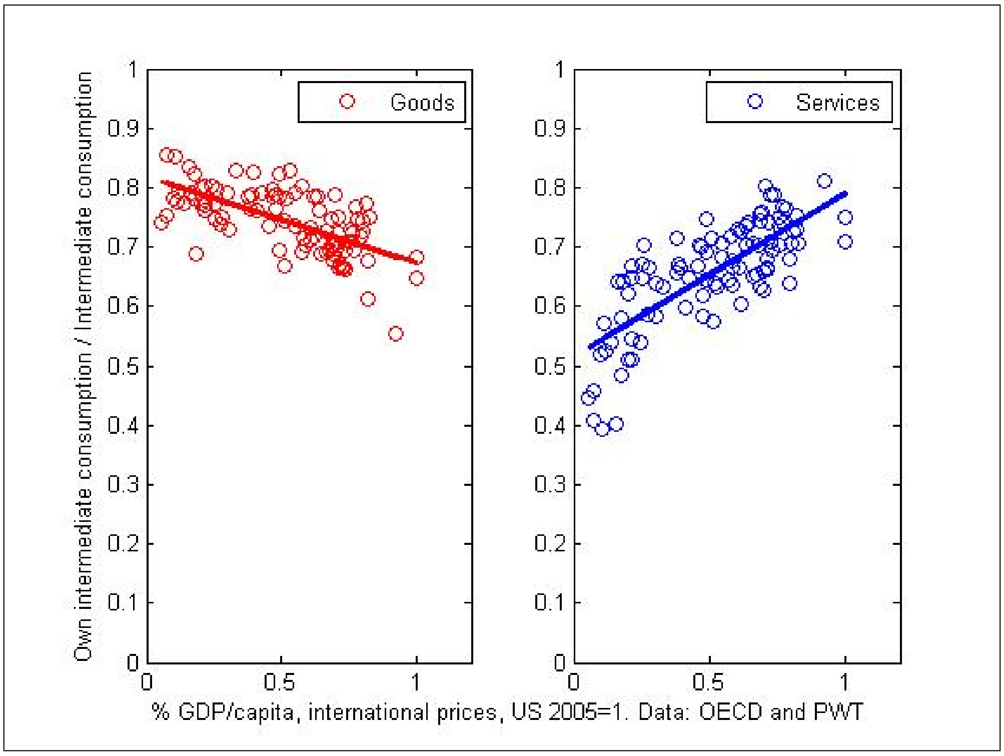

Figure 1.4: Shares of intermediates from same own industry

1.2 Economic environment

1.2.1 Model description

I consider a closed economy that is static so the firms' and households' objectives only need to be specified over intratemporal choices.

Production

All firms operate in a competitive environment. They specialize in producing either final or intermediate goods, indexed respectively by $j \in \{f, m\}$. At the final good level there is a representative firm indexed by $i \in \{g, s\}$ in each of the two industries - goods and services[6] - producing according to the constant returns to scale production function

$$y_{fi} = A_{fi}\left(\gamma_{gi}^{\frac{1}{\rho_i}} x_{gfi}^{\frac{\rho_i - 1}{\rho_i}} + \gamma_{si}^{\frac{1}{\rho_i}} x_{sfi}^{\frac{\rho_i - 1}{\rho_i}}\right)^{\frac{\sigma_i \rho_i}{\rho_i - 1}} l_{fi}^{1-\sigma_i} \tag{1.1}$$

where y_{fi}, and l_{fi} denote, respectively, firm fi's output and labor input while x_{jfi} is the firm's demand for the intermediate good supplied by industry j. $A_{fi} > 0$ is the firm's efficiency parameter, $\sigma_i \in (0, 1)$ the composite intermediate good factor share, $\rho_i \in [0, 1) \cup (1, \infty)$ the elasticity of substitution between the two intermediate inputs and $\gamma_{gi} \in (0, 1)$ their relative weights in production, with $\sum_{j=s,g} \gamma_{ji} = 1$. The firm's maximization of profits implies

$$\max_{x_{gfi} \geq 0, x_{sfi} \geq 0, l_{fi} \geq 0} \left(p_{fi} y_{fi} - p_{mg} x_{gfi} - p_{ms} x_{sfi} - w l_{fi}\right) \tag{1.2}$$

[6]Goods will have as their empircial counterpart the industry labels A-F while services industries G-Q.

where p_{fi} is the price of the firm's output, p_{mj} the price of intermediate input j and w the wage rate.

Analogously, intermediate goods producers in each industry i produce according to

$$y_{mi} = A_{mi} \left(\gamma_{gi}^{\frac{1}{\rho_i}} x_{gmi}^{\frac{\rho_i - 1}{\rho_i}} + \gamma_{si}^{\frac{1}{\rho_i}} x_{smi}^{\frac{\rho_i - 1}{\rho_i}} \right)^{\frac{\sigma_i \rho_i}{\rho_i - 1}} l_{mi}^{1-\sigma_i}, \tag{1.3}$$

with $A_{mi} > 0$, and solve

$$\max_{x_{gmi} \geq 0, x_{smi} \geq 0, l_{mi} \geq 0} \left(p_{mi} y_{mi} - p_{mg} x_{gmi} - p_{ms} x_{smi} - w l_{mi} \right). \tag{1.4}$$

Notice that the technical parameters σ, ρ and γ are assumed to vary across industries, but not across specializations or across countries. In contrast, efficiency A is specific to both industry and specialization and is thought of as the only variable that varies across countries. Also, note that specialized intermediate good producers use part of their output as an input. Market clearing implies that

$$c_i = y_{fi}, \; i \in \{g, s\}, \tag{1.5}$$

$$x_{ifg} + x_{ifs} + x_{img} + x_{ims} = y_{mi}, \; i \in \{g, s\}. \tag{1.6}$$

where c_i is consumption of final good i.

At this point several clarifications are necessary. First, note that the distinction between two industry is not only related to convenience and access to data. As argued in the previous section, there are grounds to believe that along the dimensions of interest here - intermediate goods trade and relative productivity - there is a clear-cut distinction between industries producing goods and those producing services. A further breakdown of the goods industry into consumption and investment goods would enrich the model by incorporating investment behavior. Similarly, a breakdown into agriculture and manufacturing would allow the model to capture better the phenomenon of structural transformation. Yet both would come at the price of less analytical tractability of the central issue here.[7]

Second, the Cobb-Douglas specification between composite intermediate inputs and labor can be defended empirically by the argument of stable intermediate factor shares across countries as presented in Figure (1.3). The relative mix of industry-specific intermediate goods, however, is allowed to vary systematically with relative price changes, consistent with the discussed evidence in Figure (1.4).

Third, given the form of the production function (1.1) and (1.3) I interpret A as factor-neutral efficiency. In this I follow Jones (2009) or the multifactor analysis in the EU Klems data, which implicitly assumes that efficiency is embedded in intermediate goods as well as in other production factors. This is opposed to the alternative specification $y = \left(\gamma_g^{\frac{1}{\rho}} x_g^{\frac{\rho-1}{\rho}} + \gamma_s^{\frac{1}{\rho}} x_s^{\frac{\rho-1}{\rho}} \right)^{\frac{\sigma\rho}{\rho-1}} (Bl)^{1-\sigma}$ where efficiency $B = A^{1-\sigma}$ is purely embedded in labor.[8] Independently of the specification, however, A is thought of as capturing both actual (technical and organizational) efficiency as well as the use of additional production factors such as physical and human capital that are not explicitly modeled here.

[7] This also allows to compare results with the literature that explicitly microfounds relative sectoral efficiency differences across countries and which is usually framed within two sectors. One example is Buera, Kaboski and Shin (forthcoming) who show a theoretically how in poorer countries the efficiency of tradables suffers more from financial frictions than the one of non-tradables.

[8] Moro (2007) is one exception in the literature to use the alternative specification by which technology is not embedded in intermediate goods.

Households

A representative household solves the problem

$$\max_{c_g \geq 0, c_s \geq 0} u(c_g, c_s) = \max_{c_g \geq 0, c_s \geq 0} \left(\omega_g^{\frac{1}{\rho}} c_g^{\frac{\rho-1}{\rho}} + \omega_s^{\frac{1}{\rho}} c_s^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \tag{1.7}$$

subject to

$$p_{fg} c_g + p_{fs} c_s \leq w \left(l_{fg} + l_{fs} + l_{mg} + l_{ms} \right) \tag{1.8}$$

and

$$l_{fg} + l_{fs} + l_{mg} + l_{ms} = 1, \tag{1.9}$$

where $\rho \in [0, 1) \cup (1, \infty)$ denotes the elasticity of substitution between the two final consumption goods and $\omega \in (0, 1)$ their relative weights in production, with $\sum_{i=s,g} \omega_i = 1$.

The utility function is similar to the one in Ngai and Pissarides (2007), implying that observed secular changes in the expenditure composition between final goods are driven by relative price changes, the so-called Baumol disease.[9] A second thing to note is that calling c a consumption good is a slight abuse of language. What is meant by c is actually more the final use of the good, i.e. it can be used for investment as well as consumption. Also, in view of the subsequent data analysis, note that in an open economy context c could equally represent an export (whether in the form of a final or an intermediate good - the crucial point is that it is not consumed as an intermediate in the home economy).

1.2.2 Equilibrium definition

The equilibrium is a list of production, $\{y_{ji}\}_{j\in\{f,m\},i\in\{s,g\}}$, final consumption $\{c_j\}_{j\in\{f,m\}}$, intermediate good demand $\{x_{nji}\}_{j\in\{f,m\},i,n\in\{s,g\}}$, labor allocations $\{l_{ji}\}_{j\in\{f,m\},i\in\{s,g\}}$, prices $\{p_{ji}\}_{j\in\{f,m\},i\in\{s,g\}}$, and the wage rate w such that:

i) households take $\{p_{fi}\}_{i\in\{s,g\}}$ and w as given and solve (1.7) subject to (1.8) and (2.8);

ii) the representative final good producer in industry $i \in \{g, s\}$ takes input prices $\{p_{mi}\}_{i\in\{s,g\}}$, w and output price p_{fi} as given and solves (1.2);

iii) the representative intermediate good producer in industry $i \in \{g, s\}$ takes prices w and $\{p_{mi}\}_{i\in\{s,g\}}$ as given and solves (1.4);

iv) the goods markets clear so that (1.1), (1.3), (1.5) and (1.6) are satisfied $\forall i \in \{g, s\}$;

1.3 Theoretical implications

Assuming an interior solution, the equilibrium leads to a straightforward characterization, which is described in detail in the Appendix. This subsection identifies the qualitative theoretical general equilibrium effect of movements in the efficiency parameters A on prices, intermediate input intensity and aggregate productivity. For this I consider a setup where efficiency levels

[9] Herrendorf, Rogerson and Valentinyi (2009) analyze the relative merits of this specification compared to one based on income effects (as for instance in Kongsamut, Rebelo and Xie (2001)) in accounting for secular changes in expenditure shares in the US. They find that it matches the data better when each consumption item is a composite of the value-added provided by its industry, while income effects are important when items are identified according to the final product classification, as I do in this paper. I nonetheless choose the above utility specification because all relevant datasets point to strong relative price differences across countries at different stages of development, something that Herrendorf, Rogerson and Valentinyi (2009) cannot identify from the historical US final product data. In any case, most of the ensuing theoretical results and empirical inferences about efficiency parameters do not depend on the utility specification (only international GDP comparisons do).

A in all countries (or alternatively a rich benchmark country) are fixed while the ones in a relatively poor country of interest experience simultaneous positive changes, which is to say that the country converges in income. I will consider two possible scenarios, defined as follows:

Definition 1 ***Industry-neutral growth****: Percent changes in efficiency across industries are identical conditional on the specialization, i.e.* $\frac{dA_f}{A_f} \equiv \frac{dA_{fg}}{A_{fg}} = \frac{dA_{fs}}{A_{fs}}$ *and* $\frac{dA_m}{A_m} \equiv \frac{dA_{mg}}{A_{mg}} = \frac{dA_{ms}}{A_{ms}}$.

Definition 2 ***Specialization-neutral growth****: Percent changes in efficiency across specializations are identical conditional on the industry, i.e.* $\frac{dA_g}{A_g} \equiv \frac{dA_{fg}}{A_{fg}} = \frac{dA_{mg}}{A_{mg}}$ *and* $\frac{dA_s}{A_s} \equiv \frac{dA_{fs}}{A_{fs}} = \frac{dA_{ms}}{A_{ms}}$.

1.3.1 Prices

Combining (1.23) and (1.24) from the Appendix results in the following price ratio between specializations:

$$\frac{p_{mi}}{p_{fi}} = \frac{A_{fi}}{A_{mi}}, \forall i \in \{s, g\}\,. \tag{1.10}$$

Since production functions across specializations are identically parameterized, the price ratios between final and intermediate good suppliers in each industry is fully characterized by their relative efficiency. Note that the downward sloping price ratios across specializations in Figure (1.2) suggest that poorer countries are relatively worse at producing intermediate goods in both industries. The final good price ratio p_{fs}/p_{fg} is implicitly pinned down by combining again (1.23) and (1.24):

$$\frac{p_{fs}}{p_{fg}} = \frac{(1-\sigma_g)\,\sigma_g^{\frac{\sigma_g}{1-\sigma_g}}}{(1-\sigma_s)\,\sigma_s^{\frac{\sigma_s}{1-\sigma_s}}} \frac{A_{fg}A_{mg}^{\frac{\sigma_g}{1-\sigma_g}}}{A_{fs}A_{ms}^{\frac{\sigma_s}{1-\sigma_s}}} \frac{\left(\gamma_{ss} + \left(\frac{A_{fs}}{A_{fg}}\frac{A_{mg}}{A_{ms}}\frac{p_{fs}}{p_{fg}}\right)^{\rho_s-1}\gamma_{gs}\right)^{\frac{\sigma_g}{(1-\sigma_g)(1-\rho_g)}}}{\left(\gamma_{gg} + \gamma_{sg}\left(\frac{A_{fs}}{A_{fg}}\frac{A_{mg}}{A_{ms}}\frac{p_{fs}}{p_{fg}}\right)^{1-\rho_g}\right)^{\frac{\sigma_s}{(1-\sigma_s)(1-\rho_s)}}}. \tag{1.11}$$

Because the two industries are cross-linked through trade in intermediate goods, the latter is independent of the specification of the utility function and only reflects underlying technological parameters. Combining (1.1) with (1.21) and (1.22) from the Appendix obtains an expression for the relative productivity between final good producers:

$$\frac{y_{fg}/l_{fg}}{y_{fs}/l_{fs}} = \frac{1-\sigma_s}{1-\sigma_g}\frac{p_{fs}}{p_{fg}} \tag{1.12}$$

Comparing relative final prices across rich (R) and poor (P) countries therefore gives a one-to-one mapping to relative productivities in final goods since $\frac{y_g^P/l_g^P}{y_s^P/l_s^P}/\frac{y_g^R/l_g^R}{y_s^R/l_s^R} = \frac{p_s^P/p_g^P}{p_s^R/p_g^R}$. This is not to say, however, that this price ratio is also a relevant measure of relative *efficiencies* across industries, as formalized in the following Proposition.

Proposition 1 *Assume the economy becomes more efficient across the board in the sense that* dA_{fg}, dA_{fs}, dA_{mg}, $dA_{ms} > 0$. *(i) Under industry-neutral technical change the relative price of final services to final goods* p_{fs}/p_{fg} *is increasing (decreasing) if and only if* $\sigma_g > (<)\ \sigma_s$*; (ii) under specialization-neutral technical change* p_{fs}/p_{fg} *is increasing (decreasing) if and only if* $\frac{dA_g/A_g}{dA_s/A_s} > (<)\ \frac{1-\sigma_g}{1-\sigma_s}$.

Proof. Appendix. ■

The data presented in the previous section (Figure 1.3) indicates that goods industries have higher intermediate factor shares than services ($\sigma_g > \sigma_s$). The stylized fact that the relative value of p_{fs}/p_{fg} increases as a country catches up in development hence does not imply that convergence is necessarily accompanied by higher growth in the goods industry compared to services. Because goods production (versus services) is more sensitive to the cost of intermediates, (industry-neutral) increases in efficiency are likely to magnify the productivity of the goods industry more than the one of the services industry.[10] It need not be therefore that poor countries are particularly inefficient at producing goods. The second part of Proposition 1 states that converging countries could indeed have faster growth in services compared to goods and still experience an increase in the ratio p_{fs}/p_{fg}. One implication of this is that even if rich countries were actually relatively better at producing services than goods (as may well have resulted from the analysis in Duarte and Restuccia (2010) if they had treated agriculture and manufacturing as one industry), goods may still turn out to be relatively cheaper in these countries due to the demand side of the input-output relationship. Not taking this relationship into account by focusing only on final goods can lead to a biased diagnostic on which industries are the 'problem sectors' of poor countries.

1.3.2 Intermediate good intensity

A common measure of interest in development accounting is the capital to output ratio. In a similar vein it is of interest to identify industry and specialization-specific intermediate good to output ratios. For this I define the composite intermediate input m demanded by specialized industry ji as $m_{ji} \equiv \left(\gamma_{gi}^{\frac{1}{\rho_i}} x_{gji}^{\frac{\rho_i-1}{\rho_i}} + \gamma_{si}^{\frac{1}{\rho_i}} x_{sji}^{\frac{\rho_i-1}{\rho_i}}\right)^{\frac{\rho_i}{\rho_i-1}}$ and by $\widetilde{p}_{ji}$ its associated price so that $\widetilde{p}_{ji} m_{ji} = p_{mg} x_{gji} + p_{ms} x_{sji}$. From the Cobb-Douglas specification of the production function it is clear that in equilibrium the value intensity of intermediates in production is

$$\frac{\widetilde{p}_{ji} m_{ji}}{p_{ji} y_{ji}} = \frac{p_{mg} x_{gji} + p_{ms} x_{sji}}{p_{ji} y_{ji}} = \sigma_i, \ \forall j \in \{f, m\}, i \in \{s, g\}. \tag{1.13}$$

By construction the intermediate consumption ratios in the two industries in value terms are constant across countries, which mimics the evidence in Figure (1.3). What does vary in value is the relative composition of the composite intermediate good. The combination of (1.10) with (1.21) and (1.22) obtains the relative share of the industries' intermediates that they derive from their own respective industry:

$$\begin{aligned} \frac{p_{mg} x_{gjg}}{p_{mg} x_{gjg} + p_{ms} x_{sjg}} &= \frac{\gamma_{gg}}{\gamma_{gg} + \gamma_{sg}\left(\frac{p_{ms}}{p_{mg}}\right)^{1-\rho_g}}, \ \forall j \in \{f, m\} \\ &\equiv \Gamma_{gg} \in (0,1) \end{aligned} \tag{1.14}$$

and

$$\begin{aligned} \frac{p_{ms} x_{sjs}}{p_{mg} x_{gjs} + p_{ms} x_{sjs}} &= \frac{\gamma_{ss}}{\gamma_{ss} + \gamma_{gs}\left(\frac{p_{ms}}{p_{mg}}\right)^{\rho_s-1}}, \ \forall j \in \{f, m\} \\ &\equiv \Gamma_{ss} \in (0,1). \end{aligned} \tag{1.15}$$

[10] This is analogous to international trade theories in the tradition of Hekscher and Ohlin where poor countries are thought of as being relatively unproductive in producing goods with high capital intensity, where capital endowments are fixed. Here intermediate inputs are not fixed, but their supply is relatively less abundant than labor in poor countries because their aggregate production is lower.

The *real* intensity in the composite intermediate good, however, is expected to vary across countries depending on the relative values of A as summarized in the following Proposition.

Proposition 2 *Assume the economy becomes more efficient across the board in the sense that dA_{fg}, dA_{fs}, dA_{mg}, $dA_{ms} > 0$. (i) Under industry-neutral technical change the real intermediate input intensity m_{mg}/y_{mg} is decreasing (increasing) if and only if $\sigma_g > (<)\ \sigma_s$, m_{ms}/y_{ms} is increasing (decreasing) if and only if $\sigma_g > (<)\ \sigma_s$, m_{fg}/y_{fg} is increasing (decreasing) if and only if $\frac{(1-\sigma_g)(1-\sigma_s)+\sigma_s(1-\sigma_g)(1-\Gamma_{ss})+\sigma_s(1-\sigma_g)(1-\Gamma_{gg})}{(1-\sigma_g)(1-\sigma_s)+\sigma_s(1-\sigma_g)(1-\Gamma_{ss})+\sigma_g(1-\sigma_s)(1-\Gamma_{gg})}\frac{dA_m/A_m}{dA_f/A_f} > (<)\ 1$, and m_{fs}/y_{fs} is increasing (decreasing) if and only if $\frac{(1-\sigma_g)(1-\sigma_s)+\sigma_g(1-\sigma_s)(1-\Gamma_{gg})+\sigma_g(1-\sigma_s)(1-\Gamma_{ss})}{(1-\sigma_g)(1-\sigma_s)+\sigma_g(1-\sigma_s)(1-\Gamma_{gg})+\sigma_s(1-\sigma_g)(1-\Gamma_{ss})}\frac{dA_m/A_m}{dA_f/A_f} > (<)\ 1$; (ii) under specialization-neutral technical change m_{fg}/y_{fg} and m_{mg}/y_{mg} are increasing (decreasing) and m_{fs}/y_{fs} and m_{ms}/y_{ms} are decreasing (increasing) if and only if $\frac{1-\sigma_g}{1-\sigma_s}\frac{dA_s/A_s}{dA_g/A_g} > (<)\ 1$.*

Proof. Appendix. ■

Under industry-neutral technical change, for $\sigma_g > \sigma_s$ it is expected that as a countries converges in income, the use of intermediates becomes less intensive in industries producing intermediate goods and more intensive in industries producing intermediate services. The intuition for this result is that following Proposition 1, for $\sigma_g > \sigma_s$, industry-neutral technical change implies a fall in the relative price of final goods. By (1.10), this also implies a fall in the relative price of intermediate goods relative to services, p_{mg}/p_{ms}. Since the composite intermediate good is a combination of goods and services, it becomes relatively more expensive for the intermediate goods industry and relatively less expensive for the intermediate service industry. The sign of the change is unclear for final goods producers. Notice however that for $dA_m/A_m > dA_f/A_f$ (which is also consistent with the data), the model suggests that at least the production of final services, if not of final goods as well, is likely to become more intensive in intermediate use as the economy converges. This latter point suggests that for dA_m/A_m sufficiently larger than dA_f/A_f all specialization-industry pairs but one are expected to use intermediate inputs more intensively in real terms. This is reminiscent of Hsieh and Klenow (2007) who show how richer countries use investment goods more intensively because they are more efficient at producing them.

1.3.3 Aggregate productivity

Value-added in each specialized industry ji is defined as $VA_{ji} \equiv p_{ji}y_{ji} - p_{mg}x_{gji} - p_{ms}x_{sji}$. Plugging the values for x from (1.21) and (1.22) into the expression for (1.1) results in $VA_{ji} = (1-\sigma_i)\, p_{ji}y_{ji}$. Nominal GDP (per unit of labor) is defined as $GDP \equiv \sum_{j,i} VA_{ji}$. Let $P \equiv \left(\omega_g p_g^{1-\rho} + \omega_s p_s^{1-\rho}\right)^{\frac{1}{1-\rho}}$ be the ideal price deflator. Replacing y in VA by the expression (1.1) after plugging in (1.21) and (1.22) obtains the indirect utility function, and hence the ideal real GDP measure in this economy, as either one of two alternative expressions:

$$\frac{GDP}{P} = \frac{(1-\sigma_g)\,\sigma_g^{\frac{\sigma_g}{1-\sigma_g}} A_{fg} A_{mg}^{\frac{\sigma_g}{1-\sigma_g}} \left(\gamma_{gg} + \gamma_{sg}\left(\frac{A_{fs}}{A_{fg}}\frac{A_{mg}}{A_{ms}}\frac{p_{fs}}{p_{fg}}\right)^{1-\rho_g}\right)^{\frac{\sigma_g}{(\rho_g-1)(1-\sigma_g)}}}{\left(\omega_g + \omega_s\left(\frac{p_{fs}}{p_{fg}}\right)^{1-\rho}\right)^{\frac{1}{1-\rho}}} \tag{1.16}$$

$$= \frac{(1-\sigma_s)\,\sigma_s^{\frac{\sigma_s}{1-\sigma_s}} A_{fs} A_{ms}^{\frac{\sigma_s}{1-\sigma_s}} \left(\left(\frac{A_{fs}}{A_{fg}}\frac{A_{mg}}{A_{ms}}\frac{p_{fs}}{p_{fg}}\right)^{\rho_s-1}\gamma_{gs} + \gamma_{ss}\right)^{\frac{\sigma_s}{(\rho_s-1)(1-\sigma_s)}}}{\left(\omega_s + \omega_g\left(\frac{p_{fs}}{p_{fg}}\right)^{\rho-1}\right)^{\frac{1}{1-\rho}}}.$$

The differentiation of any of these expressions allows to analyze the relative impact of changes in efficiency levels on aggregate productivity. In particular, it is of interest to note which changes have more of an impact in poor versus rich countries.

Proposition 3 *Assume the economy becomes more efficient across the board in the sense that* dA_{fg}, dA_{fs}, dA_{mg}, $dA_{ms} > 0$. *(i) Under industry-neutral technical change a percent increase in intermediate good production efficiency* A_m *increases real theoretical GDP by a factor of* $\frac{\sigma_g(1-\sigma_s)(1-\Omega_s)+\sigma_s(1-\sigma_g)\Omega_s+\sigma_g\sigma_s(2-\Gamma_{gg}-\Gamma_{ss})}{(1-\sigma_g)(1-\sigma_s)+\sigma_g(1-\sigma_s)(1-\Gamma_{gg})+\sigma_s(1-\sigma_g)(1-\Gamma_{ss})}$ *of a percent increase in final good production efficiency* A_f *where* $\Omega_s \equiv \frac{p_{fs}c_s}{p_{fg}c_g+p_{fs}c_s} = \frac{\omega_s\left(\frac{p_{fs}}{p_{fg}}\right)^{1-\rho}}{\omega_g+\omega_s\left(\frac{p_{fs}}{p_{fg}}\right)^{1-\rho}} \in (0,1)$*; (ii) under specialization-neutral technical change a percent increase in goods production efficiency* A_g *increases real theoretical GDP by a factor of* $\frac{(1-\sigma_s)(1-\Omega_s)+\sigma_s(1-\Gamma_{ss})}{(1-\sigma_g)\Omega_s+\sigma_g(1-\Gamma_{gg})}$ *of a percent increase in services production efficiency* A_s.

Proof. Appendix. ■

Structural transformation implies that the expenditure share of services Ω_s is increasing with rising income levels. Also, the evidence in Figure (...) suggests that in poorer countries a larger fraction of intermediate inputs used by the goods industry derives from its own sector (relatively large Γ_{gg}) while the opposite is true for the service industry (relatively low Γ_{ss}). As mentioned, it will be shown that industry-neutral technical change is a reasonable description of the data. The numerator in the expression of the first point in Proposition 3 suggests that poorer countries are then expected to benefit more from changes in intermediate good production efficiency (relative to final good production efficiency) than rich countries because they have a rather high value of $\sigma_g(1-\sigma_s)(1-\Omega_s)+\sigma_s(1-\sigma_g)\Omega_s$ (while the value of $2-\Gamma_{gg}-\Gamma_{ss}$ is qualitatively indeterminate). As goods industries are more intensive in intermediate inputs ($\sigma_g(1-\sigma_s) > \sigma_s(1-\sigma_g)$), poor countries stand more to gain from higher efficiency in intermediate production as they spend a larger fraction of income on goods. The denominator of that expression strengthens this point because by the same argument $\sigma_g(1-\sigma_s)(1-\Gamma_{gg})+\sigma_s(1-\sigma_g)(1-\Gamma_{ss})$ is likely to be lower in poor countries. This reflects the fact that poor countries use a higher fraction of goods in intermediate consumption while goods are more sensitive to changes in the availability of intermediates as explained in Proposition 1. Taken together, if industry-neutral technical change is a good feature of the data, there is reason to believe that poor countries are more sensitive to changes in the efficiency with which intermediates are produced. Put otherwise, inefficiencies in the production of intermediate goods are likely to strongly decrease the GDP of poor countries due to complementarities in technology and preferences.

Specialization-neutral technical change will be shown to be less good of a data description. Note, however, from the expression in the second point in Proposition 3 the effect created by the supply side of the input-output table. If poor countries spend a larger fraction of final income on goods, it is natural that changes in the efficiency of producing goods have, ceteris paribus, a relatively stronger effect (vis-à-vis improvements in producing services) than in rich countries, i.e. $\frac{(1-\sigma_s)(1-\Omega_s)}{(1-\sigma_g)\Omega_s}$ is relatively large in poor countries. The supply side of the input-output table exacerbates this effect ($\frac{\sigma_s(1-\Gamma_{ss})}{\sigma_g(1-\Gamma_{gg})}$ is also likely to be larger in poor countries) since poor countries spend a larger fraction on goods in intermediate consumption as well.

1.4 Accounting and counterfactuals

In this section I infer the county-specific implied efficiencies A for the sample of countries included in the EU Klems 1997 benchmark study of cross-country price levels and quantities at the industry level. I use this dataset because it is the only one to my knowledge that provides comprehensive information on the relative cost of intermediate goods across countries.[11] Since the construction of the model and the discussion of the theoretical results so far involved arguments based on Figures (1.1)-(1.4) that derive from different (and broader) data sources it is in order to check that the EU Klems data have the same stylized features as the ones discusses above.

1.4.1 Calibration

Procedure

The method to construct the relevant data series is described in the Appendix. The calibration of the model proceeds in three steps. First, using first order conditions, I pin down the technology-related parameters σ_g and σ_s directly and infer γ_{gg} and ρ_g as well as γ_{ss} and ρ_s from minimizing the discrepancy between the data and model predictions across all countries in the sample. In the second step I back out the parameters A_{fg}, A_{fs}, A_{mg} and A_{ms} for all countries from first order conditions. Third, to close the model I infer the preference parameters ρ and ω from minimizing the discrepancy between the data and model predictions.

Matching the condition (1.13) for both sectors with the data on intermediate good shares for all sample countries I compute average values of $\sigma_g = 0.570$ and $\sigma_s = 0.357$. Using $\gamma_{gg} + \gamma_{sg} = 1$ and $\gamma_{gs} + \gamma_{ss} = 1$, the conditions (1.14) and (1.15) can be rewritten to give

$$\log\left(\frac{p_{mg}\left(x_{gfg}+x_{gmg}\right)}{p_{ms}\left(x_{sfg}+x_{smg}\right)}\right)^k = \log\frac{\gamma_{gg}}{1-\gamma_{gg}} + \left(\rho_g - 1\right)\log\left(\frac{p_{ms}}{p_{mg}}\right)^k + \varepsilon_{gk} \tag{1.17}$$

and

$$\log\left(\frac{p_{ms}\left(x_{sfs}+x_{sms}\right)}{p_{mg}\left(x_{gfs}+x_{gms}\right)}\right)^k = \log\frac{\gamma_{ss}}{1-\gamma_{ss}} + \left(1 - \rho_s\right)\log\left(\frac{p_{ms}}{p_{mg}}\right)^k + \varepsilon_{sk} \tag{1.18}$$

for each country $k \in \{1, 2, ..., K\}$ where ε_{gk} and ε_{sk} are assumed to be white noise. Using EU Klems data on the observables on the left and right hand side the two separate OLS regression across all countries deliver $\gamma_{gg} = 0.677$ and $\rho_g = 0.178$ as well as $\gamma_{ss} = 0.572$ and $\rho_s = 0.223$. Since both elasticities are less than unity, intermediate goods and intermediate services are gross complements in the composite intermediate input of both industries.

With the parameter values in hand there is sufficient information to infer the four efficiency values A for each country. The most straightforward way to do this would be to use the productivity data for each specialized industry, y_{ji}/l_{ji}. It can be checked that the optimality conditions imply

$$\frac{y_{fg}}{l_{fg}} = \frac{A_{fg}}{A_{mg}}\frac{y_{mg}}{l_{mg}} = A_{fg}A_{mg}^{\frac{\sigma_g}{1-\sigma_g}}\sigma_g^{\frac{\sigma_g}{1-\sigma_g}}\left(\gamma_{gg} + \gamma_{sg}\left(\frac{A_{fs}}{A_{fg}}\frac{A_{mg}}{A_{ms}}\frac{p_{fs}}{p_{fg}}\right)^{1-\rho_g}\right)^{\frac{\sigma_g}{(\rho_g-1)(1-\sigma_g)}},$$

[11] The EU Klems dataset provides two series of prices, output prices and input prices. As described in the Appendix, from this it is possible to construct separate series for intermediate and final good prices.

$$\frac{y_{fs}}{l_{fs}} = \frac{A_{fs}}{A_{ms}} \frac{y_{ms}}{l_{ms}} = A_{fs} A_{ms}^{\frac{\sigma_s}{1-\sigma_s}} \sigma_s^{\frac{\sigma_s}{1-\sigma_s}} \left(\gamma_{ss} + \gamma_{gs} \left(\frac{A_{fs}}{A_{fg}} \frac{A_{mg}}{A_{ms}} \frac{p_{fs}}{p_{fg}} \right)^{\rho_s - 1} \right)^{\frac{\sigma_s}{(\rho_s-1)(1-\sigma_s)}}.$$

I can construct data on y_{ji}, but because the dataset used only provides information on total hours worked by industry but not by specialization, I need to use supplementary optimality conditions from the model for the purpose of identification. In addition to the above four equations I use (1.10) for both industries as well as $l_{fg} + l_{mg} = l_g$ and $l_{fs} + l_{ms} = l_s$. Since p_{fs}/p_{fg} is then implicitly defined in the model from (1.11) the solution is identified. Note, however, that as data on p_{fs}/p_{fg} is readily available, it appears more judicious to use it, and ex post check whether the model's implied final price ratio actually matches the one in the data. The set of data points used for each country are therefore $(p_{fs}/p_{gs})^k$, $(p_{mg}/p_{fg})^k$, $(p_{ms}/p_{fs})^k$, y_{fg}^k, y_{fs}^k, y_{mg}^k, y_{ms}^k, l_g^k and l_s^k. The resulting solution consists of the four efficiency levels A and as a by-product also includes the four levels of hours worked l.

parameter	value	target
σ_g	0.570	$\sum_k \left(\frac{p_{mg}(x_{gfg}+x_{smg})+p_{ms}(x_{sfg}+x_{gmg})}{p_{fg}y_{fg}+p_{mg}y_{mg}} \right)^k /K$
σ_s	0.357	$\sum_k \left(\frac{p_{mg}(x_{gfs}+x_{gms})+p_{ms}(x_{sfs}+x_{gms})}{p_{fs}y_{fs}+p_{ms}y_{ms}} \right)^k /K$
γ_{gg}, ρ_g	0.677, 0.178	$\left(\frac{p_{mg}(x_{gfg}+x_{gmg})}{p_{ms}(x_{sfg}+x_{smg})} \right)^k$, $\left(\frac{p_{ms}}{p_{mg}} \right)^k$
γ_{ss}, ρ_s	0.572, 0.223	$\left(\frac{p_{ms}(x_{sfs}+x_{sms})}{p_{mg}(x_{gfs}+x_{gms})} \right)^k$, $\left(\frac{p_{ms}}{p_{mg}} \right)^k$
ω_g, ρ	0.437, 0.749	$\left(\frac{p_{fg}c_g}{p_{fs}c_s} \right)^k$, $\left(\frac{p_{fs}}{p_{fg}} \right)^k$
A_{fg}^k, A_{fs}^k, A_{mg}^k, A_{ms}^k	-	$(p_{fs}/p_{gs})^k$, $(p_{mg}/p_{fg})^k$, $(p_{ms}/p_{fs})^k$, y_{fg}^k, y_{fs}^k,y_{mg}^k, y_{ms}^k, l_g^k, l_s^k

Table 1.1: Benchmark calibration

Finally, I need to pin down the utility parameters for the purpose of performing counterfactual exercises. Each country's household condition (1.25) can be rewritten to the identifying equation

$$\log \left(\frac{p_{fg}c_g}{p_{fs}c_s} \right)^k = \log \frac{\omega_g}{1-\omega_g} + (\rho - 1) \log \left(\frac{p_{fs}}{p_{fg}} \right)^k + \varepsilon_{pk}. \tag{1.19}$$

where ε_{pk} is assumed to be white noise. I construct the left-hand side of the equation using data on $\frac{p_{fg}c_g}{p_{fs}c_s}$ and perform an OLS regression to obtain values ω_g and ρ that best match the household's first order condition with the data. These are 0.437 and 0.749, so households have stronger preference for services, and less than unitary substitutability between the two goods, the latter being consistent with structural transformation as a result of faster productivity growth in the goods industry.

Model-data match

Figure (1.5) reports the model's deviation from the data for each country in several variables of interest. A perfect match would be such that all the countries lie on the 45 degree line.

The upper left panel compares the model's measure of aggregate productivity (which is just GDP/hour) with the data. It is natural that these two measures are not identical because to measure productivity consistently across countries in the model, I evaluate it at US prices, i.e. $(GDP/l)^k_{US\,price} = c^k_g + (p_{fs}/p_{fg})^{US}\, c^k_s$ while the data are based on international prices.[12] This notwithstanding, there is no apparent bias in the model's predictions vis-à-vis the data, suggesting that the model measure of aggregate productivity can be employed for counterfactual exercises.

As explained above, even though the data price ratio p_{fs}/p_{fg} is used in the calibration, it is not directly targeted. The model therefore predicts another price ratio, based on relative productivities between the final goods sectors. Again, it is apparent that the model's predictions do not depart widely from the data.

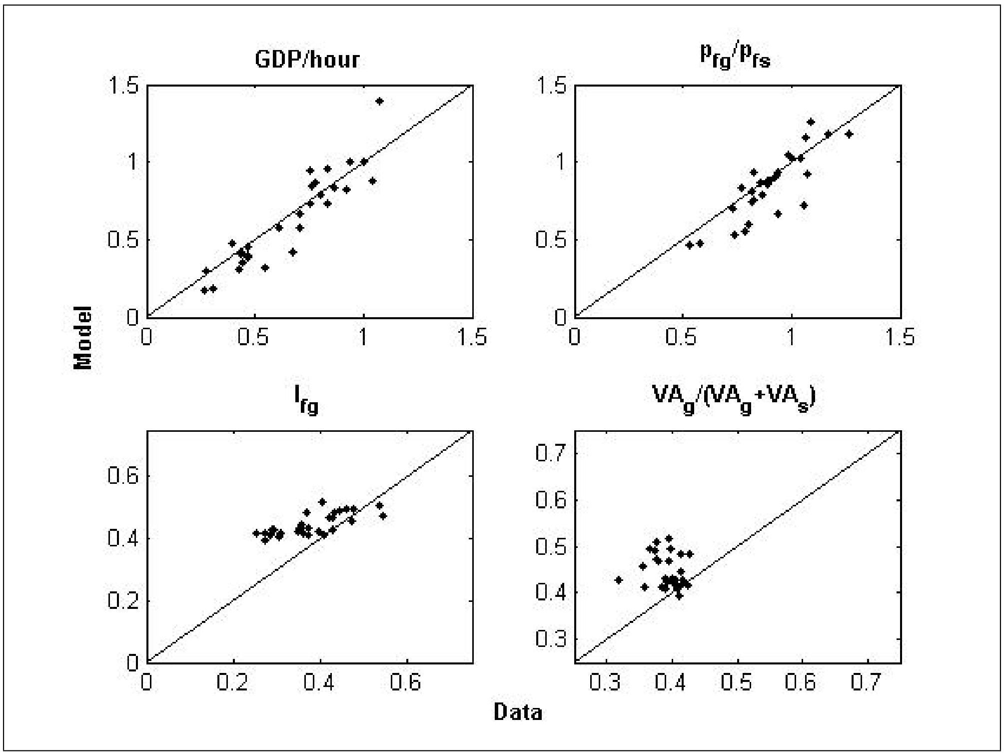

Figure 1.5: Model predictions versus data

What is of more concern is the amount of labor allocated to the goods sector l_g. The model clearly overestimates it. This is presumably because the preference parameters are based on consumption shares, but the relation between consumption shares and labor allocation in the data somewhat departs in the data. For the same reason, the model also over-predicts value-added in the goods industry (lower left panel). These departures should not be viewed with concern as regards the validity of the main result, which is the measure of the countries' efficiency levels, since the latter are not affected by preferences. The subsequent counterfactuals, however, must be regarded with some caution.

[12]In the data, aggregate productivity across countries is evaluated in international prices. Using US prices, however, is a good first order approximation of international prices. This is because the country weight used for the construction of international prices is nominal GDP and therefore the prices of large and rich countries (especially the US) are disproportionately represented.

1.4.2 Results

Figure (1.6) presents the inferred efficiency levels. Each series is normalized so that the US level equals 1 and is plotted against data on the countries' aggregate hourly productivity as given by the data. Several things stand out. First, and not surprisingly, rich countries tend to be more efficient in all specialization-industry pairs. Second, in both specializations, the relationship between efficiency and aggregate productivity appears to be rather similar for goods and services, with richer countries appearing to be only slightly more efficient at producing goods. The more pronounced difference is across specializations: compared to poor countries, rich countries tend to be particularly more efficient at producing intermediate goods.

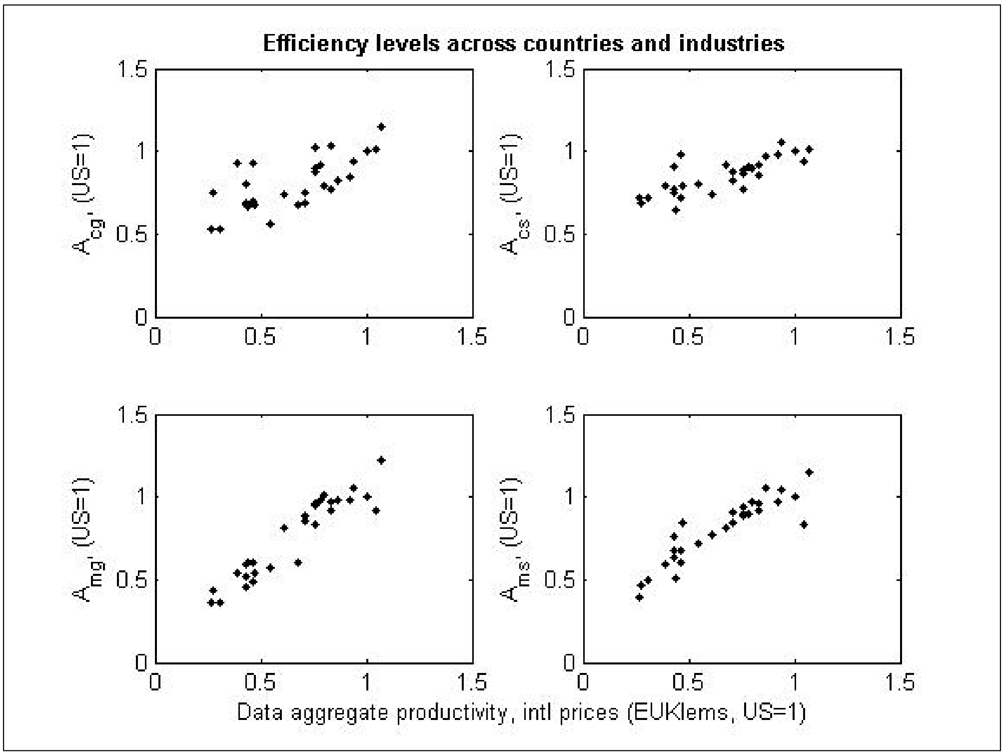

Figure 1.6: Implied efficiency levels

The first column of Table (2) presents an alternative organization of these data. It compares the mean efficiency for each category between the bottom and top quintile sample countries in terms of aggregate productivity.[13] Note that the efficiency gap between the least and most productive countries in the production of final goods is moderate, at about 10-20%, and is only slightly larger for goods than services. The efficiency gap is significantly larger for the production of intermediates at roughly 50%. Besides, the gap is more pronounced for goods compared to services.

1.4.3 Counterfactuals

Counterfactual calibration

The foremost interest in the development accounting framework proposed in the present paper is the recognition that (i) the production of final and intermediate goods commands different

[13] The most productive countries in the sample (from top down) are: Sweden, Canada, the US, the UK, Germany and Denmark. The least productive are (from botom up) Lithuania, Estonia, Poland, Latvia, the Czech Republic and the Slovak Republic.

efficiency levels across countries, that (ii) goods and services differ in their intensity of intermediate input use as well as in (iii) their prominence as suppliers of intermediates. Columns 3-5 of Table (2) present the effect of closing down any of these variations one at a time by comparing again the resulting efficiency levels between the bottom and top productive countries.

The efficiency levels inferred in column 2 result from repeating the original calibration but ignoring equation (1.10) and setting $A^k_{mg} = A^k_{fg}$ and $A^k_{ms} = A^k_{fs}$, $\forall k$. Notice that compared to the benchmark, ignoring efficiency differences across specializations implies that the efficiency gap between poor and rich countries in final goods production significantly increases while the one in intermediate goods production only slightly decreases. This also expands the efficiency gap in goods compared to services. Clearly, not allowing for the possibility that poor countries are particularly inefficient at producing intermediates overstates the overall efficiency gap between poor and rich countries to mimic their productivity differences and exaggerates in particular the gap between goods and services to mimic the price ratio differences in final goods.

	benchmark	$A^k_{mg} = A^k_{fg}$, $A^k_{ms} = A^k_{fs}$	$\sigma_g = \sigma_s = 0.5$	$\gamma_{gg} = \gamma_{ss} = 0.5$, $\rho_g = \rho_s \to 1$
A^P_{fg}/A^R_{fg}	0.830	0.520	0.748	0.795
A^P_{fs}/A^R_{fs}	0.855	0.663	1.015	0.866
A^P_{mg}/A^R_{mg}	0.456	0.520	0.410	0.436
A^P_{ms}/A^R_{ms}	0.573	0.663	0.678	0.580

Table 1.2: Alternative calibrations, average efficiency of poorest to richest quintile

The results in column 4 stem from repeating the calibration exercise but setting $\sigma_g = \sigma_s = 0.5$ so that goods and services have the intensity in the composite intermediate input. Evidently, ignoring differences in the intermediate input intensity between goods and services increases the efficiency gap between rich and poor countries in the production of goods, and decreases it in the production of services. Just as argued in the theoretical section, poor countries are likely to appear less productive in producing goods than services to a large extent because goods are more intensive input users.

Finally, column 5 presents the results from the calibration that sets $\gamma_{gg} = \gamma_{ss} = 0.5$ and $\rho_g = \rho_s \to 1$ (i.e. the composite intermediate good is a Cobb-Douglas specification) In this way the composite intermediate good in both industries has the same value composition between goods and services. Compared to the benchmark, the qualitative effect on the implied cross-country efficiency differences of rendering the supply side of the input-output matrix symmetric is the same as the one of rendering the demand side more symmetric (column 4). Quantitatively, however, the effect is much smaller.

Convergence scenarios

The second column of Table (3) presents the results on the aggregate productivity gap (which here is the GDP per capita gap) between the poorest and richest quintile from moving all countries in the sample to the US efficiency level for each category at a time. First, notice that according to the model's measure of aggregate productivity the poorest quintile countries are about 46% percent less productive than the richest countries, which is only slightly lower than the gap in the data (40%). Hence, the model's measure is likely to be a good gauge for aggregate productivity differences. Compared to this benchmark, it is obvious that having countries move to the US efficiency level in goods raises their income levels very significantly while the effect is more negligible for services. Also, the effect is negligible for final goods, but is very strong

	$\frac{(GDP/l)^P}{(GDP/l)^R}$	$\frac{\left(p_{fs}/p_{fg}\right)^P}{\left(p_{fs}/p_{fg}\right)^R}$
data	0.401	0.778
benchmark calibration	0.467	0.683
$A^k_{fg} = A^{US}_{fg}$, $A^k_{mg} = A^{US}_{mg}$	0.728	1.119
$A^k_{fs} = A^{US}_{fs}$, $A^k_{ms} = A^{US}_{ms}$	0.589	0.600
$A^k_{fg} = A^{US}_{fg}$, $A^k_{fs} = A^{US}_{fs}$	0.542	0.695
$A^k_{mg} = A^{US}_{mg}$, $A^k_{ms} = A^{US}_{ms}$	0.843	0.972

Table 1.3: Scenarios of convergence to US efficiency levels

for intermediate goods, attaining about 84%. This is to say that if poor countries were somehow able of grow as efficient as the US, by far the most prominent impact is predicted to come from boosting the efficiency in intermediate input production.

The third column of Table (3) is analogous to the second one for the final price ratio p_{fs}/p_{fg} rather than aggregate productivity. The model's prediction on the mean final price ratio of the poorest compared to the richest countries comes reasonably close to the one in the data. In light of the theoretical results on the price ratio, it is interesting to observe that poor countries are predicted to have a similar final price ratio to rich countries if they were as efficient in producing intermediates as rich countries. It confirms the intuition that the cross-country final price ratio depends as much on efficiency differences across specializations as on efficiency differences across industries.

1.5 Concluding remarks

This paper identifies that the main driving factor behind aggregate and sectoral relative productivity differences across countries is the efficiency of intermediate good production. The technical structure of the input-output relationship is such that relatively minor inefficiencies in intermediate good production are magnified strongly. The natural question to ask is, why exactly are some countries so inefficient at producing these goods? The theory presented by Acemoglu, Antràs and Helpman (2007) on contractual difficulties with specialized input suppliers may offer an important ingredient. Other theories may center on the inefficient involvement of government in either the procurement of intermediate goods or the procurement of infrastructure that is particularly crucial for smooth trade in intermediate inputs. Yet another theory may focus on low levels of competition for specialized inputs, especially when countries suffer from natural or artificial barriers to international trade. There is interest in directing future research in combining the leverage effects discussed in this paper with an explicit theory of efficiency in intermediate input production.

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1.7 Appendix

1.7.1 Data

Figures

Figure (1.1) is based on the World Bank's International Comparisons Program 2005 benchmark data. The sample includes 147 countries. Commodity agriculture is simply Food and non-alcoholic beverages (1101). Commodity Industrial consumption good includes Alcoholic beverages and tobacco (1102), Clothing and footwear (1103), Housing, water, electricity, gas and other fuels (1104), Furnishings, household equipment and household maintenance (1105). Commodity Investment corresponds to Gross capital formation (15). Commodity Services includes Health (1106), Transport (1107), Communication (1108), Recreation and culture (1109), Education (1110) and Restaurants and hotels (1111). The constructed series are geometric averages with weights based on expenditure shares on the subsectors. GDP per capita is taken from the Penn World Tables.

Figure (1.2) computes relative prices from the EU Klems 1997 benchmark data in the following way. Notice that both series are ratios between intermediate and final goods prices. The series for intermediate good prices is based on the intermediate input price deflator, PPP_IIS for services and the weighted average between the price of energy inputs (PPP_IIE) and material inputs (PPP_IIM) for goods. Each series is a geometric mean over the all the two-digit subsectors in the dataset, the weights being the supply shares (IIS and IIE+IIM, respectively) to each subsector. The intermediate input price is hence simply the mean over the prices that all the sectors in the economy pay for that particular intermediate input. The series for the final price is subsequently computed via the construction of the aggregate output price, based on the output deflator (PPP_SO). The output price for goods is a weighted average over the output prices of the subsectors composing goods: agriculture, hunting, forestry and fishing (AtB); Consumer manufacturing (Mcons), Intermediate manufacturing (Minter), Mining and quarrying (C) and

Electricity, gas and water supply (E); Investment goods, excluding hightech (Minves), Electrical and optical equipment (30t33) and Construction (F). The composite for the service output price consists of market services, excluding post and telecommunications (MSERV), Post and telecommunication (64) and Non-market services (NONMAR). The output and intermediate price for goods and services in hand, I compute the final good and final service price simply by noting that the output price is the geometric average between the final and intermediate price. The weight of the intermediate price is simply the value of aggregate intermediate consumption on the good or service (the aggregate value of IIS and IIE+IIM, respectively) as a share of aggregate output (SO). Finally, note that aggregate productivity in the data equals the ratio between total LP_VADD to total HOURS.

The data underlying Figures (1.3) and (1.4) are country-year pairs from the OECD 2005 international input-output data. The years are 1995, 2000 and 2005.[14] The sample includes OECD as well a number of poorer countries.[15] Intermediate consumption ratios are computed by adding the intermediate consumption of all the subsectors and dividing them by their total output. Similarly, own intermediate shares are computed by adding each subsector's intermediate consumption deriving from related subsectors and dividing by the composite sector's total intermediate consumption. The Goods and Service sectors are based on the following subsectors, respectively: 1-30 and 31-48. GDP per capita is taken from the Penn World Tables. Since these data report GDP per capita levels for each year as a ratio to the US, country-year pairs are constructed by using US GDP/capita growth between 1995 and 2005, also taken from the Penn World Tables.

Calibration

All the series are based on 1997 EU Klems dataset. For the construction of final and intermediate good price data, please refer to the above description of the data underlying Figure (1.2). Also, note that the definition of the subsectors composing the goods and the service industry, respectively, is of course identical to the one used in the construction of prices. Hours worked are based on the series HOURS. The series l_g and l_s are constructed by adding the hours worked in all subsectors defined to as goods and services, respectively. The series y_{fg}, y_{fs}, y_{mg} and y_{ms} are built as follows. Aggregate nominal intermediate production is the aggregate value (i.e. the addition across subsectors) of IIS for services and IIE+IIM for goods. These series are then deflated by their respective intermediate good price to arrive at y_{ms} and y_{mg}. I then construct aggregate output for goods and services by adding the relevant series (SO) across the subsectors composing each of the two industries. From the resulting value I subtract IIS for services and IIE+IIM for goods to arrive at aggregate nominal consumption. Deflating the resulting series by the relevant final good price consequently gives y_{fs} and y_{fg}.

The normalization employed is the following. I set $\left(\frac{p_{fs}}{p_{fg}}\right)^{US} = \left(\frac{p_{mg}}{p_{fg}}\right)^{US} = \left(\frac{p_{ms}}{p_{fs}}\right)^{US} = 1$, so that the price ratios of all the other countries are multiples of the US price ratio. The physical quantities allow for one normalization, which is $y_{fg}^{US} = 1$.

Luxembourg is excluded from the analysis because of lack of data on intermediate goods.

[14]Some countries report for dates other than the three, for instance 1997 instead of 1995.
[15]Amongst others Argentina, Brazil, China, India, Indonesia, and Russia.

1.7.2 Computations

Solution of the theoretical model

The firms' first order conditions with respect to l_{ji} in (1.2) and (1.4) give

$$\frac{w}{p_{ji}}\frac{l_{ji}}{y_{ji}} = 1-\sigma_i, \forall j \in \{f,m\}, i \in \{s,g\}. \tag{1.20}$$

The first order conditions with respect to x_{gji} and x_{sji} are

$$\frac{p_{mg}}{p_{ji}} = A_{ji}\sigma_i \left(\gamma_{gi}^{\frac{1}{\rho_i}} x_{gji}^{\frac{\rho_i-1}{\rho_i}} + \gamma_{si}^{\frac{1}{\rho_i}} x_{sji}^{\frac{\rho_i-1}{\rho_i}}\right)^{\frac{1-(1-\sigma_i)\rho_i}{\rho_i-1}} \gamma_{gi}^{\frac{1}{\rho_i}} x_{gji}^{\frac{-1}{\rho_i}} l_{ji}^{1-\sigma_i}, \forall j \in \{f,m\}, i \in \{s,g\},$$

$$\frac{p_{ms}}{p_{ji}} = A_{ji}\sigma_i \left(\gamma_{gi}^{\frac{1}{\rho_i}} x_{gji}^{\frac{\rho_i-1}{\rho_i}} + \gamma_{si}^{\frac{1}{\rho_i}} x_{sji}^{\frac{\rho_i-1}{\rho_i}}\right)^{\frac{1-(1-\sigma_i)\rho_i}{\rho_i-1}} \gamma_{si}^{\frac{1}{\rho_i}} x_{sji}^{\frac{-1}{\rho_i}} l_{ji}^{1-\sigma_i}, \forall j \in \{f,m\}, i \in \{s,g\},$$

which can be rewritten to, $\forall j \in \{f,m\}, i \in \{s,g\}$,

$$x_{gji} = \left(\frac{p_{ji}}{p_{mg}} A_{ji}\sigma_i\right)^{\frac{1}{1-\sigma_i}} \left(1+\frac{\gamma_{si}}{\gamma_{gi}}\left(\frac{p_{ms}}{p_{mg}}\right)^{1-\rho_i}\right)^{\frac{(1-\sigma_i)\rho_i-1}{(1-\rho_i)(1-\sigma_i)}} \gamma_{gi}^{\frac{\sigma_i}{(1-\sigma_i)(\rho_i-1)}} l_{ji}, \tag{1.21}$$

$$x_{sji} = \left(\frac{p_{ji}}{p_{ms}} A_{ji}\sigma_i\right)^{\frac{1}{1-\sigma_i}} \left(\frac{\gamma_{gi}}{\gamma_{si}}\left(\frac{p_{ms}}{p_{mg}}\right)^{\rho_i-1}+1\right)^{\frac{(1-\sigma_i)\rho_i-1}{(1-\rho_i)(1-\sigma_i)}} \gamma_{si}^{\frac{\sigma_i}{(1-\sigma_i)(\rho_i-1)}} l_{ji}. \tag{1.22}$$

Combining these two equations with (1.20) and (1.1) gives, $\forall i \in \{s,g\}$,

$$\frac{w}{p_{ig}} = \left(\frac{p_{ig}}{p_{mg}}\right)^{\frac{\sigma_g}{1-\sigma_g}} A_{ig}^{\frac{1}{1-\sigma_g}} \sigma_g^{\frac{\sigma_g}{1-\sigma_g}} (1-\sigma_g) \left(\gamma_{gg}+\gamma_{sg}\left(\frac{p_{ms}}{p_{mg}}\right)^{1-\rho_g}\right)^{\frac{\sigma_g}{(1-\sigma_g)(\rho_g-1)}} \tag{1.23}$$

$$\frac{w}{p_{is}} = \left(\frac{p_{is}}{p_{ms}}\right)^{\frac{\sigma_s}{1-\sigma_s}} A_{is}^{\frac{1}{1-\sigma_s}} \sigma_s^{\frac{\sigma_s}{1-\sigma_s}} (1-\sigma_s) \left(\gamma_{ss}+\gamma_{gs}\left(\frac{p_{ms}}{p_{mg}}\right)^{\rho_s-1}\right)^{\frac{\sigma_s}{(1-\sigma_s)(\rho_s-1)}} \tag{1.24}$$

The household's maximization problem implies:

$$\frac{p_{fs}}{p_{fg}} = \frac{u_{c_s}}{u_{c_g}} = \left[\frac{\omega_s}{\omega_g}\frac{c_g}{c_s}\right]^{\frac{1}{\rho}}. \tag{1.25}$$

These last five formulations, coupled with the clearing conditions (1.1), $\forall i \in \{g,s\}$, (1.3), (1.5), (1.6) and (2.8) fully characterize the equilibrium, leaving room for the normalization of one price.

Proof of Proposition 1

From (1.11) we have

$$\begin{aligned}\ln \frac{p_{fs}}{p_{fg}} &= \ln A_{fg} - \ln A_{fs} + \frac{\sigma_g}{1-\sigma_g} \ln A_{mg} - \frac{\sigma_s}{1-\sigma_s} \ln A_{ms} \\ &+ \frac{\sigma_g}{(\rho_g - 1)(1-\sigma_g)} \ln \left(\gamma_{gg} + \gamma_{sg} \left(\frac{A_{fs}}{A_{fg}} \frac{A_{mg}}{A_{ms}} \frac{p_{fs}}{p_{fg}} \right)^{1-\rho_g} \right) \\ &- \frac{\sigma_s}{(\rho_s - 1)(1-\sigma_s)} \ln \left(\left(\frac{A_{fs}}{A_{fg}} \frac{A_{mg}}{A_{ms}} \frac{p_{fs}}{p_{fg}} \right)^{\rho_s - 1} \gamma_{gs} + \gamma_{ss} \right).\end{aligned}$$

Differentiation gives

$$\begin{aligned}&\frac{d(p_{fs}/p_{fg})}{p_{fs}/p_{fg}} = \Lambda \left(1 + \frac{\sigma_g}{1-\sigma_g}(1-\Gamma_{gg}) + \frac{\sigma_s}{1-\sigma_s}(1-\Gamma_{ss}) \right) \frac{dA_{fg}}{A_{fg}} \\ &-\Lambda \left(1 + \frac{\sigma_g}{1-\sigma_g}(1-\Gamma_{gg}) + \frac{\sigma_s}{1-\sigma_s}(1-\Gamma_{ss}) \right) \frac{dA_{fs}}{A_{fs}} \\ &+\Lambda \left(\frac{\sigma_g}{1-\sigma_g} - \frac{\sigma_g}{1-\sigma_g}(1-\Gamma_{gg}) - \frac{\sigma_s}{1-\sigma_s}(1-\Gamma_{ss}) \right) \frac{dA_{mg}}{A_{mg}} \\ &-\Lambda \left(\frac{\sigma_s}{1-\sigma_s} - \frac{\sigma_g}{1-\sigma_g}(1-\Gamma_{gg}) - \frac{\sigma_s}{1-\sigma_s}(1-\Gamma_{ss}) \right) \frac{dA_{ms}}{A_{ms}}\end{aligned} \tag{1.26}$$

where

$$\Gamma_{gg} \equiv \frac{\gamma_{gg}}{\gamma_{gg} + \gamma_{sg} \left(\frac{A_{fs}}{A_{fg}} \frac{A_{mg}}{A_{ms}} \frac{p_{fs}}{p_{fg}} \right)^{1-\rho_g}} \in (0,1),$$

$$\Gamma_{ss} \equiv \frac{\gamma_{ss}}{\gamma_{ss} + \gamma_{gs} \left(\frac{A_{fs}}{A_{fg}} \frac{A_{mg}}{A_{ms}} \frac{p_{fs}}{p_{fg}} \right)^{\rho_s - 1}} \in (0,1),$$

$$\Lambda \equiv \left[1 + \frac{\sigma_g}{1-\sigma_g}(1-\Gamma_{gg}) + \frac{\sigma_s}{1-\sigma_s}(1-\Gamma_{ss}) \right]^{-1} \in (0,1).$$

Industry-neutral technical change ($\frac{dA_{fg}}{A_{fg}} = \frac{dA_{fs}}{A_{fs}} \equiv \frac{dA_f}{A_f}$ and $\frac{dA_{mg}}{A_{mg}} = \frac{dA_{ms}}{A_{ms}} \equiv \frac{dA_m}{A_m}$) gives

$$\frac{d(p_{fs}/p_{fg})}{p_{fs}/p_{fg}} = \frac{\sigma_g - \sigma_s}{(1-\sigma_g)(1-\sigma_s) + \sigma_g (1-\sigma_s)(1-\Gamma_{gg}) + \sigma_s (1-\sigma_g)(1-\Gamma_{ss})} \frac{dA_m}{A_m},$$

while specialization-neutral technical change ($\frac{dA_{fg}}{A_{fg}} = \frac{dA_{mg}}{A_{mg}} \equiv \frac{dA_g}{A_g}$ and $\frac{dA_{fs}}{A_{fs}} = \frac{dA_{ms}}{A_{ms}} \equiv \frac{dA_s}{A_s}$) gives:

$$\frac{d(p_{fs}/p_{fg})}{p_{fs}/p_{fg}} = \frac{(1-\sigma_s)\frac{dA_g}{A_g} - (1-\sigma_g)\frac{dA_s}{A_s}}{(1-\sigma_g)(1-\sigma_s) + \sigma_g (1-\sigma_s)(1-\Gamma_{gg}) + \sigma_s (1-\sigma_g)(1-\Gamma_{ss})}$$

Proof of Proposition 2:

From the definition $m_{ji} \equiv \left(\gamma_{gi}^{\frac{1}{\rho_i}} x_{gji}^{\frac{\rho_i - 1}{\rho_i}} + \gamma_{si}^{\frac{1}{\rho_i}} x_{sji}^{\frac{\rho_i - 1}{\rho_i}} \right)^{\frac{\rho_i}{\rho_i - 1}}$ and (1.1) and (1.3) results that

$$\frac{m_{fg}}{y_{fg}} = \frac{A_{mg}}{A_{fg}} \frac{m_{mg}}{y_{mg}} = \sigma_g \frac{A_{mg}}{A_{fg}} \left(\gamma_{gg} + \gamma_{sg} \left(\frac{A_{fs}}{A_{fg}} \frac{A_{mg}}{A_{ms}} \frac{p_{fs}}{p_{fg}} \right)^{1-\rho_g} \right)^{\frac{1}{\rho_g - 1}},$$

$$\frac{m_{fs}}{y_{fs}} = \frac{A_{ms}}{A_{fs}}\frac{m_{ms}}{y_{ms}} = \sigma_s \frac{A_{ms}}{A_{fs}} \left(\gamma_{ss} + \gamma_{gs} \left(\frac{A_{fs}}{A_{fg}} \frac{A_{mg}}{A_{ms}} \frac{p_{fs}}{p_{fg}} \right)^{\rho_s - 1} \right)^{\frac{1}{\rho_s - 1}}.$$

Differentiation and replacing $\frac{d(p_{fs}/p_{fg})}{p_{fs}/p_{fg}}$ by (1.26) obtains

$$\begin{aligned}
\frac{d\left(m_{fg}/y_{fg}\right)}{m_{fg}/y_{fg}} &= \Gamma_{gg}\frac{dA_{mg}}{A_{mg}} - \Gamma_{gg}\frac{dA_{fg}}{A_{fg}} \\
&- (1-\Gamma_{gg})\left(\frac{dA_{fs}}{A_{fs}} - \frac{dA_{ms}}{A_{ms}}\right) \\
&-\Lambda\left(1-\Gamma_{gg}\right)\left[\begin{array}{c}
\left(1+\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)+\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{fg}}{A_{fg}} \\
-\left(1+\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)+\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{fs}}{A_{fs}} \\
+\left(\frac{\sigma_g}{1-\sigma_g}-\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)-\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{mg}}{A_{mg}} \\
-\left(\frac{\sigma_s}{1-\sigma_s}-\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)-\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{ms}}{A_{ms}}
\end{array}\right],
\end{aligned}$$

$$\begin{aligned}
\frac{d\left(m_{fs}/y_{fs}\right)}{m_{fs}/y_{fs}} &= \Gamma_{ss}\frac{dA_{ms}}{A_{ms}} - \Gamma_{ss}\frac{dA_{fs}}{A_{fs}} \\
&- (1-\Gamma_{ss})\left(\frac{dA_{fg}}{A_{fg}} - \frac{dA_{mg}}{A_{mg}}\right) \\
&+\Lambda(1-\Gamma_{ss})\left[\begin{array}{c}
\left(1+\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)+\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{fg}}{A_{fg}} \\
-\left(1+\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)+\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{fs}}{A_{fs}} \\
+\left(\frac{\sigma_g}{1-\sigma_g}-\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)-\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{mg}}{A_{mg}} \\
-\left(\frac{\sigma_s}{1-\sigma_s}-\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)-\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{ms}}{A_{ms}}
\end{array}\right].
\end{aligned}$$

Industry-neutral growth ($\frac{dA_{fg}}{A_{fg}} = \frac{dA_{fs}}{A_{fs}} \equiv \frac{dA_f}{A_f}$ and $\frac{dA_{mg}}{A_{mg}} = \frac{dA_{ms}}{A_{ms}} \equiv \frac{dA_m}{A_m}$) delivers:

$$\frac{d\left(m_{mg}/y_{mg}\right)}{m_{mg}/y_{mg}} = \frac{\left(\sigma_s-\sigma_g\right)\left(1-\Gamma_{gg}\right)}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)}\frac{dA_m}{A_m},$$

$$\frac{d\left(m_{fg}/y_{fg}\right)}{m_{fg}/y_{fg}} = \frac{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{gg}\right)}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)}\frac{dA_m}{A_m} - \frac{dA_f}{A_f},$$

$$\frac{d\left(m_{ms}/y_{ms}\right)}{m_{ms}/y_{ms}} = \frac{\left(\sigma_g-\sigma_s\right)\left(1-\Gamma_{ss}\right)}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)}\frac{dA_m}{A_m},$$

$$\frac{d\left(m_{fs}/y_{fs}\right)}{m_{fs}/y_{fs}} = \frac{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{ss}\right)}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)}\frac{dA_m}{A_m} - \frac{dA_f}{A_f}.$$

while specialization-neutral growth ($\frac{dA_{fg}}{A_{fg}} = \frac{dA_{mg}}{A_{mg}}$ and $\frac{dA_{fs}}{A_{fs}} = \frac{dA_{ms}}{A_{ms}}$) is given by:

$$\begin{aligned}
\frac{d\left(m_{fg}/y_{fg}\right)}{m_{fg}/y_{fg}} &= \frac{d\left(m_{mg}/y_{mg}\right)}{m_{mg}/y_{mg}} \\
&= \frac{\left(1-\Gamma_{gg}\right)\left[\left(1-\sigma_g\right)\frac{dA_s}{A_s} - \left(1-\sigma_s\right)\frac{dA_g}{A_g}\right]}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)},
\end{aligned}$$

$$\begin{aligned}\frac{d\left(m_{fs}/y_{fs}\right)}{m_{fs}/y_{fs}} &= \frac{d\left(m_{ms}/y_{ms}\right)}{m_{ms}/y_{ms}} \\ &= \frac{\left(1-\Gamma_{ss}\right)\left[\left(1-\sigma_s\right)\frac{dA_g}{A_g}-\left(1-\sigma_g\right)\frac{dA_s}{A_s}\right]}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)}.\end{aligned}$$

Proof of Proposition 3:

Taking logs of (1.16), differentiating and replacing $\frac{d\left(p_{fs}/p_{fg}\right)}{p_{fs}/p_{fg}}$ by (1.26) gives

$$\begin{aligned}\frac{d\left(GDP/P\right)}{GDP/P} &= \left[1+\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)\right]\frac{dA_{fg}}{A_{fg}}+\left[\frac{\sigma_g}{1-\sigma_g}-\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)\right]\frac{dA_{mg}}{A_{mg}} \\ &\quad -\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)\left[\frac{dA_{fs}}{A_{fs}}-\frac{dA_{ms}}{A_{ms}}\right] \\ &\quad -\Lambda\left[\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)+\Omega_s\right] \\ &\quad \times\left[\begin{array}{c}\left(1+\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)+\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{fg}}{A_{fg}} \\ -\left(1+\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)+\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{fs}}{A_{fs}} \\ +\left(\frac{\sigma_g}{1-\sigma_g}-\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)-\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{mg}}{A_{mg}} \\ -\left(\frac{\sigma_s}{1-\sigma_s}-\frac{\sigma_g}{1-\sigma_g}\left(1-\Gamma_{gg}\right)-\frac{\sigma_s}{1-\sigma_s}\left(1-\Gamma_{ss}\right)\right)\frac{dA_{ms}}{A_{ms}}\end{array}\right].\end{aligned}$$

where $\Omega_s \equiv \frac{\omega_s\left(\frac{p_{fs}}{p_{fg}}\right)^{1-\rho}}{\omega_g+\omega_s\left(\frac{p_{fs}}{p_{fg}}\right)^{1-\rho}}$. Industry-neutral technical change ($\frac{dA_{fg}}{A_{fg}} = \frac{dA_{fs}}{A_{fs}} \equiv \frac{dA_f}{A_f}$ and $\frac{dA_{mg}}{A_{mg}} = \frac{dA_{ms}}{A_{ms}} \equiv \frac{dA_m}{A_m}$) gives:

$$\frac{d\left(GDP/P\right)}{GDP/P} = \frac{\Lambda\left\{\begin{array}{c}\left[\left(1-\sigma_g\right)\left(1-\sigma_s\right)+\sigma_g\left(1-\sigma_s\right)\left(1-\Gamma_{gg}\right)+\sigma_s\left(1-\sigma_g\right)\left(1-\Gamma_{ss}\right)\right]\frac{dA_f}{A_f} \\ +\left[\sigma_g\left(1-\sigma_s\right)\left(1-\Omega_s\right)+\sigma_s\left(1-\sigma_g\right)\Omega_s+\sigma_g\sigma_s\left(2-\Gamma_{gg}-\Gamma_{ss}\right)\right]\frac{dA_m}{A_m}\end{array}\right\}}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)},$$

while specialization-neutral technical change ($\frac{dA_{fg}}{A_{fg}} = \frac{dA_{mg}}{A_{mg}} \equiv \frac{dA_g}{A_g}$ and $\frac{dA_{fs}}{A_{fs}} = \frac{dA_{ms}}{A_{ms}} \equiv \frac{dA_s}{A_s}$) gives:

$$\frac{d\left(GDP/P\right)}{GDP/P} = \frac{\Lambda\left\{\left[\left(1-\sigma_s\right)\left(1-\Omega_s\right)+\sigma_s\left(1-\Gamma_{ss}\right)\right]\frac{dA_g}{A_g}+\left[\left(1-\sigma_g\right)\Omega_s+\sigma_g\left(1-\Gamma_{gg}\right)\right]\frac{dA_s}{A_s}\right\}}{\left(1-\sigma_g\right)\left(1-\sigma_s\right)}.$$

Chapter 2

MANAGERIAL DELEGATION AND AGGREGATE PRODUCTIVITY

2.1 Introduction

Why is income per capita so different across countries? Much of the evidence shows that factor endowments such as physical and human capital fall short of quantitatively matching the bulk of the difference.[1] To explain the remaining total factor productivity (TFP) gap, the literature has increasingly focused on the institutional environment of economies. In this context, recently collected data on managerial performance across countries provide valuable insights. In a series of papers Bloom and his co-authors demonstrate that firms in poorer countries are badly managed.[2] Their finding is that, by performing relatively minor and cheap changes in the daily management (e.g. improving monitoring, target setting and incentive schemes to modern management standards) firms could potentially boost output per worker significantly. Importantly, these studies suggest that one major source of managerial inefficiency in less developed countries is insufficient delegation of decision-making. Hence, many efficiency-enhancing measures are left on the table; workers who are best informed about particular problems are not endowed with sufficient authority to solve them.[3]

This paper addresses the phenomenon of poor management in three ways. First, I present evidence that, in the aggregate, relatively few workers in less developed countries are employed in problem-solving positions, i.e. there are relatively few "managerial workers" as I refer to them henceforth. I then construct a theoretical model where the scarcity of managerial workers is a result of sub-optimal decentralization within firms. In the model, this results from insufficient property protection and hence a higher risk of expropriation by middle management. Third, I use the model as a measuring device to gauge to what extent the underlying institutional weakness impacts GDP per capita.

The theoretical model features firms that are heterogeneous in their efficiency and that hire production and managerial workers to produce output. The technology is such that more effi-

[1] Caselli (2005) offers an excellent review of these findings.

[2] Bloom and Van Reenen (2007) is an initial survey study of management practices across a few developed countries while Bloom and Van Reenen (2010) provide further evidence for an enlarged set of countries. Bloom, Eifert, Mahajan, McKenzie and Roberts (2010) is a field experiment in India that measures the sensitivity of firms' management practice to external professional advice. See also Bloom, Mahajan, McKenzie and Roberts (2010) for a review of the findings.

[3] See also Bloom, Sadun and Van Reenen (2009) for an estimation of how decentralization of decision-making across countries depends on firm-specific and country-specific characteristics, and especially how it is related to trust and the rule of law.

cient firms, wishing to employ more workers, have an incentive to disperse managerial tasks across a larger number of managerial layers. I call this "delegation." Delegation also implies that the relative share of problem solvers in the firm increases. At the same time, each additional layer of middle managers may divert revenue from the firm. In equilibrium, owners in the model compensate managerial workers for not stealing, which makes delegation more costly. Countries in the model differ institutionally by the share of revenue that managers can expropriate.

Theoretically, the model delivers the following findings. The share of managerial workers for similarly efficient firms is lower in countries with poor property protection. This is a direct consequence of a shorter managerial hierarchy. The resulting drop in the firm's managerial quality - a manifestation of *misallocation within* the firm - translates into bad management practice. In addition, more efficient and therefore larger firms suffer relatively more from poor property protection than their smaller peers, especially since own-account workers and firms with single management layers face no incentive incompatibility. This implies that ineffective property protection inefficiently channels resources into relatively unproductive firms, creating *misallocation across* firms. Therefore, such an economy features smaller production units and depressed output.[4]

The empirical application of the model rests on the observation depicted in Figure (2.1), namely that the overall share of managerial workers is significantly lower in poor relative to rich countries.[5] Estimation results presented in the subsequent section show that differences in the level of education and - crucially for this paper - differences in an indicator of contract enforcement tend to explain the share of managerial workers across countries, not GDP per capita itself. As contract enforcement is difficult to quantify directly, I use the model's prediction on the share of managerial workers to infer it indirectly. I calibrate the model to match the ratio of managerial workers in the US along with data on the US firm size ditribution. Subsequently I vary the institutional parameter to match the managerial share in poorer countries.

I find that in the extreme case of no property protection, the simulated managerial share drops by 10 percentage points. Such a drop in the managerial share in the data is associated with countries having income levels of about one-tenth of the US. At the same time the model predicts labor productivity in such an environment to decline by about 18 percent compared to the US. While the mechanism in the present paper does not *per se* generate the order of magnitude in productivity differences across countries that are observed in the data, it goes some way in addressing them by offering an additional source of inefficiency. Also, as the model abstracts from any kind of accumulated capital, productivity losses are equivalent to pure TFP losses.[6]

The identification procedure appears robust in the sense that the model performs well on a variety of other features that characterize differences between rich an poor countries. It is shown that the lack of property protection induces a significant drop in the average firm size, a widely observed property in poor countries (see for instance Tybout (2000) for a review). Also, as individuals in the model know their productivity in running their own business, similarly

[4] This is similar to the generic size-dependent policies analyzed in Guner, Ventura and Xi (2008).

[5] Eeckhout and Jovanovic (forthcoming) also point out this relationship from data collected by the ILO and analyze how it has changed through time as a response to the increase in international trade and outsourcing/offshoring. Acemoglu and Newman (2004) use the same data for a subset of OECD countries to study agency problems within the firm, but their treatment of managers is more akin to that of supervisors.

[6] Moreover, the model is only concerned with the non-agricultural business sector where productivity differences between the poorest and richest countries are far less pronounced than in the aggregate economy. The difference is a factor of 5 in the non-agricultural sector and about 32 overall according to Restuccia, Yang and Zhu (2008).

to Lucas (1978), many choose to become self-employed rather than work for a relatively low wage. This generates a substantial amount of self-employment, another feature typical in poor countries (see for instance Gollin (2008)). Furthermore, I show that poor property protection causes a rise in misallocation, measured as productivity dispersion along the lines of Restuccia and Rogerson (2008), Hsieh and Klenow (2009) and Bartelsman, Haltiwanger and Scarpetta (2009).

This paper is closely related to the literature analyzing the link between credit frictions and TFP across countries, such as Greenwood, Sanchez and Wang (2009), Amaral and Quintin (2010), Buera, Kaboski and Shin (2011), Moll (2010) and Midrigan and Xu (2010) and Caselli and Gennaioli (2011). These papers have in common a game between the capital-provider and the entrepreneur where poor institutions decrease the flow of credit. Here, the friction is similar, only that the game is played out inside the firm rather than between the owner and his middle management. Another difference is that credit frictions can be partially circumvented through retained earnings, while the problem of trust within firms is a permanent state.

In a different vein, this paper also builds on theoretical studies of the problem of delegation of authority within firms. The classical trade-off is that of the costly state-verification process. The principal would like to delegate tasks but needs to employ resources to control for the outcome, as for instance in Townsend (1979). Aghion and Tirole (1997) show that principals (firm owners) may have an interest in exercising less control over agents when the latter are better informed because this boosts their incentive for initiatives. Another delegation problem is considered in Rajan and Zingales (2001) where the principal faces a trade-off between enhancing productivity by delegating knowledge and the risk of encouraging the creation of spin-off from the firm. Dessein (2002) combines an environment in which communication is costly with an agency problem to analyze under what circumstances delegation from uninformed principals to informed agents is optimal. Finally, the present paper is most closely related to Garicano (2000) where delegation is represented by a knowledge hierarchy in which the most important tasks are optimally delegated to the bottom of the hierarchy to save on communication costs, while upper echelons of the hierachy specialize in solving less common tasks. The model here captures the rationale for a hierarchy tractably by leaving out a more structural interpretation. In addition to the technological trade-off, the hierarchy is subject to a commitment problem on the part of middle managers. The game results in a contract that is akin to optimal debt contracts analyzed in Kehoe and Levine (1993), Kocherlakota (1996) and Alvarez and Jermann (2000).

The next section describes the empirical motivation. Section 3 then presents the model environment and Section 4 the theoretical implications of the stationary equilibrium. In Section 5 I describe the calibration of the model and the model's predictions for different institutional environments. I end with concluding remarks.

2.2 Empirical motivation

Figure (2.1) presents a striking negative cross-country correlation between the share of what I label "managerial workers" and GDP per capita. The employment data stems from the ILO and builds mainly on labor force surveys. For each country I compute the number of employees categorized as managers, professionals and administrative workers (categories 0, 1 and 2, 3 in the ILO classification) and divide it by the total working population excluding agricultural and non-classifiable workers (categories 6 and X). Non-managerial workers, labeled "production workers" henceforth, are clerks, service and sales workers, craft and related trade workers, plant and machine operators and workers in elementary occupations (4, 5, 7, 8 and 9). I then compute averages over the sampling years 1999 to 2008. GDP per capita is taken from the Penn

World Tables and represents averages over the same time period.

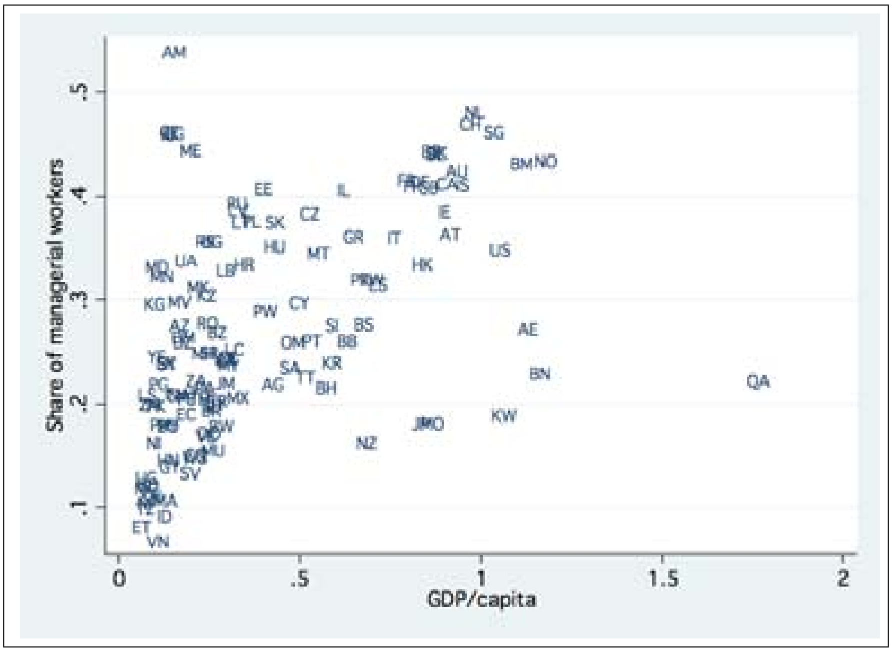

Figure 2.1: Share of managerial workers and GDP per capita

To understand whether the correlation is driven by omitted variables I run a regression controling for several candidate variables x of the form

$$\log\left(\frac{share_i}{share_{US}}\right) = \alpha + \sum_j \beta_j \log\left(\frac{x_{j,i}}{x_{j,US}}\right) + \epsilon_i.$$

Table (2.1) presents the resulting OLS regressions. The first column reports the regression with GDP per capita (the US income per capita normalized to 1) being the only explanatory variable. This reflects the observation discussed in Figure (2.1), i.e. for a decrease in GDP per capita of 1 percent (relative to the US), the proportion of managerial workers is expected to drop by 0.23 percent vis-a-vis the US (which has a managerial share of 0.35). The correlation is strongly significant in the statistical sense.

In the second and third column I control for the sectoral composition of the workforce by adding the share of workers employed in services and agriculture as well as the share of government spending, which arguably acts as a proxy for the share of public employees. The data are derived from the World Bank and the Penn World Tables, and represent averages over the period 1999 through 2008. The share of service workers as well as government spending come out statistically significant, which indicates that managerial workers may be more prevalent in the service industry and the public sector. Notice that GDP per capita, however, keeps its strong explanatory power. In the next column I add another obvious candidate, which is the share of the population with completed or attempted tertiary education, taken from the dataset in Barro and Lee (2005). This statistic is again constructed as country averages over the period of interest. It seems intuitive that countries with higher educational attainments have more managerial workers assuming that the latter are characterized by higher skills. Education turns out to be an important explanatory variable yet GDP per capita still appears highly significant (both statistically and economically) in explaining occupations across countries. I also add private

Regressor	Coeff (SE)	Coeff (SE)	Coeff (SE)	Coeff (SE)	Coeff (SE)	Coeff (SE)	Coeff (SE)
Constant	0.025	−0.013	−0.038	0.054	0.015	0.087	0.120
	(0.052)	(0.056)	(0.057)	(0.063)	(0.070)	(0.072)	(0.078)
GDP/capita (% of US)	0.230^{***}	0.160^{**}	0.164^{***}	0.151^{**}	0.183^{**}	0.089	0.047
	(0.028)	(0.059)	(0.059)	(0.067)	(0.072)	(0.075)	(0.086)
Services employment (%)		0.364^{**}	0.348^{**}	0.043	0.038	0.100	0.175
		(0.147)	(0.147)	(0.182)	(0.181)	(0.186)	(0.200)
Agriculture employment (%)		0.037	0.035	0.007	−0.007	−0.035	−0.038
		(0.047)	(0.047)	(0.051)	(0.051)	(0.055)	(0.060)
Government spending (%)			0.101	0.145^{*}	0.146^{*}	0.131^{*}	0.160^{*}
			(0.063)	(0.079)	(0.079)	(0.076)	(0.084)
Tertiary education (%)				0.150^{***}	0.156^{***}	0.182^{***}	0165^{***}
				(0.048)	(0.048)	(0.051)	(0.052)
Credit/GDP (%)					−0.064	−0.084	−0.078
					(0.053)	(0.051)	(0.055)
Contract enforcement (%)						0.727^{***}	0.679^{***}
						(0.239)	(0.250)
Self-employed & employers (%)							−0.059
							(0.067)
Observations	125	122	122	105	105	99	93
R^2	0.349	0.380	0.393	0.436	0.444	0.487	0.507

Table 2.1: Regression on the managerial share

credit/GDP, an indicator for the quality of financial markets, which does not seem to matter statistically.

Subsequently, I add to the regression an indicator for contract enforcement, as in the remainder I will argue that contract enforcement (or rather the lack thereof) is the crucial driving factor of the share of managerial workers across countries. For this I use data from the World Bank's Doing Business database on the cost of suing for a claim as a percentage of the value of the claim and subtract it from 1 (i.e. the percent of the claim that is expected to be recovered in a lawsuit). Again, I use averages over the years of interest. Interestingly GDP per capita now loses statistical significance while contract enforcement turns out very significant, along with education and, to a lesser extent, the size of the public sector. Since the model will also create cross-country differences in firm size and the share of self-employment, I finally also add the proportion of employers and self-employed in the population that is available from the ILO and similarly covers the period 1999-2008. One could argue that very small firms (captured by a high number of employers and self-employed) demand relatively fewer managerial workers, but the variable turns out not to matter at all in the regression.

I take from these regression results two things. First, contract enforcement appears to matter in determining the managerial share. In fact, according to the measurea decrease from US levels of contract enforcement (0.87) to levels associated with the worst enforcement (Jamaica at around 0.55) predics a drop in the managerial share by more than 30 percent. Second, in the remainder I will not use the above indicator for contract enforcement, but rather calibrate it indirectly and discipline the calibration by targeting the number of managerial workers. Variations in the model-based indicator of contract enforcement will vary the share of managerial workers. To get a sense of what the model-based outcome in the share of managerial workers corresponds to in terms of a country's GDP per capita, I will use the regression results in column 5, which does not use any explanatory variables assumed or generated in the model. In this sense, a country with GDP per capita equal to 0.1 of the US is expected to have a managerial share implicit from $\log\left(\frac{share_i}{0.35}\right) = 0.015 + 0.183\log(0.1)$, i.e. 0.26, as opposed to the US managerial share of 0.35.

2.3 Economic environment

The economy is populated by atomless infinitely-lived agents of measure 1. Each agent is endowed with one unit of time per period and a fixed and known level of project quality (or talent to run a firm) $z \in Z$ drawn from the cumulative distribution function $G(z)$. An agent's discounted utility reads $U = \sum_{t=0}^{\infty} \beta^t c_t$ where $\beta \in (0,1)$ is the discount factor of time t. I assume linear utility to neutralize precaution due to risk, which can be interpreted as a short-cut for modelling complete financial markets.

2.3.1 Occupational choice

At the beginning of each time period an agent with project quality z can run his own business and earn $V(z,1)$ where 1 denotes that the agent occupies the first hierarchical position in that firm. The agent's alternative is to enter the labor market to become a worker and earn an expected value V^{lm}. Agents optimally choose $V(z) = \max\left\{V(z,1), V^{lm}\right\}$, with $\overline{z}$ denoting the threshold value such that $V(\overline{z},1) = V^{lm}$. The value of being an entrepreneur is $V(z,1) = \frac{\pi(z)}{1-\beta}$ where $\pi(z)$ represents period profits, i.e. the agents' choice of becoming an entrepreneur is permanent.[7]

Workers are ex-ante identical on the labor market. Ex-post, they are different in that some of them are offered the possibility of becoming managerial workers at firm $s \in Z$ in managerial position $l \in \{2,3,...,L(s)\}$. This occurs randomly with (endogenous) probability $q(s,l) \in [0,1]$. Workers are able to accept or decline the contract that they are offered, and in equilibrium they will always accept. All other workers become production workers.

Signing a contract as a production worker procures $V^n = w + \beta V^{lm}$; a worker earns a competitive wage w and subsequently receives the expected value of searching in the labor market again. Signing a contract as a managerial worker in firm s and position l, on the other hand, is valued at $V(s,l)$. The expected value of entering the labor market is hence $V^{lm} = \int_{s\geq\overline{z}} \sum_{l=2}^{L(s)} q(s,l)V(s,l) + \left(1 - \int_{s\geq\overline{z}} \sum_{l=2}^{L(s)} q(s,l)\right) V^n$.

2.3.2 Production

An active entrepreneur with quality z maximizes profits by deciding whether to be a self-employed worker, a firm with one single management layer (i.e. himself) or whether to run a business with multiple managerial layers, so $\pi(z) = \max\left\{\pi^{se}(z), \pi^{sl}(z), \pi^{ml}(z)\right\}$.

Self-employment and single-layer firms

Upon paying a period fixed cost κ^{se}, period profits of the self-employed entrepreneur are given by

$$\pi^{se}(z) = \max_{n,x_1} y - \kappa^{se} = \max_{n,x_1} z x_1^{\gamma} n^{1-\frac{\gamma}{1-\theta}} - \kappa^{se}.$$

This is subject to the time comstraint $n + x_1 = 1$, where n is the amount of production hours worked and x_1 is the amount of hours spent managing the business and solving problems. I assume that γ,$\theta \in [0,1)$ and - for the problem to be well-defined - that $\gamma + \theta \leq 1$. The parameter γ is the technical intensity of managerial work, while the parameter θ is interpreted as the cost of communication (or the inverse of the span of control) between managerial work and the hierarchy beneath, in this case the layer of production work. When $\theta = 0$, there is no

[7]The fact that this choice is permanent rests on the assumption that in the initial period there are no incumbent workers in any firm. However, if there were incumbent workers, the permanent occupational choice would just as well come about in the stationary equilibrium because there is exogenous separation, as will become clear below.

communication cost and no loss of control, and the production function has constant returns to scale in problem-solving and production work. When $\theta = 1 - \gamma$, on the other hand, production work produces no value because no problem solutions are executed.

Alternatively, the entrepreneur pays a higher fixed cost $\kappa^{ef} > \kappa^{se}$ and runs an employer firm. This allows him to go beyond his size-constraint by employing workers. With a single management layer the firm's profits then equal

$$\pi^{sl}(z) = \max_{n,x_1}\left[y - w(n + x_1 - 1)\right] - \kappa^{ef} = \max_{n,x_1}\left[z x_1^{\gamma} n^{1-\frac{\gamma}{1-\theta}} - w(n + x_1 - 1)\right] - \kappa^{ef}, \tag{2.1}$$

subject to $x_1 \leq 1$. This constraint precludes the entrepreneur from hiring workers to accomplish his own managerial tasks.

Multi-layer firms

If the entrepreneur wishes to expand the amount of managerial tasks he needs to add additional (descrete) managerial layers $l = \{2, 3, ..., L\}$ up to the optimum choice L. The profit function is

$$\begin{aligned}
\pi^{ml}(z) &= \max_{L,n,\{x_l,m_l\}_{l=2}^{L}}\left[y - wn - w\sum_{l=2}^{L} m_l x_l\right] - \kappa^{ef} \qquad (2.2)\\
&= \max_{L,n,\{x_l,m_l\}_{l=2}^{L}}\left[z\prod_{l=2}^{L} x_l^{\gamma\theta^{L-l}} n^{1-\frac{\gamma}{1-\theta}} - wn - w\sum_{l=2}^{L} m_l x_l\right] - \kappa^{ef},
\end{aligned}$$

assuming that the entrepreneur occupies the top echelon of the managerial hierarchy ($x_1 = 1$), and subject to the participation constraint(s) of each middle manager:

$$V(z,l) \geq V^{out}(z,l),\ l \in \{2, 3, ..., L\}. \tag{2.3}$$

To gain understanding, first abstract from the participation constraints and the managerial markups m, and consider the trade-off faced by the entrepreneur who adds a second managerial layer ($L = 2$). The benefit consists of the option to increase the number of problems solved. The cost, as compared to running a single-layer firm, is the entrepreneur's opportunity cost of not employing his time at solving problems as he now oversees the production process from the first hierarchical position. It is obvious that for a high enough z he has an interest in doing so. Now consider the choice of employing additional layers of middle managers such that $L = 3$, 4, 5, etc. With decreasing returns to scale, it is evident that initial units of an additional managerial layer have a relatively stronger impact on productivity than marginal units of preceding layer. Note, however, that an additional layer l only increases production for $x_l > 1$. This turns out to be desirable if the firm has high efficiency z. Also, average units in the additional layer of management are relatively less effective as the exponent θ^{L-l} decreases.

The lower the managerial layer, the more efficient it is at dealing with problems as it is located closer to the production process where problems arise. The firm, however, may have an interest in positioning managers in various layers due to the concavity of the production function in managerial tasks. One justification for the benefit of additional layers is that each layer specializes in a particular type of problem. For the communication to be effective, however, each layer needs to surpass a minimum size, which can be interpreted as a fixed cost in the setup of a longer chain of command. Only firms that employ relatively many production workers have an incentive in acquiring large amounts of knowledge though increased specialization. The described mechanism is reminiscent of the knowledge-hierarchy modeled in Garicano (2000).

The notion of delegation or decentralization in the present model is hence simply the length of the chain of command.

Employing outside managerial workers is associated with a cost over and above the regular wage w due to institutional reasons. I assume that the revenue of production y flows upward in the hierachy, i.e. it is first collected by the lowest managerial rank and then successively handed up through the layers until reaching the entrepreneur. This assumption rests on the premise that the managers closest to the production process have immediate control over the value of y and only lose this authority when they transfer revenue up to the next hierarchy rank. Given these circumstances I assume that in each managerial layer, a particular middle manager handles y/x_l amount of revenue. Furthermore I assume that he can expropriate up to a fraction $1-\lambda$ of it, where $\lambda \in [0,1]$ governs the quality of institutions. In particular λ reflects the degree of property protection and can be interpreted as the fraction of stolen output that the entrepreneur can formally or informally recover. I will further assume that it takes one unit of time for the entrepreneur to discover the expropriation.

The entrepreneur plays a game of Stackelberg leader with each of his middle managers. More to the point, the entrepreneur has the possibility to offer each middle manager a contract that specifies a time-invariant wage markup m_l such that the middle manager does not steal from him. At the same time he threatens to fire the middle manager upon discovering any revenue loss. This threat is perfectly credible as it is costless for the owner to exchange middle managers. Let $\beta \in (0,1)$ be the time discount factor and $\delta \in (0,1)$ an exogenous separation rate. We have that the staying value for a middle manager is then

$$V(z,l) = m_l w + \beta\left[\delta V^{lm} + (1-\delta)V(z,l)\right] = \frac{m_l w + \beta\delta V^{lm}}{1-\beta(1-\delta)}.$$

where V^{lm} is the value of re-entering the labor market.[8] Alternatively, if a middle manager decides to divert resources, his value is

$$V^{x,out}(z,l) = (1-\lambda)\frac{y}{x_l} + w + \beta V^{lm}.$$

Let $1+a \equiv \frac{1-\beta}{w}V^{lm}$. It can be checked that the participation constraint (2.3) holds with equality for

$$m_l w = [1+\beta(1-\delta)a]w + (1-\lambda)[1-\beta(1-\delta)]\frac{y}{x_l}.$$

so that

$$V(z,l) = \frac{[1+\beta(1-\delta)a]w + (1-\lambda)[1-\beta(1-\delta)]\frac{y}{x_l} + \beta\delta V^{lm}}{1-\beta(1-\delta)}. \tag{2.4}$$

The markup hence consists of two parts. The second part is the discounted private benefit of expropriation, $(1-\lambda)[1-\beta(1-\delta)]\frac{y}{x_l}$, which depends positively on the amount that can potentially be stolen and negatively on the effective discount factor $\beta(1-\delta)$, which expresses the opportunity cost of not being able to steal from that particular firm in the future. The first part $w+\beta(1-\delta)aw$ is the regular wage plus the outside opportunity cost of re-entering the labor market. To the extent that there exists a positive labor market premium in the economy, agents employed in the labor market earn in expectation strictly more than the discounted sum of wages, i.e. $V^{lm} > \frac{w}{1-\beta}$ and a is positive as will be shown below. The outside option depends

[8]Notice that compensation implies that the middle manager, unless separated, remains with the same employer in the subsequent period. The underlying assumption for this is that incumbent managers are the first to negotiate a contract with the firm in the subsequent period. It is shown below that in such circumstances remaining with the firm is always better than searching in the labor market.

positively on the discount factor because the possibility of a relatively high remuneration in the future strengthens the middle manager's bargaining position.

The profit function of firms with multiple managerial layers can hence be rewritten more concisely as

$$\pi^{ml}(z) = \max_{L,n,\{x_l\}_{l=2}^{L}} \left\{ \begin{array}{c} \left[1-(1-\lambda)(L-1)(1-[\beta(1-\delta)])\right] z \prod_{l=2}^{L} x_l^{\gamma\theta^{L-l}} n^{1-\frac{\gamma}{1-\theta}} \\ -wn - w\left(1+a\left[\beta(1-\delta)\right]\right)\sum_{l=2}^{L} x_l - \kappa^{ef} \end{array} \right\}. \tag{2.5}$$

It is clear that the presence of institutional constraints ($\lambda < 1$) renders the introduction of additional managerial layers more costly.

2.4 Equilibrium

2.4.1 Characterization

Labor market value

The characteristic of this labor market is that incumbent managerial workers have an advantage. First, note that each agent offered a managerial contract with firm $s \in Z$ as described above accepts the contract. To see this, the agents who are either chosen to be the first to negotiate a managerial contract with the highest paying job (s,l). These agents can be either randomly chosen workers searching in the labor market or incumbent managerial workers. They have an interest in signing the contract because trying to find any other match in the labor market would result in lower managerial rents. As to the firm, it also has an interest in signing such a contract as it pays the minimum amount while still preventing workers from stealing.[9] Since all workers are identical, it is also impossible that other workers undercut such an offer as it would not be credible. Similarly, the agents matched with the second-highest paying job will sign their contract because the only alternative contract offering more is provided by a position that is already filled. This logic continues for all initial negotiations, implying that agents matched for negotation as production workers have no other period option but to take a production worker contract, which is competitive.

Managerial workers therefore remain in their position as long as they are not exogenously separated. New managerial job openings become vacant only when incumbents are exogenously separated, which occurs at the rate δ. Let $N(s)$ denote the total number of workers of firm s, of which $N(s)-1$ are employed workers. The endogenous probability of becoming a managerial worker in firm s, position l, is therefore $q(s,l) = \delta \frac{x_l(s)dG(s)}{\int_{s\geq\bar{z}}\left[N(s)-1-(1-\delta)\sum_{l=2}^{L(s)} x_l(s)\right]dG(s)}$. It is given by the mass of managerial posts (s,l) divided by the searching individuals, which are incumbent production workers and displaced managerial workers. Combining this with $V(s,l)$ from (2.4) gives

$$(1-\beta)V^{lm} = w + \frac{\delta \int_{s\geq\bar{z}} \sum_{l=2}^{L(s)} \left([\beta(1-\delta)]\, aw + (1-\lambda)\frac{y(s)}{x_l(s)}\left(1-[\beta(1-\delta)]\right)\right) x_l(s)dG(s)}{\int_{s\geq\bar{z}}\left([1-\beta(1-\delta)][N(s)-1] + \delta\beta(1-\delta)\sum_{l=2}^{L(s)} x_l(s)\right) dG(s)}.$$

[9] Here I assume that firms are under the constraint of preventing stealing. Consider the alternative, in which middle managers steal and there is no compensation. The cost of the managerial layer l is then $wx_l(z)+(1-\lambda)y(z)$ which ought to be compared to $w(1+a[\beta(1-\delta)])x_l + [1-(1-\lambda)(1-[\beta(1-\delta)])]y(z)$. Compensation is therefore profit-maximizing as long as $(1-\lambda)\frac{y(z)}{x_l(z)} \geq aw$. In fact, in all the calibrations and simulations presented below this condition holds for all firms and all mangerial layers.

Finally, substituting in $a \equiv \frac{1-\beta}{w} V^{lm} - 1$, the expected period value of entering the labor market is $V^{lm} = \frac{w}{1-\beta}(1+a)$ where

$$a = \frac{(1-\lambda)\delta}{w} \frac{\int_{s \geq \bar{z}} [L(s) - 1]\, y(z)\, dG(s)}{\int_{s \geq \bar{z}} \left[N(s) - 1 - (1-\delta)\sum_{l=2}^{L(s)} x_l(s)\right] dG(s)} \geq 0. \tag{2.6}$$

The labor market premium a is equal to the total economy-wide revenue that can potentially be expropriated by middle managers, weighted by the probability of a managerial re-shuffle, and divided by the number of employees in the economy. Note that the premium a is equal to 0 for the extreme cases where stealing is not possible ($\lambda = 1$) and/or where workers do not switch firms and where managerial workers hence face no opportunity cost in remaining with a given employer ($\delta = 0$) and/or when there are no firms with a positive mass of middle managers, $L(s) = 1$, $\forall z$. Otherwise, the value of a is strictly positive because managerial workers earn rents over and above the market wage. Notice also that in the partial equilibrium (i.e. for a given value of the wage w) an economy with a low value of λ is one where entering the labor market is relatively more interesting as opposed to running a firm. Finally, while property protection (λ) has a direct negative impact on a, in the general equilibrium that relation may be overturned by an indirect effect. As will be shown, λ is also likely to positively impact the optimal number of layers $L(s)$, which implies that there is more scope for rents in the labor market, pushing up the labor market premium.

Organizational choice

Each firm's optimal organizational pattern depends on its relative productivity z/w, the relative premium of entering the labor market a, and the institutional parameter λ. Here I summarize the most relevant choice variables. All computations and proofs are relegated to the Appendix.

Proposition 4 *The optimal level of managerial layers $L(z/w, a; \lambda)$ is weakly increasing in z/w, weakly increasing in λ and weakly decreasing in a.*
Proof. *See the Appendix.* ■

Adding a managerial layer boosts production if and only if the additional layer of middle management employs a minimum amount of workers (i.e. $x_l > 1$). In fact, the choice of adding an additional layer can be understood as increasing production enough to overcome a simulateneous decrease in the profit share. Only firms with a sufficiently large relative efficiency z/w choose to do so. Also, it is obvious that an increase in the parameter λ renders the addition of another layer more attractive as each layer needs to obtain a lower compensation. Finally, a decrease in the the wage premium a also encourages firms to add more layers as additional managerial workers are less costly to compensate for not stealing. As argued above, the relation between a and λ is not clear. If we suppose that it is of second-order importance (as suggested by all simulations with reasonable parameter values), then the Proposition above states that all else equal, firms in countries with poor property protection are likely to have relatively few managerial layers. In this sense, there is misallocation in the degree of delegation.

Proposition 5 *The ratio of employed managerial workers to employed production workers is weakly increasing in $L(z/w, a; \lambda)$ and weakly decreasing in a.*
Proof. *See the Appendix.* ■

Notice that this Proposition only refers to *employed* workers. The overall ratio of managerial to production workers depends also on the entrepreneur's activity, but this naturally wanes in importance for firms that have a large number of workers. Ignoring the weight of the entrepreneurs and assuming again that the movement in a is of second-order importance, the Proposition suggests that countries with a low degree of property protection have relatively few managerial workers. This is the key relationship in the model that I exploit to infer the value of λ across countries.

2.4.2 Stationary equilibrium definition

The stationary equilibrium is a list of firm managerial layers $L(z)$, output $y(z)$, production workers $n(z)$, managerial workers $x_l(z)$, total employees $N(z)$, profits $\pi(z)$, managerial markups $m_l(z)$ and consumption $c(z)$, $\forall z \in Z, \forall l \in \{1, 2, ..., L(z)\}$; the value functions $V(z)$, $V(z,l)$, $V^{out}(z,l)$, V^n, and V^{lm}, $\forall l \in \{1, 2, ..., L(z)\}$; a wage w, the probability of becoming a manager in firm z in position l, $q(z,l)$,$\forall z \in Z$, $\forall l \in \{2, 3, ..., L(z)\}$, a labor market premium a, a cutoff producivity $\overline{z}$ and a lump-sum transfer T such that:

i) all firms solve their profit maximization problem;

ii) all agents solve their occupational problem;

iii) $V(z,l) = \frac{(1+[\beta(1-\delta)]a)w+(1-\lambda)\frac{y(z)}{x_l(z)}(1-[\beta(1-\delta)])+\beta\delta V^{lm}}{1-\beta(1-\delta)}$, $\forall z \in Z, \forall l \in \{2, 3, ..., L(z)\}$;

iii) $V(z) = \max\left\{V(z,1), V^{lm}\right\} = \max\left\{\frac{\pi(z)}{1-\beta}, V^{lm}\right\}$, $\forall z \in Z$;

iv) $q(z,l) = \delta \frac{x_l(z)dG(z)}{\int_{z\geq\overline{z}}\left[N(z)-1-(1-\delta)\sum_{l=2}^{L(z)} x_l(z)\right]dG(z)}$;

v) $\overline{z}$ is such that $V(\overline{z},l) = V^{lm}$

vi) $V^{lm} = \frac{1}{1-\beta}(1+a)\,w$ where

$$a = \frac{(1-\lambda)\delta}{w}\frac{\int_{z\geq\overline{z}}[L(z)-1]\,y(z)\,dG(z)}{\int_{z\geq\overline{z}}\left[N(z)-1-(1-\delta)\sum_{l=2}^{L(z)} x_l(z)\right]dG(z)};$$

vii) feasibility reads $\int_{z>\overline{z}} y(z)\frac{dG(z)}{1-G(\overline{z})} = \int_z c(z)dG(z)$;

viii) the labor market clears, i.e.

$$\int_{z>\overline{z}}\left(n(z)+\sum_{l=1}^{L} x_l(z)\right)\frac{dG(z)}{1-G(\overline{z})} = 1.$$

ix) all fixed costs are rebated lump-sum to the agents, i.e.

$$\int_{z>\overline{z}}^{z^{se}} \kappa^{se}\frac{dG(z)}{1-G(\overline{z})} + \int_{z>z^{se}} \kappa^{ef}\frac{dG(z)}{1-G(\overline{z})} = T,$$

with z^{se} being the productivity cutoff for the self-employed.

2.5 Empirical results

2.5.1 Calibration procedure

The calibration proceeds as follows. I first choose the time period to be year, under the assumpiton that this is the time that firms need to discover wrongdoings per managerial layer. This can be defended on the grounds that the diagnosis of the firm's performance and the analysis of necessary adjustements are medium-term projects. I hence choose the discount factor to be $\beta = 0.95$. I set the exogenous separation rate δ to 0.152 so that $1/\delta$ equals the average US job tenure, which was about 6.6 years in the nineties 1997 according to Auer, Berg and Coulibaly (2005). As the calibration is obviously quite sensitive to the notion of a time period I later analyze the sensitivity of the model to other values. Second, I fix the distribution $G(z)$

paramater	value	target	data	model
Discount factor (β)	0.950	Interest rate	0.050	-
Separation rate (δ)	0.152	Avg job tenure	6.600	-
Std deviation of $\log z$ (σ)	1.081	Pareto tail of firm CDF	-1.060	-1.103
Largest efficiency (z_{max})	5.916	Largest firm	2 mil.	2 mil.
Expropriation (λ)	0.483	Emp share large firms	0.254	0.264
Managerial share (γ)	0.276	Share of managers	0.350	0.366
Communication cost (θ)	0.465	Profit share firms	0.150	0.150
Fixed cost employer firms (κ^{ef})	1.062	Average firm size	20.40	20.24
Fixed cost self-employed (κ^{se})	0.290	Share of self-employed	0.070	0.071

Table 2.2: Benchmark calibration

to be log-normal such that $\log z \sim \mathcal{N}(0,\sigma^2)$ on the support $[0, z_{max}]$. This leaves 7 parameters (σ, z_{max}, λ, θ, σ, κ^{ef} and κ^{se}), which I choose jointly to minimize the sum of the quadratic discrepancy of 7 model moments from their empirical counterparts for the U.S. around 2005. Notice that in the absence of the possibility to add managerial layers, the firm size distribution in terms of the number of workers would directly inherit the properties of z and therefore feature a thin tail, which is at odds with the evidence according to which the right tail of the US firm size distribution closely follows a Pareto distribution. The possibility of adding layers, however, implies that firms can dampen the decreasing returns to scale, which thickens the right tail of the distribution. According to Luttmer (2007) the proportion of firms with more than n employees approximately equals $n^{-1.06}$. To match this I regress the log of the inverse distribution of firms from 100 workers onward on the log of firm size to back out the slope. If the distribution was perfectly Pareto, this statistic should ideally equal -1.06. Since the right side of the distribution has thicker tails the higher is λ and the higher is the dispersion of the distribution σ, these two parameters are key in matching the right tail, together with the highest efficiency level z_{max}. To discipline the resulting distribution I require that firms with more than 10,000 employees account for about 25.4 percent of employment (US Business Census (2011)) and that the largest firm (Walmart) employs about 2 mio. workers.

Next, the parameters γ and θ are crucial determinants of the firms' returns to scale. I require that the average profit share of business firms (all firms that are not own-account workers) to roughly match 0.15, which is the computed US residual share not accruing to labor and physical capital as summarized by Atkeson and Kehoe (2005). At the same time, the model also ought to match the overall share of managerial workers in the US economy, which is about 0.35 according to the ILO data presented in section 2. Finally, the average size of business firms and the share of own-account workers in the economy is principally determined by κ^{ef} and κ^{se}. The corresponding moments to match from the US economy are 20.4 (US Business Census (2011)) and 0.07 (Bureau of Labor Statistics (2011)). The resulting parameters are summarized in Table (2.2).

2.5.2 Model outcome

Figure (2.2) summarizes the main firm characteristics in equilibrium as a function of firm size. First, notice how firm size is related to the firm-specific efficiency level. In a standard

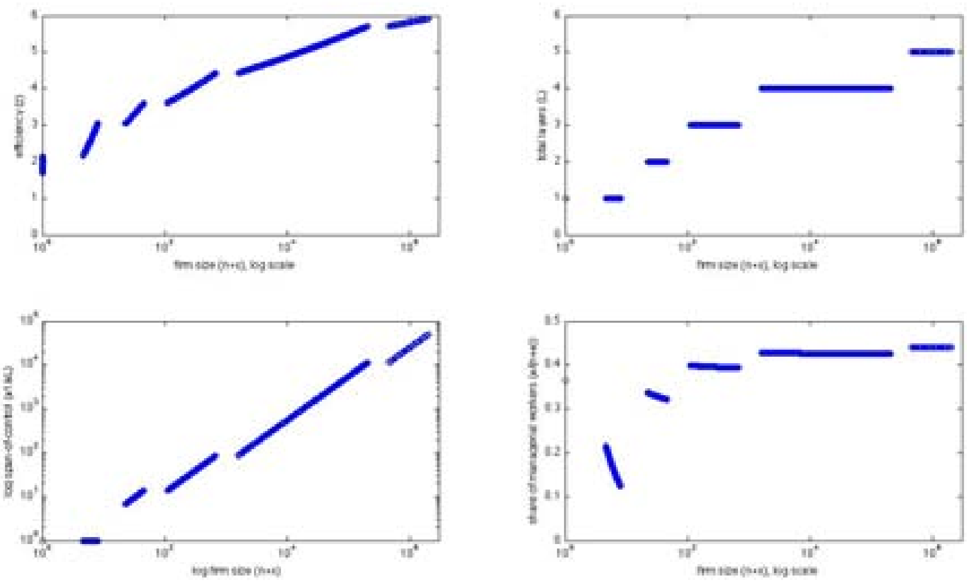

Figure 2.2: Equilibrium implications: model-specific statistics

model of heterogenous firms with decreasing returns to scale in labor, the plot in the left upper panel would typically be a straight upward sloping line. Here, the possibility for the firm to mitigate decreasing returns to scale implies that the plot is a succession of upward sloping lines whose slope is decreasing in each managerial layer. It reflects that a unit increase in efficiency z at high levels of z is associated with a larger percentage increase in labor than a unit change at low levels of z as labor can be leveraged more with a longer chain-of-command. The associated relation between the optimal number of layers and firm size is traced in the upper right panel. At the benchmark calibration, the longest hierarchy has 5 layers. The choice of layers seems roughly in accordance with a spatial interpretation of a hierachy. Small firms are constrained by management at about 10 workers (say, a team). The next jumps occur at roughly 50 (a department), 800 (a production unit) and 200,000 workers (a conglomerate).

The lower left panel depicts the span-of-control, which is defined as the sum of managerial workers in the first managerial layer per top manager. Finally, the last subplot traces the managerial ratio. For own-account workers it is just the time spent solving problems.[10] For small firms the ratio is decreasing as the number of managers is constrained (consisting only of the entrepreneur himself) while the number of production workers is unlimited. As firms increase layers, the ratio of employed managers to production workers increases. For a given layer, the ratio is slightly downward sloping as the entrepreneur himself represents one more manager.

The next four graphs in Figure (2.3) plot equilibrium characteristics that be quite readily compared to their counterparts in the data. The first subplot depicts productivity, which takes a U-shaped form. The jumps from self-employment to a single-layer employment firm and then on a multi-layer firm are associated with productivity losses. These major changes in the firm structure demand high fixed cost outlays in terms of additional workers, akin to an overhead labor cost. Multi-layer firms, on the other hand, see their productivity increase with each addi-

[10]Another natural interpretation is that own-account workers specialize in either production work or managerial work (a typical example of the latter being independent professional workers). In this sense the above managerial ratio can simply by viewed as the proportion of aggregate workers specializing in managerial tasks.

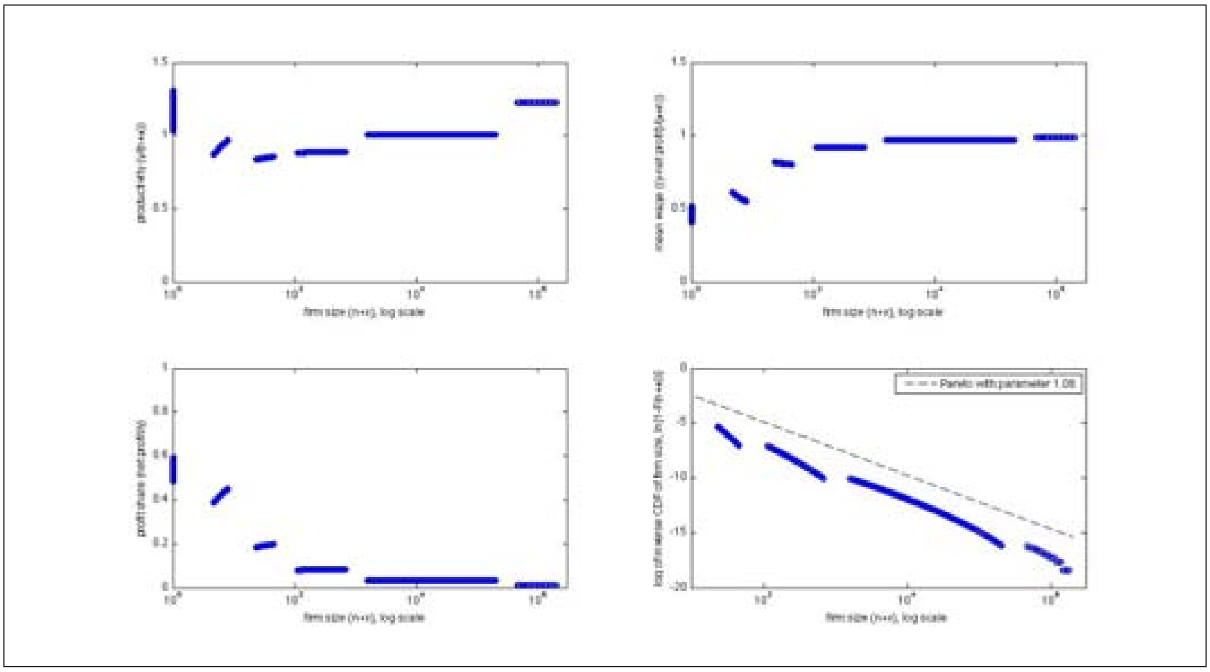

Figure 2.3: Equilibrium implications - observables

tional layer as the changes in the structure are used to increase the leverage of the entrepreneur's project. The fact that over the most relevant part of the support there is a positive correlation between productivity and firm size is arguably a realistic feature of the present model, as opposed to standard models where productivity across firms is flat.[11] Furthermore, as depicted in upper right panel, the model predicts that the average wage increases with firm-size. This is consistent with a large body of evidence from the US according to which larger firms indeed pay higher wages than their less productive peers (see for instance Idson and Oi (1999)).

Another property of the model is that the profit share is decreasing, as can be observed in the lower left panel. Hard evidence on this is hard to come by, given that profits here are rents on organizational capital rather than physical capital. Finally, the last panel plots the firms size distribution as well as a line with the approximate slope of the US size distribution of firms with more than 100 employees. Though the slope parameter is targeted in the calibration *on average*, there could still be large deviations from the Pareto distribution around that average. But that departure does not seem particularly strong so that the model is rather consistent with a thick-tailed distribution, except at the very end of the distribution where firm growth seems size dependent.

2.5.3 Simulations

We are now ready to measure the impact of changes in the degree of property protection on several variables of interest.

Individual firms

To make the changes clear, I first analyze how firms vary their optimal choice in response to changes in λ from its benchmark value of 0.483 to the halving of that value to 0.282 and to 0, respectively.

[11]See Bartelsman, Haltiwanger and Scarpetta (2011) on the disperion of labor productivity. Also, Syverson (2011) offers a comprehensive review of the literature on multi-factor productivity dispersion.

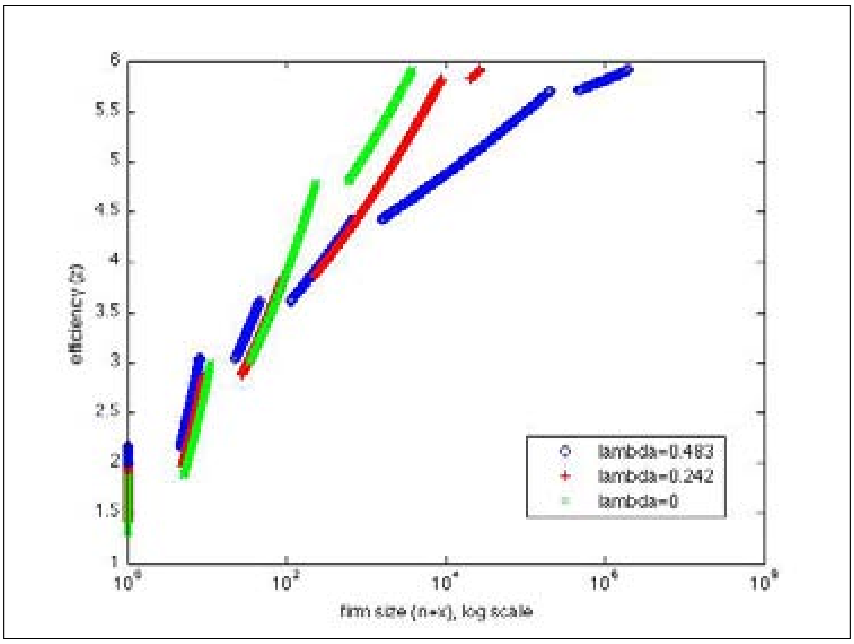

Figure 2.4: Efficiency

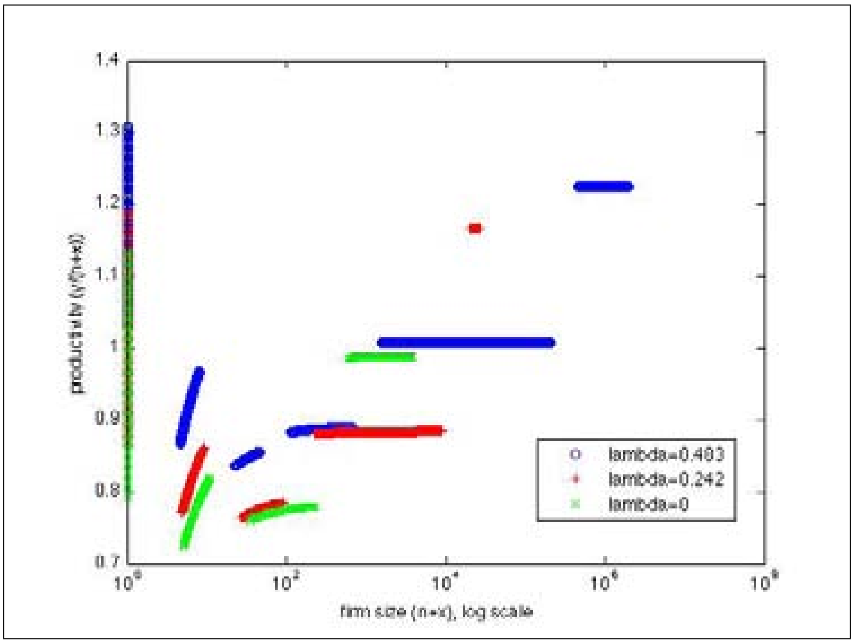

Figure 2.5: Productivity

From Figure (2.4) it is immediately evident that the worsening of property protection induces firms to be smaller. In particular, very efficient firms are reluctant to invest in additional managerial layers and hence cannot leverage their efficiency to the extent similar firms can do in an environment characterized by a high λ. It is also clear from the graph that firms of similar size in the three scenarios have shorter hierarchies the worse is property protection. This can be viewed as a direct model counterpart of the notion that the delegation of decision-making in poor countries is low.

Next, Figure (2.5) shows how productivity moves across the different environments. Inter-

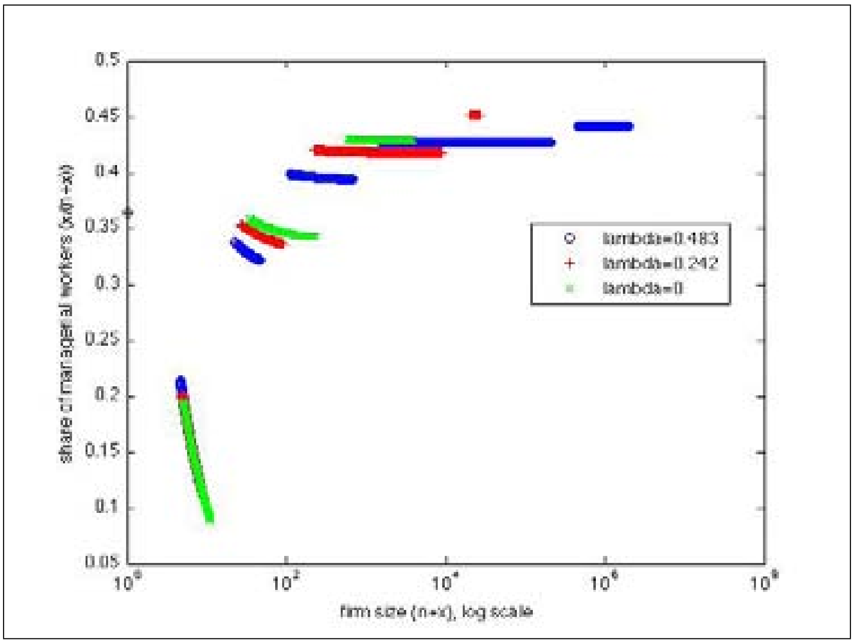

Figure 2.6: Proportion of managerial workers

estingly, note that both the largest as well as small single-layer firms tend to be more productive in countries with more property protection. On the one hand this reflects that the most efficient firms can scale up in such an environment, on the other hand it means that the smallest firms tend to have higher intrinsic efficiency levels as there are fewer operating firms given that wages are higher.

Another key variable of interest is the composition of occupations across firms. From Figure (2.6) we have that for a given firm size, firms in the more adverse environment do *not* have a lower managerial share. In fact, the share is higher because the labor market premium a drops with a decline in λ, making managerial workers relatively less costly *given* a particular hierachy length. If the managerial share in the aggregate decreases, it must be because of a composition effect. This consists of the fact that firms in the low λ economy have shorter hierarchies, and the fact that there is a large mass of firms willing to circumvent agency issues by operating with a single managerial layer. The fact that these firms are more prevalent in the adverse environment is visible from Figure (2.7). Note that lower levels of λ translate into a significantly thinner (and shorter) tail of the firm size distriution.

Aggregate economy

The effect of the institutional paramater λ on the aggregate economy is summarized in Figure (2.8), where λ varies between 0 and its benchmark value.

Aggregate productivity, the actual variable of interest in the present paper, is depicted in the upper left panel. Passing from the US level of property protection to no protection is associated with a productivity loss of about 18 percent. It is also apparent that the loss is more sensitive to changes at higher levels of λ. As explained in the first Section, the estimation results explaining the managerial share suggest that the lowest possible managerial share of 0.255 is associated with countries that have income levels at around 10 percent of the US.[12]

[12] In fact, using column 4 from Table 1, it results that using the coefficient for the constant (0.015) an income level of 0.0865 of the US is required to generate a managerial share of 0.255, while income levels of 0.125 of the US match the managerial share of 0.255 in absence of the constant.

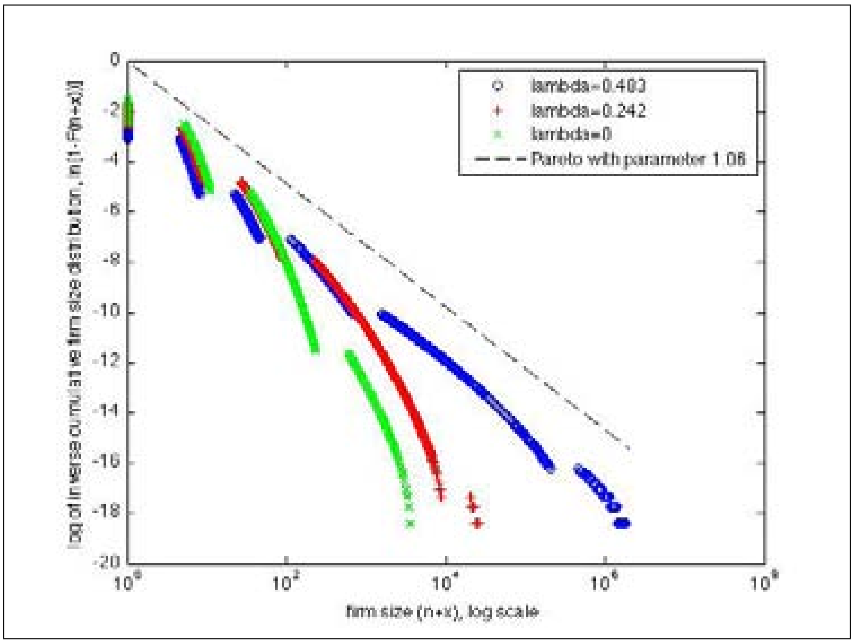

Figure 2.7: Firm size distribution

The lower two panels of Figure (2.8) offer some evidence to believe that the simulated economy of λ could well represent a country with income levels of about a tenth the US. We have that the average employer firm size decreases in the most adverse economic environment by roughly one-half, to about 10 workers. This is very much in line with evidence on firm size in countries that have income levels of about a tenth of the US, as shown in Tybout (2000). Also, the level of self-employment increases strongly, for which there is also ample support, as in Gollin (2008).

Finally, Figure (2.9) offers additional qualitative support for the model. It shows the coefficient of variation of two variables. The first is firm labor productivity (output by the number of workers) and The first plot relates to different contractual environments the coefficient of variation of an underying firm-specific efficiency generated from a simple Lucas span-of-control model. It is measured as a residual from $\hat{z} = \dfrac{y(z)}{(n(z)+x(z))^{0.85}}$ where y and $n + x$ are simulated firm-specific production and employment levels. (If the model was correct, $\hat{z}$ would thus be degenerate). Note that as contracual enforcement worsens, the underlying efficiency becomes more dispersed. This is similar to increase in dispersion of that variable that Hsieh and Klenow (2009) observe for India and China compared to US. It is also consistent with the existence of a dispersion in generic tax wedges as modeld by Restuccia and Rogerson (2008). As for the second plot, it measures the covariance between employer firm size and productivity. Note that as contractual enforcement worsens, the covariance drops significantly and for lower values fluctuates around 0. This is exactly in line with the findings of Bartelsman, Haltwanger and Scarpetta (2009) who show that this covariance is strongly positive in the US while it drops to slightly negative values in poorer Eastern European countries.

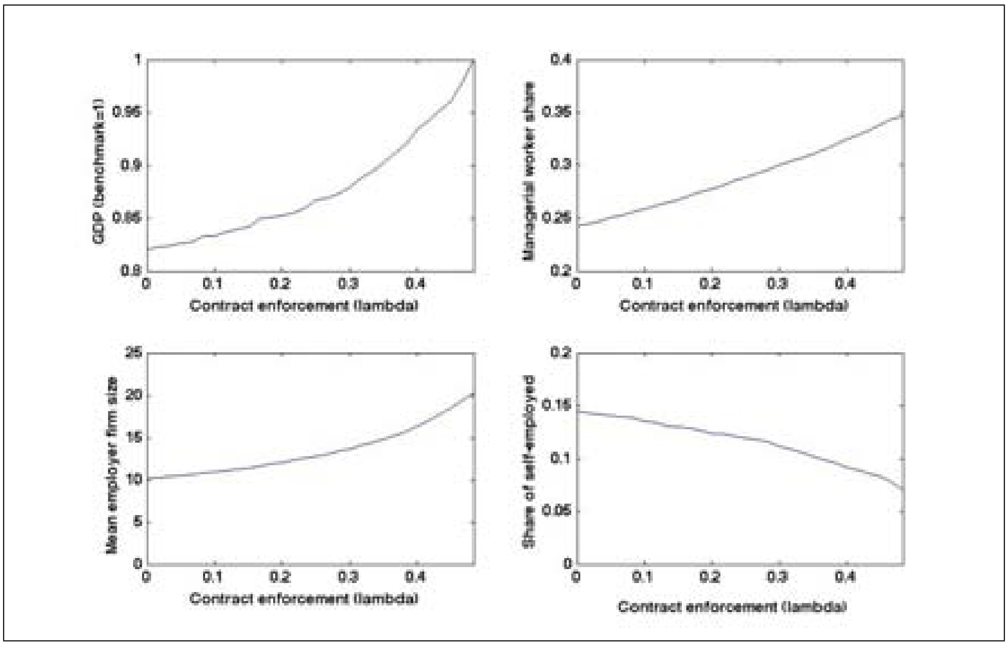

Figure 2.8: Property protection and aggregate statistics

2.6 Concluding remarks

This paper proposes a tractable model to address the technological benefits of delegation in large organizations. Adding additional layers increases the span of control of the entrepreneur, but is associated with a fixed cost. Besides, adding an addtional layer is associated with an extra cost that increases with the lack of property protection as middle managers can steal from the firm they work for. The threat of expropriation affects the firm's organization choice, which consists of the number of managerial layers as well as the number of managerial and production workers. The calibrated version of the model predicts that countries with poor contract enforcement have smaller firms on average and more self-employed workers as firms are reluctant to add layers to their managerial structure. Importantly, an environment with no property protection generates a 10 percentage points fall in the aggregate share of managerial workers, which is a value associated with countries with one-tenth of US GDP per capita. The model predicts an associated drop in the aggregate labor productivity of 18 percent. This result is not trivial given that the productivity drop only concerns the non-agricultural sector and given that it represents a pure TFP loss.

The paper offers several extensions worth pursuing. One of them is the introduction of the choice of human capital on the part of the workers in conjunction with the assumption that managerial workers are the only workers making use of human capital. Intuitively, in an environment in which the probability of becoming a managerial worker is low, workers ought to have a reduced incentive ex ante to invest in human capital. Such an outcome would be consistent with the data discussed in the regression results. It could possibly also increase the productivity loss associated with low property protection. Another potentially fruitful extension involves modeling the entrepreneur's stock of trustworthy relations, i.e. the number of middle managers that he can hire without the need for extra compensation. If entrepreneurs were different along this additional characteristic, then misallocation could occur via an extra channel, namely the possibility that incompetent but well-connected enrepreneurs would suboptimally drain too much labor from the labor market. This would parallel the literature on credit con-

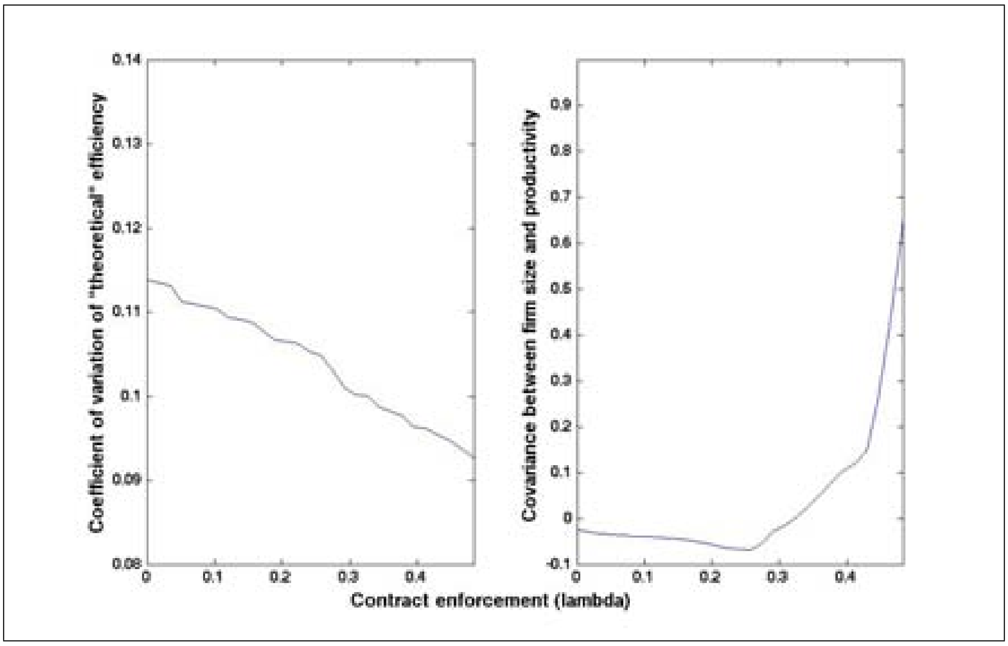

Figure 2.9: Dispersion in labor productivity and theoretical efficiency

straints where the entrepreneur's wealth is typically an important determinant on how much he can borrow. Finally, the addition of physical capital and credit constraints would allow to analyze the relative quantitative importance of firms' external versus internal constraints.

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2.8 Appendix

2.8.1 Computations

The optimizing behavior of firms with multiple layers ($L \geq 2$) involves the following first order conditions with respect to (2.5):

$$n = \left[\frac{1-\theta-\gamma}{1-\theta} \left[1 - (1-\lambda)(L-1)(1-[\beta(1-\delta)]) \right] \frac{z}{w} \prod_{l=2}^{L} x_l^{\gamma\theta^{L-l}} \right]^{\frac{1-\theta}{\gamma}},$$

$$\frac{x_L}{n} = \frac{\gamma(1-\theta)}{1-\theta-\gamma} \frac{1}{(1+a[\beta(1-\delta)])} \tag{2.7}$$

and, for $L \geq 3$

$$\frac{x_l}{x_L} = \theta^{L-l}, \forall l \in \{2, ..., L\}.$$

The sum of employed managerial workers (excluding the entrepreneur) $x \equiv \sum_{l=1}^{L-1} x_l$ as a function of production labor is

$$x = \frac{\gamma}{1-\theta-\gamma} \frac{\left(1-\theta^{L-1}\right)}{(1+a[\beta(1-\delta)])} n.$$

Production labor demand equals

$$\begin{aligned} n &= \left(\frac{\gamma(1-\theta)}{1-\theta-\gamma} \frac{1}{(1+a[\beta(1-\delta)])} \right)^{\frac{1-\theta^{L-1}}{\theta^{L-1}}} \\ &\quad \left[\frac{1-\theta-\gamma}{1-\theta} \left[1-(1-\lambda)(L-1)(1-[\beta(1-\delta)]) \right] \frac{z}{w} \theta^{\gamma \sum_{l=1}^{L-2} l\theta^l} \right]^{\frac{1-\theta}{\gamma\theta^{L-1}}}. \end{aligned} \tag{2.8}$$

Production equals

$$y = \frac{1-\theta}{1-\theta-\gamma} \frac{w}{[1-(1-\lambda)(L-1)(1-[\beta(1-\delta)])]} n$$

and gross profits relative to the wage level are given by

$$\begin{aligned} \frac{\pi^{ml}+\kappa^{bf}}{w} &= \frac{\gamma\theta^{L-1}}{1-\theta-\gamma} n \\ &= \theta^{L-1} \frac{(1+a[\beta(1-\delta)])}{1-\theta} \left[\Xi \frac{z}{w} \theta^{\gamma \sum_{l=1}^{L-1}(l-1)\theta^{l-1}} \right]^{\frac{1-\theta}{\gamma\theta^{L-1}}} \end{aligned} \tag{2.9}$$

where

$$\begin{aligned} \Xi &\equiv \gamma^{\frac{\gamma}{1-\theta}} \left(\frac{1-\theta-\gamma}{1-\theta} \right)^{\frac{1-\theta-\gamma}{1-\theta}} \left(\frac{1}{(1+a[\beta(1-\delta)])} \right)^{\frac{\gamma}{1-\theta}} \\ &\quad [1-(1-\lambda)(L-1)(1-[\beta(1-\delta)])] \\ &\in (0,1) \end{aligned}$$

We also have that the gross profit ratio equals

$$\frac{\pi^{ml}+\kappa^{bf}}{y} = \frac{\gamma\theta^{L-1}}{1-\theta} [1-(1-\lambda)(L-1)(1-[\beta(1-\delta)])]$$

2.8.2 Proofs

Proposition 1:

Consider the profit function (2.9). The condition that $\pi_{L+1} \geq \pi_L, \forall L \geq 2$ is given by

$$\frac{z}{w} [1-(1-\lambda)(L-1)(1-[\beta(1-\delta)])] \frac{1-\theta-\gamma}{1-\theta} \left(\frac{1-\theta}{(1-\theta-\gamma)[1+a\beta(1-\delta)]} \right)^{\gamma(1-\theta)} \geq \frac{1}{\theta^{1-\theta^L(1-\theta)}}.$$

It follows that for each level of $\frac{z}{w}$ there exists an optimal finite level of L, with L being weakly increasing in $\frac{z}{w}$. It is also immediate that L is increasing in λ and decreasing in a.

Proposition 2:

Single-layer firms do not have any emloyed managerial workers. Multi-layer firms have a ratio between employed managerial and production workers equal to $\frac{\gamma}{1-\theta-\gamma} \frac{\left(1-\theta^{L(z/w,a;\lambda)-1}\right)}{(1+a[\beta(1-\delta)])}$.

Chapter 3

PROGRESSIVE INCOME TAXATION AND AGGREGATE PRODUCTIVITY

3.1 Introduction

The purpose of this chapter is to investigate the link between progressive labor taxation and aggregate productivity.[1] Our focus is on the implications of labor tax progressivity on (i) the decision margin between working as a production worker and working as a manager and (ii) the manager's decision margin on whether to invest in his firm.

As documented in more detail in the following section this analysis is motivated by three phenomena that have been occurring over the last two to three decades in the developed world. First, the highest marginal labor taxes have been decreasing strongly in most developed countries, in particular in English-speaking ones and most notably in the US. Second, income inequality has been rising over the same time period, with the highest top percent income earners gaining an increasingly large share of aggregate income. While income inequality has been increasing in most countries (see e.g. Krueger, Perri, Pistaferri and Violante (2010) as well as references therein), the trend toward an ever stronger concentration of income has been most salient in the US. Third, starting with the mid-nineties European countries have seen their labor productivity gap to the US open up once again after decades of catching-up.

We would like to argue that these three phenomena are linked in the following way. The dramatic fall in marginal income taxes prompted the most able workers - managers - to search more intensively for better matches with suitable firms. Once matched, lower labor taxes also made it more lucrative to improve the match with the firm. The intuition for this is simple. If projects are risky then lowering the labor tax progressivity decompresses the distribution of outcomes. Given that returns are bounded by zero on the downside, but are potentially infinite on the upside, risky projects are more likely to be undertaken.[2] As a consequence the quality of the best matches improved, resulting both in aggregate labor productivity but also in increased (gross) income inequality since most of the benefits accrue to the most talented managers.

To test this hypothesis empirically we construct a model that features agents who are heterogenous in their human capital endowment. Agents can choose whether to be workers or run their own firm by becoming managers. To become managers, however, they need to find a suitable project. Projects are supplied by firms who bargain with the manager over the surplus of the match, just as in the canonical Diamond-Mortensen-Pissarides search and matching

[1]This is joint work with Tomaz Cajner, Universitat Pompeu Fabra.

[2]Importantly, we base our analysis on the assumption that individuals are risk neutral or equivalently able to insure against risk.

model.[3] The manager-firm pair, when matched, subsequently jointly decide whether to invest in the firm's technology. The role of the government is to levey a progressive labor income tax and distribute the proceeds in a lump-sum fashion.

We parameterize the model to some of the more relevant features of the US economy under the assumption of a flat-tax regime coupled with a general allowance. This allows to gauge the effect of decreasing the top marginal income tax from 0.7 percent to 0.4 percent. We find that the results depend crucially on the bargaining mechanism used. Our preferred regime - Nash bargaining - offers predictions that are qualitatively in line with the three phenomena mentioned above - (gross) income inequality rises and aggregate labor productivity jumps up. Quantitatively, however, the effects on inequality are tiny and rather small - an increase of about half a percent - on aggregate productivity.

The existing literature has studied labor taxation from various perspectives. The positive analysis has focused on two main channels of tax effects on economic outcomes. First, several researchers argued that taxes distort labor supply decisions (Mirrless (1971), Prescott (2004), Conesa and Krueger (2006)).[4] Note that while it seems intuitive that labor income taxes decrease hours worked and hence aggregate production, it is less straightforward to argue that they depress aggregate productivity as the marginal hours forgone are likely to be less productive than inframarginal ones.

Second, there is ample empirical evidence that taxes affect reported taxable income, for example due to tax avoidance (see Saez, Slemrod and Giertz (2012) for a review of this evidence). In addition, Piketty, Saez and Stantcheva (2012) have recently emphasized a third channel, namely a bargaining channel, according to which top earners will be excessively involved in bargaining and rent-seeking activities when taxes are relatively low. Here, we are able to explicitly derive the effect of labor taxes (and their progressivity) on the managerial surplus share.

The following section presents the empirical motivation. It is followed by the model environment, the description of the stationary equilibrium and the empirical application. The final section concludes.

3.2 Evidence

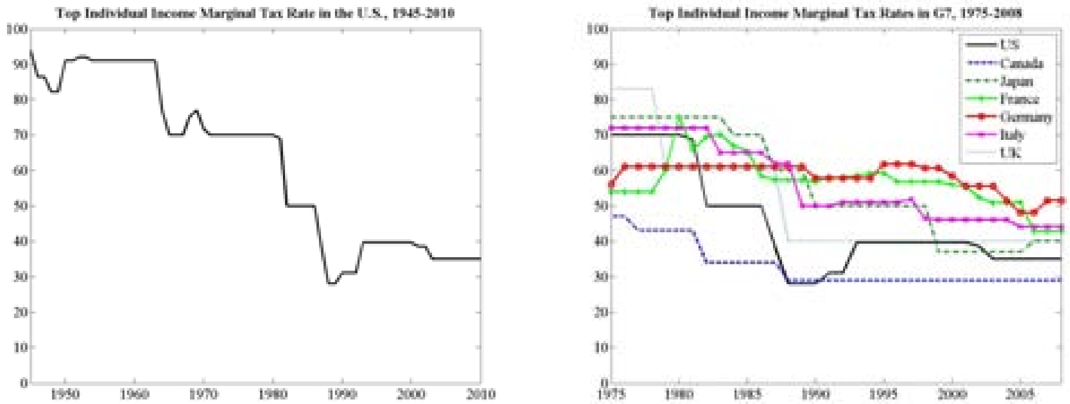
3.2.1 Tax Progressivity

Historically, one of the most customary ways for governments to achieve their redistributive aims was through progressive taxation. However, the progressivity of the tax code has diminished substantially over the past decades, and especially so in Anglo-Saxon countries. Panel A of Figure 3.1 illustrates the dramatic decline of top statutory individual income marginal tax rates in the US over the post-war period. In the early-1960s the top individual income marginal tax rate was 91 percent in the US, which subsequently declined to as low as 28 percent at the end of 1980s, and reached 35 percent in 2000s. Although focusing on top statutory marginal tax rates could in principle be misleading due to several exemptions and deductions in tax systems, the analysis in Piketty and Saez (2007) shows that the progressivity of the US tax code

[3] Papers on taxation in search models also include Boone and Bovenberg (2002) and Hungerbuehler, Lehmann, Parmentier, and Van der Linden (2006).

[4] An important strand of the literature also examined the optimal tax structure. Conesa, Kitao and Krueger (2009) find that the optimal capital income tax rate is 36 percent, whereas labor income should be optimally taxed with a progressive tax, roughly, a flat tax of 23 percent with a deduction of 17 percent of average household income. In this paper we abstract from capital taxation and focus exclusively on labor taxation.

undoubtedly declined since 1960.[5]



(a) Top Marginal Tax Rate - US

(b) Top Marginal Tax Rates - G7

Figure 3.1: Top Individual Income Marginal Tax Rates

Source: Tax Policy Center, Piketty, Saez and Stantcheva (2011).

The trend of decreasing tax progressivity has not been confined to the US, but instead holds broadly in all G7 countries - see Panel B of Figure 3.1. However, one important distinction between Anglo-Saxon and continental European countries is particularly striking: the progressivity of the income tax code declined relatively more in Anglo-Saxon countries over the past decades, which in turn implied that the ranking of countries in terms of tax progressivity became overturned. Whereas a few decades ago Anglo-Saxon countries like the US and the UK experienced higher tax progressivity than continental European countries, today the reverse is true.

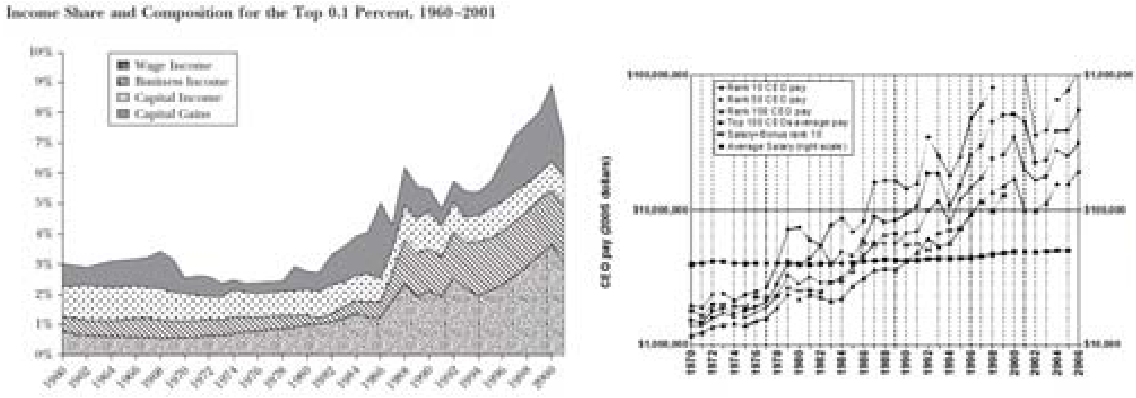
The described changes in tax progressivity seem to have affected income inequality and top income (and wage) shares (Piketty and Saez (2003) and Atkinson, Piketty and Saez (2011)). Moreover, the income composition at the top of income distribution, as evidenced in Panel A of Figure 3.2, also appears to have adjusted, possibly due to these particular tax changes. Finally, the income of CEOs in the US surged tremendously - see Panel B of Figure 3.2. This is in a sharp contrast with the evidence on the managerial pay in France: “In France, the ratio between the average wage of managers and the average wage of production workers has declined enormously in the long run (during both the 1900-1950 and the 1950-98 periods), although the top decile and top percentile wage shares have been roughly constant (the explanation for this paradox is simply that the number of managerial jobs has increased a lot)” - see Piketty (2003), footnote 43.

3.2.2 Productivity Growth

Panel A of Figure 3.3 depicts the evolution of the labor productivity level relative to the US for G7 countries from 1970 onwards. Our empirical measure of labor productivity consists of real GDP per hour worked, converted to US dollars using 2010 purchasing power parities.[6] As it emerges from the figure, Western Europe and Japan experienced a relatively rapid catch-up

[5] Piketty, Saez and Santcheva (2011) also emphasize the contribution of a drop in corporate taxes to the decline in tax progressivity.

[6] While conceptually the preferred measure of labor productivity corresponds to the GDP per hour worked, empirically this measure suffers from severe data reliability issues. In particular, the estimates of hours worked are



(a) Income Share and Composition (b) CEO's pay

Figure 3.2: Top Income in the US

Source: Piketty and Saez (2003), Piketty and Saez (2007).

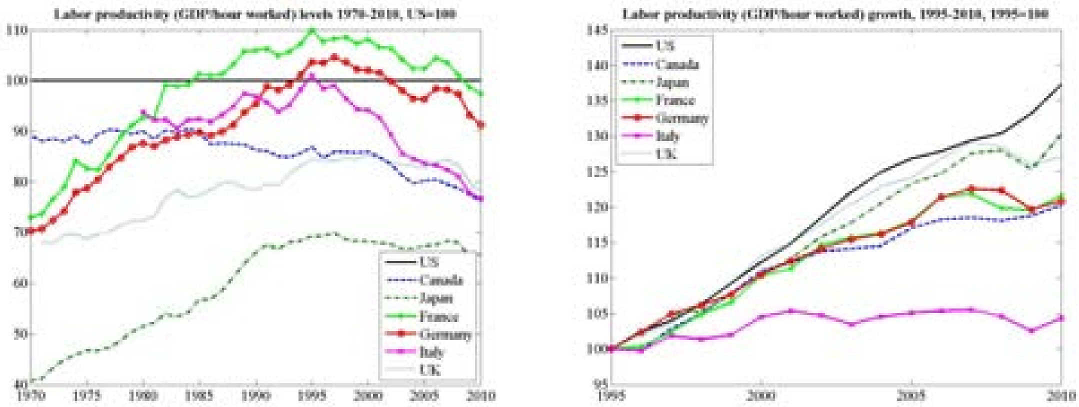
process with respect to the US up to around 1995, when this process suddenly reversed. This reversal is especially pronounced for the continental European countries (France, Germany, Italy).

Panel B of Figure 3.3 focuses on comparisons of labor productivity growth from 1995. The figure reveals that the continental Europe/US labor productivity growth gap opened considerably during the last 15 years. In the case of France and Germany, the gap in cumulative labor productivity growth versus the US over 1995-2010 amounts to more than 15 percentage points, while Italy experienced a drop in relative productivity of roughly 30 percentage points.[7] Given the short period of time, these differences are striking and imply non-negligible effects on standards of living. Interestingly, only the UK seems to have been able to keep pace with the US in terms of labor productivity growth during the recent period.

The converging-diverging productivity patterns have been extensively documented in the literature – see, e.g., van Ark, O'Mahoney, and Timmer (2008). One potential explanation for these patterns was proposed by Dew-Becker and Gordon (2008), who single out: i) the declining capital-labor ratio in Europe, and ii) the labor force composition effect as the two primary sources for these developments. A decline in the capital-labor ratio could have occurred due to European labor market policies that promoted employment growth and this could in turn lead to lower productivity. However, and as mentioned by Dew-Becker and Gordon (2008), the negative trade-off between productivity and employment growth within Europe can only be of a short-run nature. In the medium run, one should expect that capital adjustments take place through higher investments. A subsequent increase in the capital-labor ratio and in productivity growth should hence follow relatively quickly. In this paper, we are primarily interested in the medium-run productivity growth patterns and would like to explain why the European labor

obtained through different data sources in different countries, leading to systematic biases in estimated labor input. Different data sources on hours worked include labor force surveys, establishment surveys, national accounts, and administrative data. Due to the measurement issues, organizations that provide estimates of hours worked even advise not to compare levels of hours worked across countries and instead rather focus on their growth rates. The estimates of hours worked are regularly produced by the US Bureau of Labor Statistics (BLS), the Organization for Economic Cooperation and Development (OECD), and the Conference Board (CB).

[7]The higher drop in labor productivity for Italy could be related to its increased employment rate during the period under analysis, which might have involved the employment entry of less productive individuals.



(a) Productivity levels

(b) Productivity growth

Figure 3.3: Labor productivity level and growth

Source: Bureau of Labour Statistics.

productivity growth failed to recover even after a period of 15 years.[8] The second source, the labor force composition effect, stipulates that an increase in employment rate typically implies the inclusion of workers with lower skills into the labor force. This compositional change could be further amplified through the channel of immigration. In our view, this explanation can be mostly confined to Italy and even in this cases presents only part of the story.

3.2.3 Link Between Tax Progressivity and Productivity

Does tax progressivity affect in an economically significant way productivity growth patterns between countries? This question has been notoriously hard to answer, as many confounding factors inherently shape the evolution of productivity growth in different countries. For example, it is widely known that during most of the post-war period European countries exhibited a faster GDP and productivity growth than the US, which merely reflected ongoing catching-up processes. One way to abstract from catching-up growth is simply to focus on the period after 1995, since many observers noted that roughly by this year Europe managed to catch-up with the US. Another reason to focus on the period after 1995 is the fact that the whole world was subject to several technological improvements and globalization processes during the last 15 years. Some authors argued that economic policies and institutions in place might affect the behavior of an economy differently under different economic environments.

Figure 3.4 shows the correlation between a decrease in top individual marginal tax rates during period 1975-2007 and productivity growth during period 1995-2007.[9] The strong apparent negative correlation demands a closer look trough the lens of a structural model.

[8] This is not to say that there may not have been insufficient capital reallocation in Europe relative to the US over the period of interest. We would only like to argue that rigidities in the reallocation of labor in Europe are more binding, relative to the US, than rigidities in capital reallocation.

[9] Another reason for focusing on a period some years after the tax decreases actually took place is the presumed lag with which economic agents respond to tax changes. Better tax incentives surely cannot be expected to generate visible productivity increases due to better allocation of resources in a very short period of time.

Figure 3.4: Productivity Growth and Tax Progressivity

3.3 Model Environment

The economy is populated by a continuum of mass 1 of infinetely-lived individuals. These are characterized by their human capital endowment $h \in H$, drawn from a cumulative distribution $G(h)$. Agents have linear period utility in consumption which they discount at the rate β.

3.3.1 Agents and Firms

All agents start out as production workers, procuring value

$$W(h) = wh - t(wh) + \beta\left(f \int M(h,z)\,\mathrm{d}F(z) + (1-f)W(h)\right).$$

As a production worker the agent earns an efficiency wage w on his human capital, net of (non-linear) labor taxes $t(wh)$. In the subsequent period he may find a project with (endogenous) probability f that allows him to become a managerial worker with (endogenous) probability f. In this case his continuation value is denoted by $M(h,z)$, indexed by the quality of the project $z \in Z$ which is drawn from an exogenous cumulative distribution $F(z)$. In case his search for projects is unfruitful he continues to earn $W(h)$.

The value of running a firm is given by

$$\begin{aligned} M(h,z) = \max\Big\{ & W(h), w(h,z) - t[w(h,z)] \\ & + \beta\Big[(1-\delta)\big((1-I_u)\int M(h,z')\,\mathrm{d}F(z'|z, I_u = 0) \\ & + I_u \int M(h,z')\,\mathrm{d}F(z'|z, I_u = 1)\big) + \delta W(h)\Big]\Big\}. \end{aligned}$$

An agent who is given the option to run a firm can always opt to be a production worker instead. Alternatively, he earns a period managerial compensation $w(h,z)$, net of labor taxes $t[w(h,z)]$. In the subsequent period the manager continues to exercise the option to work as a manager unless the project dies, which happens at the (exogenous) hazard rate δ. Else, he reverts to being a production worker. In case the project continues, its quality is subject to evolve to z'. The associated conditional probability distribution $dF(z'|z, I_u)$ depends on whether the firm in the current period decides to update its technology ($I_u = 1$) or not ($I_u = 0$).

The firm employing the manager earns value

$$\begin{aligned}\Pi(h, z) =& \max \Big\{ 0, \pi(h, z) + \phi I_u \\ &+ \beta(1 - \delta)\big((1 - I_u) \int \Pi(h, z')\, \mathrm{d}F(z'|z, I_u = 0) \\ &+ I_u \int \Pi(h, z')\, \mathrm{d}F(z'|z, I_u = 1)\big) \Big\}.\end{aligned}$$

The firm's alternative to producing is to abandon the project and earning 0. In case of production, the firm earns period profits $\pi(h, z) = \max_e \{y(h, z, e) - we - w(h, z)\}$ where y is the production function and e is efficiency labor. The firm also decides whether to update its efficiency z at the cost ϕ expressed in units of the consumption good. Its continuation value depends on the decision to update the technology, conditional on its survival.

There is an infinite mass of potential projects or firms. We assume free entry, so that in each period the value of creating projects is 0. More precisely we assume that

$$\psi P = \beta m(N, P) \int_z \int_h \Pi(h, z)\, \mathrm{d}Q(h, 0)\, \mathrm{d}F(z).$$

P is the mass of projects created in the economy and ψ is its asssociated cost, measured in units of the consumption good. The total cost of creating projects equals the discounted expected value of project creation. The latter depends on the mass of of matches $m(N, P)$ which is a function of the amount of projects P as well as the amount of available searchers N. Project creation furthermore depends on the expected value of the project quality as well as the quality of the available (i.e. potential) managers whose (endogenous) probability function is $dQ(h, 0)$. Following the above problem of the agent we assume that the agent needs to be a current production worker (denoted by 0) so as to be able to apply for new projects. Underlying this assumption is the belief that current managerial workers are "locked" in their current firm and do not have the option to sort out new potential projects. It follows from this as well that the mass of searchers satisfies $N = \int_h \mathrm{d}Q(h, 0)$.

3.3.2 Technology

The production technology is given by $y(h, z, e) = x(h, z)e^\sigma$, $\sigma \in (0, 1)$. We assume that firms operate a technology featuring decreasing returns to scale in efficiency units of labor e. The firm's technology is fully characterized by the function $x(h, z)$. Importantly, we suppose that x is supermodular in its two arguments, which flows from the natural assumation that good projects are relatively more valuable in combination with good managers than with bad managers. Also, the firm and the manager must both provide their input for production to occur, so $x(h, 0) = h(0, z) = 0$. For simplicity we set $x(h, z) = hz$. As we assume that the labor market for production workers is competitive, the firm's optimality condition is $e(h, z) = \left(\frac{\sigma h z}{w}\right)^{\frac{1}{1-\sigma}}$ and $\pi(h, z) = \left(\frac{1-\sigma}{\sigma}\right) \left(\frac{\sigma h z}{w}\right)^{\frac{1}{1-\sigma}} w - w(h, z)$.

The technology matching projects and potential managers is given by the Cobb-Douglas function $m(N, P) = \mu N^\lambda P^{1-\lambda}$ where μ is the matching efficiency and λ the relative significance of searchers in creating a match. This implies that the firm's probability of finding a potential manager $\frac{m(N,P)}{P}$ is decreasing and convex in the mass of projects P. The probability of the production worker to become a potential manager is assumed to follow $f = \frac{m(N,P)}{N}$ and is therefore decreasing and convex in the mass of searchers N.

The government levies a progressive labor tax. We define the tax system parsimoniously as

$$t(i_l) = \max\{0, i_l - (1-\tau)(i_l^{1-\gamma}) - \tau\alpha\}$$

where i_l is the agent's period labor income ($i_l = wh$ for production workers and $i_l = w(h,z)$ for managers), $\alpha \geq 0$ is a general allowance, $\tau \geq 0$ governs the ("average") marginal tax rate and $\gamma \in [0,1]$ measures the ("marginal") progressivity of the tax system. Notice that we preclude negative taxation. In what follows we will consider separately two technologies. One is such that $\gamma = 0$ which implies a flat tax system where a higher α increases progressivity. Alternatively, by setting $\alpha = 0$, the progressivity of the tax system is increasing in the value of γ.

The technology governing the evolution of project qualities is given by the following specification. If the firm decides not to upgrade its project we simply have $F(z'|z, I_u = 0) = 1$ if $z' = z$ and $F(z'|z, I_u = 0) = 0$ if $z' \neq z$, i.e. the firm's project quality remains unchanged from one period to the other. In case of upgrading, the quality evolution is governed by

$$dF(z'|z, I_u = 1) = \begin{cases} 0 & \text{if } z' < z \\ F(z) & \text{if } z' = z \\ dF(z) & \text{if } z' > z. \end{cases}$$

Such an evolution ensures that the probability of drawing a superior project quality $z' > z$ is decreasing in the current quality z.[10]

3.3.3 Wage bargaining

As firms and managers mutually require each other to create a valuable project it is natural to posit that they bargain over the match surplus. We will experiment with two bargaining mechanisms: Nash bargaining and "Naive" bargaining. The Nash bargaining protocol determines the (gross) wage as:

$$w(h,z) = \arg\max \eta \log[M(h,z) - W(h)] + (1-\eta)\log\Pi(h,z)$$

where η is the relative bargaining power of the manager. Taking first order conditions we have:

$$\eta \frac{1 - \frac{\partial t[w(h,z)]}{\partial w(h,z)}}{M(h,z) - W(h)} - (1-\eta)\frac{1}{\Pi(h,z)} = 0. \tag{3.1}$$

The surplus of the match is defined as $S(h,z) \equiv \max\{0, M(h,z) - W(h) + \Pi(h,z)\}$. Define the match-specifc surplus share of the manager as $s(h,z) \equiv \frac{M(h,z)-W(h)}{S(h,z)}$. Using (3.1) gives

$$s(h,z) = 1 - \frac{1-\eta}{1 - \eta\frac{\partial t[w(h,z)]}{\partial w(h,z)}}. \tag{3.2}$$

In the absence of labor taxes, the surplus share of the manager simply equals his bargaining power.

Alternatively, in the Naive bargaining we simply posit that the manager's surplus share equals $s(h,z) = \eta$ in all states of the world.

[10]See Bhattacharya, Guner and Ventura (2012) for an alternative mechanism to model the trade-off of upgrading technology.

3.4 Stationary equilibium

3.4.1 Definition

Given tax policies (τ, α, γ), the stationary equilibrium consists of the value functions $W(h)$, $M(h,z)$, $J(h,z)$, $S(h,z)$, managerial wages $w(h,z)$ and profits $\pi(h,z)$, upgrading choices $I_u(h,z)$, efficiency production worker employment $e(h,z)$, production $y(h,z)$, the mass of new projects P and production workers N, a wage w per efficiency unit, a stationary cumulative distribution $Q(h,z) \cup Q(h,0)$ of employment types, and government consumption G such that:
i) agents maximize $W(h)$ and $M(h,z)$;
ii) firms maximize $\Pi(h,z)$;
iii) the labor market for production workers clears, i.e. $\int_h \int_z e(h,z)\,\mathrm{d}Q(h,z) = \int_h h\,\mathrm{d}Q(h,0)$;
iv) there is free entry of firms, i.e. $P = \beta m(N,P) \int_z \int_h \Pi(h,z)\,\mathrm{d}Q(h,0)\,\mathrm{d}F(z)$;
v) match surplus is shared according either according to Nash bargaining and the manager's share is $s(h,z) = 1 - \frac{1-\eta}{1-\eta \frac{\partial t[w(h,z)]}{\partial w(h,z)}}$ or according to Naive bargaining where $s(h,z) = \eta$;
vi) the distribution function is stationary, i.e. $Q'(h,z) = Q(h,z)$ such that $\int_h \int_z \mathrm{d}Q(h,z) + \int_h h\,\mathrm{d}Q(h,0) = 1$;
vii) government consumption equals $G = T \equiv \int_h \int_z t[w(h,z)]\,\mathrm{d}Q(h,z) + \int_h t(wh)\,\mathrm{d}Q(h,0)$.

3.4.2 Characterization of the stationary equilibrium

Given a wage w that clears the labor market for production workers and given a stationary distribution $Q(h,z) \cup Q(h,0)$ of employment types the equilibrium can be succinctly summarized by the following equations: the "tightness" of the managerial labor market $\theta \equiv \frac{P}{N}$, the surplus-splitting rule (3.2), the equilibrium surplus function

$$S(h,z) = \max\left\{0, \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma h z}{w}\right)^{\frac{1}{1-\sigma}} w - \phi I_u - wh + t(wh) - t[w(h,z)] \right.$$
$$\left. - \beta f \mathbb{E}_{z'}[s(h,z)S(h,z)] + \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[S(h,z')] \right\} \tag{3.3}$$

as well as the wage-setting rule (see Appendix):

$$w(h,z) = \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma h z}{w}\right)^{\frac{1}{1-\sigma}} w - \phi I_u$$
$$- [1 - s(h,z)]\Big[S(h,z) - \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[S(h,z')]\Big]. \tag{3.4}$$

In equilibrium there must exist managers who are willing to produce as otherwise the labor market does not clear. Since the surplus of creating a match is increasing in both h and z there exists a threshold pair ($\underline{h}$, $\underline{z}$) such that matches of the type ($h > \underline{h}$, $\underline{z}$) and ($\underline{h}$, $z > \underline{z}$) are always filled. In case the sets H and Z are bounded above, there may exist agents with a low enough h who never become managers and there may exist projects of low enough quality z such that no manager is willing to run them. Note that once a match is formed there is no endogenous separation as the quality of the project and the level of human capital never depreciate within the match. Furthermore, the evolution of the project's quality after upgrading the technology in conjuction with a bounded set Z implies that there exists a ceiling value $\bar{z}_u(h)$ following which firms are not willing to upgrade. The reason for this is that upgrading implies a fixed cost, while the benefits of a higher project quality are increasingly less likely to realize as the project quality improves since $1 - F(z)$ is decreasing in z. Notice moreover that $\bar{z}_u(h)$ is increasing in h.

From (3.2) we have that the labor tax negatively impacts the manager's share of the surplus. The reason for this, as also noted in Pissarides (1998), is that since the labor tax only affects the wage, an increase in the wage decreases the surplus while an increase in profits does not. Notice that a fully linear tax system ($\alpha = 0$, $\gamma = 1$) implies $s(h, z) = 1 - \frac{1-\eta}{1-\eta\tau}$ so that the manager's share is constant across pairs (h,z). A progressive tax system, on the other hand, implies that $\frac{\partial^2 t[w(h,z)]}{\partial^2 w(h,z)} \geq 0$ and hence increases in the surplus, which increase the managerial wage, negatively impact the manager's surplus share.

3.5 Quantitative experiment

3.5.1 Parameterization

We parameterize the model roughly to some of the more salient features of the US economy. First, let the time period be a year, so the discount factor is set to 0.95. We work with the simplifiying assumption that the US tax system is characterized by a flat tax on labor income, combined with a general allowance. This implies that $\gamma = 0$ which is arguably a strong simplication but turns out not to matter under the condition that managerial workers are concentrated among the top income earners and hence pay the highest marginal tax in all circumstances. Let the marginal tax rate be $\tau = 0.7$, in line with the US in the beginning of the 1980s and $\alpha = 1$, which in equilibrium will be consistent with workers having a general allowance of $\tau\alpha$ that exempts them from about 70 percent of the mean wage. The efficiency of the matching function is normalized to $\mu = 1$ and the matching significance of workers is set to $\lambda = 0.5$. To ensure the Hosios condition on the bargaining market we furthermore set the bargaining share of managers to $\eta = 0.5$. Decreasing returns to scale at the firm level and the exogenous death rate of firms are given by the standard parameters $\sigma = 0.85$ and $\delta = 0.1$. Next, we assume a uniform distribution for projects and a log-nogmal distribution of human capital endowment: $z \sim \mathcal{U}[0,1]$ and $\log h \sim \mathcal{N}(0,\nu_h^2)$. Without a strong prior on how updating differs from *ab initio* project creation, our stance is that they represent an equal cost: $\phi = \psi$. Notice that in this case updating is more lucrative since it is not subject to the search friction. This leaves two parameters: ϕ and ν_h^2. They are chosen jointly to roughly match two statistics: an average firm size of 20 workers, as well as the gross income share of the top 1 percent in the US, which was about 8% in the US in the beginning of the 1980s as computed by Atkinson, Piketty and Saez (2011). We look at two scenarios at a time. In the first scenario the wage is determined according to Nash bargaining. In the second scenario we use the Naive bargaining method. For this we set $\phi = 0.05$ and $\nu_h^2 = 0.30$ in the first case, and $\phi = 2$ and $\nu_h^2 = 0.37$ in the second case. In the second case we are not able to match well the income share of the top earners, but this should not matter much insofar we are concerned with the effect of the tax *change*.

3.5.2 Results

We are now ready to simulate the changes from passing to a regime of less progressive labor income taxation. Our experiment consists of changing τ to 0.4, in line with the changes that occurred in the US during the 1980s. At the same time α is adjusted downward to balance the ratio of taxes to GDP. The summary statistics of interest are summarized in Table (3.1).

Consider first the impact of the tax change in the environment with Nash bargaining. The tax change increases the share of gross income that goes to top earners, but the effect is minimal. While the net income share of the top earners evidently increases significantly, we conclude that

statistic	Nash bargaining ($\tau = 0.7$)	Nash bargaining ($\tau = 0.4$)	Naive bargaining ($\tau = 0.7$)	Naive bargaining ($\tau = 0.4$)
General allowance (α)	1	0.883	1	0.835
Tax/GDP	0.141	0.141	0.181	0.181
Gross income share 1 %	8.23%	8.25%	12.49%	11.17%
Gross income share 5 %	15.75%	15.79%	19.58%	18.28%
Gross income share 10 %	32.75%	22.78%	27.75%	26.26%
Average firm size	22.26	30.45	21.91	71.59
Wage per efficiency unit (w)	0.926	0.925	0.969	0.985
Average wage	0.999	1.000	1.071	1.081
Mass of projects (P)	1.222	1.219	0.011	0.014
GDP	1.018	1.022	1.092	1.124

Table 3.1: Simulation results

the slashing of top income tax rates cannot account for the large increase in the gross income inequality experienced over the last three decades. The average firm size in the new environment increases from about 22 to about 30 as marginal entrepreneurs prefer to work as production workers. Note that the wage per efficiency unit as well as the average wages remain practically unchanged. Importantly, however, GDP increases by about 0.5 percent. Qualitatively thus, the tax changes combined with the Nash bargaining regime are in line with the divergence in gross income inequality and productvity (which is just GDP here as all agents work) between the US and Europe over the last two to three decades. Quantitatively, though, this model is not capable of matching the data.

Next, observe the effect of the tax change in the Naive bargaining regime. Now, the gross income of the best earners decreases. The economy is populated by significantly fewer entrepreneurs as the average firm size more than triples. In the Naive bargaining regime, compared to Nash bargaining, firms stand more to gain from a decrease in the marginal tax rates as the tax burden is not shouldered entirely by the manager. This spurs the creation of more projects and can explain the large increase in the average firm size. The quality of the projects operated improves strongly as reflected in the increase in GDP, which ups by about 3 percent.

3.6 Concluding remarks

This project is an attempt to link three important macroeconomic phenomena that have been prominent over the last two to three decades: the lowering of top marginal labor income tax rates, the considerable increase in the income share of top earners, and the distinct aggregate labor productivity consequences that these may have had on Europe and the US. The mechanism developed here - tying firm creation and risk-taking to the (progressivity) of income taxes can account for the concomitant occurrrence of the three phenomena. It does not, however, come quantitatively close to match the data. We leave it to future work to extend the above argument to a richer setting - quite likely involving a life-cycle compenent coupled with human capital accumulation - to provide a better description of the data.

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3.8 Appendix

The equilibrium surplus function is obtained by plugging into the surplus function $S(h,z) \equiv \max\{0, M(h,z) - W(h) + \Pi(h,z)\}$ the Bellman values for $J(h,z)$, $W(h)$ and $M(h,z)$:

$$\begin{aligned} S(h,z) = &\max\Bigg\{0, \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma hz}{w}\right)^{\frac{1}{1-\sigma}} w - t[w(h,z)] + \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[S(h,z')] \\ &- (1-\beta)W(h) - \phi I_u\Bigg\} \end{aligned}$$

where $\left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma hz}{w}\right)^{\frac{1}{1-\sigma}} w$ is the equilibrium value of $y(h,z,e) - we(h,z)$. Using $W(h)$ again we have

$$\begin{aligned} S(h,z) = &\max\Bigg\{0, \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma hz}{w}\right)^{\frac{1}{1-\sigma}} w - \phi I_u - wh + t(wh) - t[w(h,z)] \\ &- \beta f\mathbb{E}_{z'}[s(h,z')S(h,z')] + \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[S(h,z')]\Bigg\}. \end{aligned} \tag{3.5}$$

To derive the wage equation start from (3.1):

$$\eta\left(1 - \frac{\partial t[w(h,z)]}{\partial w(h,z)}\right)\Pi(h,z) = (1-\eta)[M(h,z) - W(h)] \tag{3.6}$$

Plugging into equation (3.6) the Bellman values for $J(h,z)$, $W(h)$ and $M(h,z)$:

$$\begin{aligned} &\eta\left(1 - \frac{\partial t[w(h,z)]}{\partial w(h,z)}\right)\Bigg[\left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma hz}{w}\right)^{\frac{1}{1-\sigma}} w - w(h,z) \\ &- \phi I_u + \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[\Pi(h,z')]\Bigg] \\ =&(1-\eta)\Big[w(h,z) - t[w(h,z)] + \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[M(h,z') - W(h)] - (1-\beta)W(h)\Big] \\ =&(1-\eta)\Big[w(h,z) - t[w(h,z)] + \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[M(h,z') - W(h)] - wh + t(wh) \\ &- \beta f\mathbb{E}_{z'}[M(h,z') - W(h)]\Big] \end{aligned}$$

Using equation (3.6) again, several next-period terms cancel out and we are left with:

$$\begin{aligned} &\eta\left(1 - \frac{\partial t[w(h,z)]}{\partial w(h,z)}\right)\left[\left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma hz}{w}\right)^{\frac{1}{1-\sigma}} w - w(h,z) - \phi I_u\right] \\ =&(1-\eta)\Big[w(h,z) - t[w(h,z)] - wh + t(wh) - \beta f\mathbb{E}_{z'}[M(h,z') - W(h)]\Big] \end{aligned}$$

Re-ordering terms and using the surplus-splitting rule (3.2):

$$
\begin{aligned}
w(h,z) = {} & \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma h z}{w}\right)^{\frac{1}{1-\sigma}} w - \phi I_u \\
& - [1-s(h,z)]\Bigg[\left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma h z}{w}\right)^{\frac{1}{1-\sigma}} w - \phi I_u \\
& - wh + t(wh) - t[w(h,z)] - \beta f \mathbb{E}_{z'}[s(h,z')S(h,z)]\Bigg].
\end{aligned}
$$

Finally, using the equilibrium value of the surplus:

$$
\begin{aligned}
w(h,z) = {} & \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\sigma h z}{w}\right)^{\frac{1}{1-\sigma}} w - \phi I_u \\
& - [1-s(h,z)]\Bigg[S(h,z) - \beta(1-\delta)\mathbb{E}_{z'|z,I_u}[S(h,z')]\Bigg].
\end{aligned}
$$