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**THEORETICAL AND EMPIRICAL PERSPECTIVES ON RESOURCE
MISALLOCATION AND ITS CONSEQUENCES**

A dissertation submitted in partial satisfaction
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ECONOMICS

by

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Theoretical and Empirical Perspectives on Resource Misallocation and its Consequences

Jeffrey Hancuff

Abstract

Traditional cross-country income accounting exercises have found large portions of aggregate total factor productivity remained unexplained. This dissertation sets out to quantify how far between-sector misallocation can go in explaining these differences. In Chapter 2, I introduce a model based on Jones (2011a) whose primary components are an input-output structure, imperfect competition, sector level frictions, a Cobb-Douglas production functions with capital, labor, and intermediate factors, and an aggregate final good. I show that the wedge created by imperfect competition and frictions will be reflected by measuring markups by sector. Further, I introduce a definition of an aggregate markup which reflects not only the sector level markup, but also the markups included in input sectors. I estimate the markups by sector using instruments for international intermediate goods, domestic intermediate goods, and labor price changes, and estimate the degree to which TFP and output would change from 39 countries shifting to US levels of wedges. Developing countries have predicted increases in aggregate productivity between 0% and 27% and output increases of between 0% to 60%.

In Chapter 3, I use the model to perform hypothetical estimations how output would change if countries were to move to US levels of human capital stock per hour, capital stock per hour, sector-level productivities, sector

demand parameters, and wedges. Sector productivity, capital, and human capital levels have consistently large and positive impacts on output. Movements to US level of sectoral demand have the largest effects, but also vary the most, with some countries facing large contractions and others increasing over 1000%. Accounting for markups also provides a larger estimate of multipliers on productivity, human capital, and capital stock than had been previously found. When accounting for the multiplier effect arising from sectors' dependence on inputs, the predicted effect of capital, human capital, misallocation, and productivity explain all of the differences in income as compared to the US for most countries in the sample.

Chapter 1

Introduction

A fundamental interest of economists is identifying the determinants of income differences between countries. As Lucas (1988) wrote, “The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think about anything else.” The field has come a long way towards answering this question in both distinguishing between the deeper roots of the distribution of resources and political capital¹ as well as the economic institutions which directly affect the incentives of individuals within a country to produce and accumulate human and physical capital.²

The literature has further grown around identifying, in addition to capital and labor differences, what drives the large differences in the productivity of these two factors. Solow (1956) provided the basis for growth theory and emphasized the role of capital accumulation in determining income differences. Lucas (1988) identified

¹Acemoglu, Johnson, & Robinson (2005) provide a thorough review.

²North, 1987, North, 1989; North, 1990 provide the basis for the institutions literature; Rodrik, 2000 & Rodrik 2008 provide more recent reviews

the role of human capital accumulation in determining long-term income differences.³ However, the majority of the between country income differences still remain unexplained by these factors (Caselli, 2005).

This dissertation seeks to illuminate how accounting for the input-output structure of the economy and between-sector misallocation can help disentangle cross-country income differences.

In Chapter 2, I identify the theoretical role which wedges play in determining between-sector misallocation. I estimate these wedges using markups which may reflect both market power of firms within a sector and frictions such as corruption, taxes, insecure property rights, and capital frictions. The level of aggregate wedges, determined by the accumulated markup of both the final good and the markups of its input sectors, drive firms to limit their use of intermediate inputs from other sectors and inefficiently compensate with their own capital and labor. The variation in the aggregate wedge leads firms and consumers to consume less from sectors with high markups.

Chapter 2 continues to measure these wedges between countries, and finds a consistently higher level of these wedges in developing countries than in developed countries. It shows that aggregate wedges more closely correlate to a country's GDP per capita than the average wedge. It concludes by performing hypothetical estimates of how much aggregate output would change in 39 countries if subject to US levels of wedges.

Chapter 3 leverages these estimates of wedges to predict the effect of moving to

³More recently, Bils & Klenow (2000) and Lagakos, Moll, et al (2012) have explored further the role of human capital in development accounting.

US levels of capital, human capital, wedges, demand between sectors, and sector productivity in the context of the model. This provides several advantages over traditional growth accounting. First, it provides more accurate estimates of the true effect of increasing traditional factors such as capital, human capital, or sector-level productivity by accounting for the interdependence of sectors which create a multiplier effect. Additionally, controlling for markups and human capital yield more accurate measures of sector productivity. Finally, it can answer many policy-relevant questions: Would a country benefit from reallocation to certain sectors? Is current sectoral allocation of production driven by markups and market frictions or by different relative demand? These questions do not have uniform answers across countries. Some developing countries with high variation in productivity benefit hugely from reallocation along US demand parameters. Others with uniformly low productivity across sectors face no change or a contraction from sector reallocation.

Chapter 3 also estimates the multipliers for all countries, which measure how much a increase of sector productivity, human capital, or capital generate in aggregate output. When correcting for sector wedges arising from markups, multipliers are substantially larger than had been previously estimated in Jones (2011a). It concludes by comparing predicted growth to actual income differences. When accounting for the higher multiplier, moving to US levels of human capital, capital, wedges, and sector productivity, closes all of the income gap between countries for most countries in the sample.

Chapter 2

Between Sector Misallocation: Theory and Estimation

2.1 Introduction

A long literature has sought to explain and account for cross-country differences in output. Traditional growth accounting divides output differences into those explained by labor, capital, and total factor productivity. In this accounting, TFP differences account for most of the differences between countries (Klenow & Rodriguez-Clare, 1997; Hall and Jones, 1999; Caselli, 2005). A large literature has posited explanations for these TFP differences. Potential roles have been shown for a wide range of factors including technology, human capital, labor inflexibility, and institutions.

Recently, a number of prominent contributions on misallocation of resources

between- and within-sectors have arisen from the growth literature. Within-sector misallocation arises from the existence of and heterogeneity in frictions between firms which keep capital and labor from going to the most productive firms within an sector, preventing individual firms from equating marginal products of labor and capital (Restuccia & Rogerson, 2008; Hsieh & Klenow, 2009; Bartelsman, Haltiwanger, & Scarpetta, 2009). Between-sector misallocation arises when certain sectors face different frictions or are differentially affected by the same frictions and thus allocate resources away from the most productive sectors (Jones, 2011a; Jones 2011b; McMillan & Rodrik, 2011; Buera, Kaboski, & Shin, 2007).

Additionally, across developing countries and emerging markets there is a strongly negative relationship between markups and GDP per capita. This is true both on an aggregate level and between fairly specific sectors. Gali (1995) first noticed this negative relationship between markups and development for all countries by comparing labor shares of income between countries. There are a number of factors which could drive this negative relationship: higher real interest rates, higher relative costs of capital goods, higher market power which may depend on the size of the market, insecure property rights, corruption or economic rent seeking, etc. The model extends a potential explanation for this negative relationship by estimating the effects of market power and frictions on both sector output and aggregate output.

In this paper, I evaluate theoretically the role of wedges created by markups in determining aggregate productivity and misallocation between sectors.¹ Addition-

¹I refer to both markups and wedges throughout the dissertation. I refer to the markup as $\frac{p}{mc}$, as it is usually measured. However, I allow for both frictions and market power to drive markups. I refer to wedges as the corresponding wedge given by τ , as $\frac{p}{mc} = \frac{1}{1-\tau}$. While markup is the more natural term when referring to relative prices between sectors, wedges are the more natural term

ally, I estimate to what degree this can explain output and TFP differences extending a model developed in Jones (2011a) to include imperfect competition. The primary components of this model are an input-output structure, imperfect competition, sector level frictions, a Cobb-Douglas production functions with capital, labor, and intermediate factors, and an aggregate final good. First, I discuss what drives these wedges reflected in markups. Second, I discuss how factors which drive markups affect aggregate productivity. Third, I discuss how heterogeneity in markups and the input-output structure of the economy may affect allocation of resources away from the most productive sectors.

There are a number of factors which could drive markups. The first category is frictions which divert a portion of output or driving up costs not reflected in costs of labor, capital, and intermediates² (e.g. taxes, corruption costs, capital frictions, labor frictions, etc.).³ The second category of factors determining relative market power of firms. Relative market power can be determined through barriers to entry (e.g. costs to entry, permitting for entry or access to inputs, limited access to inputs, corruption preventing entry, etc), a limited supply such as natural resources or a limited dissemination of production processes (due to high capital requirements, high sector-specific human capital requirements, etc) or demand differentiation between goods.⁴

when discussing the misallocation between sectors as it measures the relative distortion created by the markup.

²Throughout the paper, I will use intermediates to refer to any products used by an sector produced by a separate firm.

³Banerjee, Mullainathan, & Hanna (2009) and Olken and Pande (2011) review the literature on corruption and pricing behavior

⁴In this paper, I abstract away from fixed costs as a driver of increasing returns to scale. However, I hope to address this in extensions to the work which relax the assumption of constant returns to

Factors from both categories are important barriers to development. In the model, both play similar roles in that they drive a wedge between the price and the marginal product of labor, capital, and intermediate goods. While a friction restricts production because of a reduced incentive to produce, market power provides an incentive to restrict production to increase profit.⁵ Both will lead to an underproduction of high markup sectors relative to the rest of the economy.

Both frictions and market power also affect output through misallocation of resources. The input-output structure of the economy causes wedges to not only drive production away from that sector’s final goods but also from sectors using their goods as intermediate goods. The input-output structure and the assumption of intermediate inputs as a Cobb-Douglas factor of production provides a way to estimate the misallocation between sectors driven by factors which drive markups, and culminates in the definition of an “aggregate markup,” which integrates the effect not only the markup on the final good, but also the markups in the goods used for intermediate production. This facilitates estimation of the aggregate between-sector misallocation in the economy.

Empirically, I estimate these wedges and the misallocation arising from the wedges. To do this I follow the markups literature which has arisen from Hall (1988). However, I follow Basu and Fernald (1995) who showed Hall’s original use of value added

scale.

⁵Markups may also have a variety of within-sector static and dynamic misallocation. Higher sector markups will affect entry and exit decisions as well as the reallocation of resources within sector. In the context of this model and measurement, these effects are subsumed in the sector level productivity. Peters (2012) models both the dynamic misallocation arising from sector markups and finds that sectors with a higher markup correspond to a much higher level of dynamic misallocation than the static misallocation looked at by Hsieh and Klenow (2009).

as the dependent variable as opposed to gross output created an additional source of bias.⁶ I identify exogenous variation in the markups by using prices of a basket of international goods based on each sector’s international intermediate use. Unfortunately, I cannot avoid the aggregation bias discussed in Basu and Fernald (1997) from using sector aggregates. The aggregation bias arises from the unobserved within-sector reallocation between firms, and is positive if firms whose input growth are more correlated with sector input growth have higher markups.⁷ Basu and Fernald also showed that aggregation bias may drive markups below the theoretically plausible level of 1. For this reason and because the estimated markup jointly determines the structural parameters of the Cobb-Douglas production function, I bound the results based on upper and lower bounds according to the assumption of constant returns to scale.

Using these estimates of markups as representative of the wedges between sectors, I estimate the degree to which TFP and GDP in 39 developing and developed countries would change if they shifted to US levels of wedges.

2.2 Literature Review

In this section, I review three strands of literature related to my research. The first is the growth literature proposing different factors explaining the TFP gap between countries. The second is the literature which focuses on factor misallocation and

⁶They find that measured productivity spillovers between sector disappear once the gross output and intermediate inputs are used as opposed to value added.

⁷Aggregation bias arises when reallocation within sector is correlated with the cyclicalities of markups within that sector (Basu & Fernald, 1997)

its ability to explain these differences. The final strand discusses the relationship between markups and factor misallocation as well as the link between barriers to entry and markups.

2.2.1 Explanatory Factors for Differences in Output, TFP

While the literature on the process of economic growth has emphasized a variety of potential processes each of which may have effected or prevented economic growth, one perhaps more practical empirical question is how important various factors have been in explaining differences in output. To this question of which factors explain the large and sustained differences in cross country levels of output and TFP, many potential explanations have been proposed: technology, capital stocks, human capital, misallocation of resources between or within sector, labor policies, and the functioning of capital markets.

In this literature on how different frictions affect total factor productivity, Lagos (2006) presents a labor search model on how different types of labor frictions and the distribution of shocks affect the measured TFP. Restuccia and Rogerson (2008) and Hsieh and Klenow (2009) evaluate the degree to which heterogeneity of frictions within sectors affect TFP. Parente and Prescott (1999) and Aghion and Howitt (1990) put forth theoretical models for how monopoly power may act as a barrier to productivity upgrading. Banerjee and Duflo (2005) find empirically that the cost of finance (and presumably marginal product of capital) varies widely to firms in India. Epifani and Gancia (2011) provide theory which shows that heterogeneity in markups may be a source of potential exacerbation of distortions from the pro-competitive

impacts of trade as well as evidence that heterogeneity in markups increases with openness.

In Rebelo (1991) and Hall and Jones (1999), they pursue a theoretical and empirical hypothesis, respectively, that unexplained cross country differences may be due to institutions and policies. Mankiw, Romer, & Weil (1992) use human capital to modify the Solow growth model to provide consistent estimations of the effect of population growth and savings on output. Manuelli and Seshadri (2005) and Erosa, Koreshkova, & Restuccia (2010) also use human capital to close this convergence gap. Chari, Kehoe and McGrattan (1997) include organizational capital. Klenow & Rodriguez-Clare (2005) include accumulation of ideas as a produced factor.

Acemoglu (2009) and Jones (2011b) discuss the impacts of the capital share of production on the productivity multiplier. In Acemoglu (2009), the effect of tax distortion on output is subject to a multiplier of $\frac{\alpha}{1-\alpha}$, so that a capital share of $\frac{1}{3}$ (the approximate capital share of output) creates a multiplier of $\frac{1}{2}$, but a capital share of $\frac{2}{3}$ creates a multiplier of 2. The result is that an eightfold difference in frictions or productivity between rich and poor countries leads to a $8^{\frac{1}{2}} \approx 3$ -fold difference in output under a lower capital share, but a $8^2 \approx 64$ -fold difference in output under the higher capital share. There have been numerous explanations for what may explain the additional endogenous process which creates the much larger multiplier.

Jones (2011a) emphasizes the multiplier is substantially greater when integrating the effect of intermediate inputs, consistent with actual differences in output between rich and poor countries. He compares the multiplier calculated from the model with differentiated inputs depending on sector to the multiplier calculated without

differentiation between inputs. He also visually compares the input-output matrices between US, India, and China, and notices that they are broadly (and surprisingly) comparable, suggesting a relatively limited role of between-sector misallocation. He doesn't venture to calculate the frictions, only shows theoretically that variation in frictions can cause misallocation.

Additionally, Jones (2011a) shows that the $2/3$ share of intermediates and capital estimated from the model leads to a multiplier effect on productivity differences of 3 (calculated by $\frac{1}{1-2/3}$). In this situation a 2-fold difference in sector-level productivity between rich and poor countries leads to a $2^3 = 8$ -fold difference in total output.⁸

2.2.2 Misallocation and Economic Growth Literature

A large literature has evaluated the misallocation of resources toward firms and sectors which may not have been the most productive. Most of these have focused on within-sector misallocation due to heterogeneity in frictions within the sector.

Within Sector Misallocation Hsieh and Klenow (2009) evaluate the relative cost of intra-sector misallocation. By comparing the ratios of the marginal product of capital to the marginal product of labor, they deduce the distribution of frictions. These frictions distort firms' input hiring decisions, moving firms away from their optimal capital-labor ratios and increasing the dispersion of marginal products. From the

⁸The multiplier effect arises similarly to the multiplier for capital common in the growth literature. An increase in productivity, also leads to increasing the equilibrium capital stock. The equilibrium level of capital is given by $\frac{\alpha A p}{r}^{\frac{1}{1-\alpha}} L$. Because both the output and the equilibrium capital stock increase as a result of the productivity shock, output goes up by $A^{\frac{1}{1-\alpha}}$. For a sector with a capital share of $2/3$, the corresponding multiplier for a doubling of productivity is 2^3 . When inputs are factors of production, this logic extends to inputs in exactly the same way.

ratio of marginal product of labor to output, they deduce the friction on productivity. Given the distribution of frictions across firms, they use the ratio of output to Cobb-Douglas inputs to estimate productivity. They derive a distribution of revenue and physical productivity for China, India, and compare the potential gains if the distribution of intra-sector productivity in China and India were similar to the distribution in the US. They find that if the marginal products in China and India were equalized across firms to the degree they are in the US, manufacturing TFP would be 30-50% higher in China and 40-60% in India.

Bartelsman, Haltiwanger, & Scarpetta (2008) provide evidence that within sector covariance of size and productivity varies substantially between countries. They find that in the US manufacturing, labor productivity is 50 percent higher than it would be if employment was randomly allocated. The covariance between size and productivity is much lower in Western Europe, and close to zero for Eastern European countries.

Midrigan and Xu (2009) evaluate whether capital frictions could generate the between-establishment variation in average product of capital, and find that modeling capital adjustment costs, financing frictions and investment risk to account for the dispersion in the marginal product accounts for only 10% of the misallocation in the data.

Peters (2012) adds to the static misallocation a dynamic component. In his model he sees the static and dynamic misallocation as simultaneously determined by the same factors, and estimates the benefits of increased entry competition both statically and dynamically. He finds that when calibrating his model, only a small

fraction, 10%, of the gains from competition are from the static reallocation, while capital accumulation accounts for 30% and change in the equilibrium growth rate accounts for 60%.

Epifani and Gancia (2011) estimate the effect of misallocation and markup heterogeneity and the effect of trade liberalization on increasing the standard deviation of price-cost margins. After modeling the theoretical result from Lerner (1934) that monopoly pricing is only distortionary if there is heterogeneity in markups across sectors, they put forth the possibility that trade may worsen a developing economy's relative distortions if they increase competition in sectors that are already below the average price cost markup. They suggest a potential role for industrial policy to limit the procompetitive effect of trade in already disproportionately competitive sectors.

Banerjee and Duflo (2005) find empirically that the actual cost of finance varies widely throughout firms in India indicating substantial barriers preventing capital adoption and a very high marginal product of capital.

Collard-Wexler, Asker, & De Loecker (2011) analyze the relationship between dynamic productivity variation and cross-sectional dispersion in productivity. They find that volatility in productivity shocks can account for a substantial part of both cross-country productivity dispersion and dispersion of marginal revenue product of capital. In the presence of costly capital adjustment, firms may be operating rationally with respect to underinvesting as compared to their marginal revenue product of capital due to higher productivity volatility. The welfare and policy implications arise from whether the government has any ability to change either the investment adjustment costs or the volatility in productivity shocks. If the

productivity shocks arise from frictions and uncertainty with which firms face those frictions then reducing the volatility or the uncertainty associated with distortions may contribute to a more socially optimal process.

Between Sector Misallocation For misallocation between sectors, McMillan and Rodrik (2011) have shown that in developing countries structural change is not necessarily positive. For 1990-2005, they show that in Africa and Latin America labor has moved out of the most productive sectors and into lower productivity sectors. Two potential explanations which they pursue for this seeming contradiction are barriers to labor reallocation and overvaluation of their currency due to natural resources or monetary actions which may make higher productivity manufacturing relatively uncompetitive as compared to capital intensive natural resources or subsistence farming or services. One additional hypothesis which I pursue is that in addition to distortions specifically on labor reallocation, there may be sector-specific distortions or monopoly power disproportionate present in more productive sectors or inputs to those sectors preventing their growth.

Jones (2011a) introduces a model where distortions may affect aggregate output through misallocation between sectors. The deviations in TFP between countries are explained not only through the direct effect of the distortion on individual sectors, but also through misallocating capital, labor, and production between sectors.

However, he finds that intermediate goods shares are remarkably similar across countries, even as disparate as the US, India, China, Brazil, etc across 48 sectors. The tentative conclusion he draws is that misallocation of resources between sectors does not play a substantial role, as compared to the direct effect of the friction. He

also finds that the aggregate intermediate goods share is a relatively good estimate on the multiplier effect. The estimate overestimates the multiplier by approximately 10%, but on the whole is fairly accurate based on aggregate inputs.

Buera, Kaboski, and Shin (2009) look at aggregate and sector TFP, and show that the TFP gap between rich and poor countries varies systematically across industrial sectors of the economy according to their establishment size. Since tradable and investment goods sectors operate at much larger scales than those in the non-tradable sector, sectors with larger scales have more financing needs and are disproportionately affected by financial frictions. Financial frictions account for a substantial part of the observed cross-country patterns in TFP, both at aggregate and sector levels.

They find that financial frictions can explain a factor of two difference in per capita income across countries. Accounts for almost all of the observed elasticity of the relative price of tradables to non-tradables with respect to per-capita income. However, they accept that financial frictions may be representatives of more fundamental institutions. La Porta et al (1998) document that these financial development indicators are strongly related to underlying institutional difference such as the enforcement of contracts, creditor protection, etc.

2.2.3 Markups Literature

There is a long literature both in the industrial organization and macro literature on markups. These deal with how policy changes affect markups, the degree to which markups reflect market power, and the pro- or counter-cyclicality of markups. First, I briefly review the literature on the measurement and cyclicity of markups.

Second, I discuss how markups may reflect barriers to development.

In developed countries, a large literature arose from Hall (1986) and Hall (1988) on the measurement of markups. The approach pioneered was the measurement of markup as the elasticity of output with respect to an input as compared to the input share of output. Hall (1990) extends the previous work to relax the assumption of constant returns to scale. Basu and Fernald (1995) and Basu (1995) showed that Hall's approach which was estimated in terms of value added as the goods and capital and labor was biased when intermediate goods were omitted. Basu and Fernald (1997) also identify aggregation bias driven by the correlation between the markup of the firm and the cyclical growth of input growth. Finally, they suggest demand-side instruments may cause this aggregation bias to be exacerbated if demand shocks are disproportionately borne or affect certain types of firms and cause reallocation within sector to or from high markups firms.

Many approaches have used different margins to measure markups while using the same underlying framework. Bils (1987) used the labor margin, suggesting that marginal wage may be more procyclical than the hourly wage. Rotemberg and Woodford (1999) review the many corrections and alternative specifications to estimating the markup based on the labor and intermediate input margin such as for overhead labor, a CES production function, marginal wage not being equal to the average wage, labor hoarding, etc.

De Loecker and Warzynski (2009) build on the Hall (1986) literature and develop a method to measure markup over marginal cost which uses Olley and Pakes (1996) to control for unobserved productivity shocks and find markup estimates that are

substantially higher than the uncorrected estimates.

Nekarda and Ramey (2013) review the literature and find that markups are procyclical with demand shocks and either procyclical or acyclical in response to productivity shocks.

With regard to markups and development, Parente and Prescott (1999) present a model where coalitions of factor suppliers can act as monopolists to all firms using its output. They propose a model where a farm sector works competitively and an industrial sector can form coalitions which may prevent the adoption of more productive technology. In their case, they find that dissolving coalitions or monopolies preventing the adoption of higher technology investments may theoretically raise output by a factor of 3 without increases in inputs.

Herrendorf and Teixeira (2003) also present a two-sector version of the neoclassical growth model with coalitions of factor suppliers in the capital sectors to show that coalitions' monopoly rights lead to blocking the adoption of efficient technology.

Herrendorf and Texeira (2011) further show that barriers to entry are a quantitatively important reason for differences in income gaps between developed and developing countries. They develop a general equilibrium model and evaluate to what degree it explains variation in country level data. In their setup, they include an agricultural good, a manufactured consumption good and an investment good, and a continuum of intermediate goods. They find that barriers to entry explain approximately one half of the income gap with the US. This is the closest in spirit to the proposed research with the main difference being the use of the input-output structure and sector level markups to estimate the degree of monopoly power in each

sector.

2.3 Model

In this section I develop a simple general equilibrium two-sector model. The primary components of this model are an input-output structure, imperfect competition, sector level frictions, a Cobb-Douglas production functions with capital, labor, and intermediate factors, and an aggregate final good. This model is closely related to Jones (2011a) with the primary difference being monopolistic competition. It is expressed with 2 sectors for clarity but is easily extended to n sectors.

Intermediate goods from separate sectors are considered as Cobb-Douglas factors for each sector's production function which drives the between-sector misallocation results. Basu and Fernald (1995) find the Solow residual tends to be positively correlated with input use, and show formally that using only the value added production function as opposed to gross output and including inputs as factors of production bias Hall's original estimates of markups. The more salient addition is that each sector's input is a separate factor of production. Intuitively, intermediate goods from different sectors may not be perfectly substitutable. However, this substitutability between inputs of different sectors is important for determining the misallocation results, because it determines how much a firm can substitute away from a particularly high markup sector towards a low markup sector.

Finally, an important assumption of the model is that output is considered a final good based on a Cobb-Douglas aggregate of all sectors' production. To com-

pute between-sector misallocation it is necessary to fix the elasticity of substitution between sector output to determine the degree of structural change as a result of relative price changes between sectors. The elasticity of substitution between sectors is assumed to be one with weights according to their share of final goods and export output. This also entails the assumption that the shares of final good production value shares in each sector remains the same, even if production in certain sectors increases more than others. This is a strong assumption and almost surely underweights the reallocation benefit a country would receive through productivity enhancing structural change associated with lower markups.

In Appendix .2, I discuss relaxing the assumption of elasticity equal to 1 for all goods, and allowing it to be any level in a constant elasticity of substitution framework. A general elasticity of substitution parameter reflects the case where the final output may be substitutes or complements, where a CES estimate of ∞ reflects perfect substitutes, and 0 reflects perfect complements. While relaxing this assumption changes the results, the primary effect is to change the relative weightings between the frictions of relatively large and small sectors.

In Appendix .8, I extend the model to allow the levels of the aggregate capital stock to change. While the first presentation of the model includes a fixed aggregate capital stock and hence corresponds to differences in misallocation arising in TFP, the estimates including capital accumulation offer a longer term estimate of how much misallocation would change output levels as a whole. I use this version of the model to generate estimate the change in total output from moving to US levels of markups.

In Appendix .9, I include a version of the model integrating international trade and considering international goods as separate inputs. This offers more accurate estimates of the impact of changing domestic frictions and monopoly power on misallocation. It is this international version of the model which I use for empirical estimation of TFP change from moving to US levels of markups.

2.3.1 Firms

Firms choose capital, labor, and intermediates from both sectors to maximize profits. There is a unit measure of firms in each of the two sectors producing a monopolistically differentiated product.⁹

$$\max_{q_{1_i}, K_{1_i}, H_{1_i}, m_{1_i1}, m_{1_i2}} (1 - \tau_1)p_{1_i}(q_{1_i})q_{1_i} - p_1m_{1_i1} - p_2m_{1_i2} - rK_{1_i} - wH_{1_i} \quad (2.1)$$

$$s.t. \quad q_{1_i} = A_1 K_{1_i}^{\alpha_1} H_{1_i}^{\epsilon_1} m_{1_i1}^{\lambda_{11}} m_{1_i2}^{\lambda_{12}}$$

q_{1_i} is the gross output (final and intermediate goods) produced by firm i in sector 1, K_{1_i} is the capital used by firm i in sector 1, H_{1_i} is the human capital used by firm i in sector 1, m_{1_i1} is the number of intermediate inputs from sector 1 used by firm i

⁹As compared to Hsieh and Klenow (2009), modeling the friction as a sector friction does not necessarily mean that the frictions inherently are completely sector specific. It is very possible that these sector level markups measured are the composite of national frictions affecting capital and labor and affect sectors according to their capital and labor dependence, and reflecting the aggregate of those two frictions. The observed sector level friction would be equal to $(1 - \tau_O) = (1 - \tau_s)(1 - \tau_K)^\alpha(1 - \tau_L)^\epsilon$, where τ_O is the observed wedge τ_s is the true sector specific friction such as taxes or corruption, τ_K is the capital friction, τ_L is the labor specific friction.

in sector 1, m_{1i2} is the number of intermediate inputs from sector 2 used by firm i in sector 1. α_1 is the coefficient on capital in the Cobb Douglas production function, ϵ_1 is the coefficient on labor, λ_{11} is the coefficient on the intermediate produced by sector 1 on the Cobb Douglas production function in sector 1, λ_{12} is the coefficient on the intermediate produced by sector 2 on the Cobb Douglas production function in sector 1. All coefficients sum to one: $\lambda_{s1} + \lambda_{s2} + \alpha_s + \epsilon_s = 1$. Price of output from sector 1 is given by p_1 . Price of output from sector 2 is given by p_2 . r is the rental rate of capital. w is the wage for one unit of human capital. Firms in sector 2 act similarly.

The output (for both final and intermediate goods) from a specific sector is a composite of the monopolistically competitive firms within the sector with constant elasticity of substitution for sector s , σ_s for $s \in \{1, 2\}$. This determines the price as a function of output for each firm, i , in each sector s .

$$\max_{q_{s_i}} \left(\int q_{s_i}^{\frac{\sigma_s-1}{\sigma_s}} di \right)^{\frac{\sigma_s}{\sigma_s-1}} \quad (2.2)$$

$$s.t. \quad I = \int p_{s_i} q_{s_i} di \quad (2.3)$$

with $\sigma_s > 1$ so that within sector goods are substitutes.¹⁰

¹⁰This monopolistically competitive setting is the only difference between this setup and the assumptions of the Jones (2011a) model.

The composite final good is given by the maximization equation

$$\max_{y_1, y_2} Y - p_1 y_1 - p_2 y_2 \quad (2.4)$$

$$s.t. \quad Y = y_1^{\beta_1} y_2^{\beta_2} \quad (2.5)$$

where Y is the aggregation into a final good available internationally and y_s is total final goods from sector s . The coefficients sum to 1, $\beta_1 + \beta_2 = 1$. Here the choice of Cobb-Douglas aggregation is chosen for ease of exposition. In the case of constant elasticity of substitution with the elasticity of substitution coefficient $\neq 1$, the output in sectors 1 and 2 as shares of output would not solely depend on the input shares and coefficients, but also on the relative prices between sectors.

2.3.2 Market Clearing Conditions

The gross production is allocated between final goods and exports, capital formation, and inputs:

$$Q_j = y_j + m_{1j} + m_{2j} \quad (2.6)$$

where Q_j is the gross quantity produced in sector j , y_j is the final good and export output, x_j is the gross fixed capital formation, and m_{sj} is the domestically produced input from sector j used by sector s .

Wages clear a human capital market with a fixed human capital stock.

$$H = H_1 + H_2 \quad (2.7)$$

The interest rate moves so that the capital market clears:¹¹

$$K = K_1 + K_2 \quad (2.8)$$

2.4 Competitive Equilibrium

Definition A *competitive equilibrium* with misallocation in this environment is a collection of C , Y , Q_s , K_s , H_s , y_s , m_s , and prices p_j , w , and r for $s=1, \dots, N$ and $j=1, \dots, N$ such that

1) $\{y_s\}$ solves the profit maximization problem of a representative firm in the perfectly competitive final goods market

$$\max_{y_1, y_2} Y - p_1 y_1 - p_2 y_2$$

taking $\{p_s\}$ as given.

2) $\{m_s\}$, K_s , H_s solve the profit maximization problem of a representative firm in the monopolistic competition sector $s=1, \dots, N$, $i \in [0, 1]$:

$$\max_{q_{s_i}, K_{s_i}, H_{s_i}, m_{s_i1}, m_{s_i2}} (1 - \tau_s) p_{s_i}(q_{s_i}) q_{s_i} - p_1 m_{s_i1} - p_2 m_{s_i2} - r K_{s_i} - w H_{s_i}$$

¹¹This market clearing condition implicitly assumes capital can be reallocated between sectors. I refer to misallocation and reallocation in the medium- to long-term sense. Capital becomes misallocated to sectors because of high markups or high frictions driving investment away from that sector as compared to the other ones. While short-term reallocation of capital and labor between sectors may not be feasible or efficient given specific types of capital and skills, a hypothetical reduction of this misallocation would involve removing the barriers to entry or frictions, allowing those sectors to grow relative to others.

$$s.t. \quad q_{s_i} = A_s K_{s_i}^{\alpha_s} H_{s_i}^{\epsilon_s} m_{s_i1}^{\lambda_{s1}} m_{s_i2}^{\lambda_{s2}}$$

where $p_{s_i}(q_{s_i})$ is given by the solution to:

$$\max_{Q_{s_i}} \left(\int Q_{s_i}^{\frac{\sigma_s-1}{\sigma_s}} di \right)^{\frac{\sigma_s}{\sigma_s-1}}$$

$$s.t. \quad I = \int p_{s_i} Q_{s_i} di$$

3) Markets Clear w clears the labor market:

$$H = H_1 + H_2$$

r clears the capital market:

$$K = K_1 + K_2$$

p_j clears the sector j market:

$$Q_j = y_j + m_{1j} + m_{2j}$$

4) Production functions for Q_{s_i} Q_s and Y :

$$Q_s = \left(\int Q_{s_i}^{\frac{\sigma_s-1}{\sigma_s}} di \right)^{\frac{\sigma_s}{\sigma_s-1}}$$

$$Q_s = A_s \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) H_s^{\epsilon_s} K_s^{\alpha_s} M_{s1}^{\lambda_{s1}} M_{s2}^{\lambda_{s2}}$$

$$Y = y_1^{\beta_1} y_2^{\beta_2}$$

2.5 Equilibrium Output

Equilibrium output is given in logs by:

$$\log Y = \beta' \omega_y + \beta' (I - B)^{-1} (a + \omega^Q + \omega + \epsilon \log H + \alpha \log K) \quad (2.9)$$

The exponential form is given by the form:

$$Y = A^\psi (1 - \tau)^\psi H^{\psi_H} K^{\psi_K} \xi \quad (2.10)$$

where the multipliers are given by

$$\psi = \beta' (I - B)^{-1} \mathbf{1}$$

$$\psi_H = \beta' (I - B)^{-1} \epsilon$$

$$\psi_K = \beta' (I - B)^{-1} \alpha$$

and ξ is given by

$$\log(\xi) = \beta' \omega_y + \beta'(I - B)^{-1}(\omega + \tilde{\eta}_a + \tilde{\eta}_\tau)$$

$$A\eta_{as} = A_s$$

$$(1 - \tau)\eta_{\tau_s} = \frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s)$$

where A is the weighted average of the productivity: $\log(A) = \beta_1 \log(A_1) + \beta_2 \log(A_2)$, and τ is the weighted average of the markups: $\log(1 - \tau) = \beta_1 \log(\frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)) + \beta_2 \log(\frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2))$. $\tilde{\eta}_a$ and $\tilde{\eta}_\tau$ are vectors of the logged η_{as} and η_{τ_s} terms.

Table 2.1: Variables in the Model

Vector/Matrix	Element	Explanation
β	β_s	The vector of exponents of final goods and export production
γ	$\frac{p_s Q_s}{Y}$	The ratio of gross output from sector s to GDP
B	λ_{sj}	The undistorted input-output matrix
\bar{B}	$\frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q)\lambda_{sj}$	The distorted input-output matrix
θ_s^K	$\frac{\alpha_s \gamma_s}{\sum_{j=1}^N \frac{\sigma_j - 1}{\sigma_j}(1 - \tau_j^Q)\alpha_j \gamma_j}$	The allocation term for capital
θ_s^H	$\frac{\epsilon_s \gamma_s}{\sum_{j=1}^N \frac{\sigma_j - 1}{\sigma_j}(1 - \tau_j^Q)\epsilon_j \gamma_j}$	The allocation term for human capital
ω^K	$\alpha_s \log(\theta_s^K)$	Realized sectoral allocation term for capital
ω^L	$\epsilon_s \log(\theta_s^H)$	Realized sectoral allocation term for human capital
ω^m	$\sum_{j=1}^N \lambda_{sj} \log(\frac{\gamma_s}{\gamma_j} \lambda_{sj})$	Sectoral allocation term for domestic intermediates
ω^Q	$\log(\frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q))$	Vector of frictions and market power
ω	$\omega^K + \omega^L + \omega^m$	Sum of allocation terms
ω_y	$\log(\frac{\beta_s}{\gamma_s})$	Shares of final goods, exports, and GFCF to total sector output
a	$\log(A_s)$	Vector of logged sector productivity
$\tilde{\eta}_a$	$\log(\eta_{as})$	Vector of the logged variance of productivities
$\tilde{\eta}_\tau$	$\log(\eta_{\tau_s})$	Vector of the logged variance of frictions and market power

2.6 Special Cases

This section presents the properties arising from special cases of the model to build intuition. Proposition 1 estimates the effect of wedges when the wedges are homogeneous between sectors with symmetrical input dependence. Proposition 2 estimates the effect of heterogeneous wedges with symmetrical input dependence. Proposition 3 estimates the effect of wedges to sectors when one sector is an input sector and the second sector is a final goods sector.

Proposition 1-Effect of Constant Sector Markup on Aggregate Output: Suppose that the frictions and market power between sectors are equal, $\frac{\sigma_1-1}{\sigma_1}(1-\tau_1) = \frac{\sigma_1-1}{\sigma_1}(1-\tau_2) = 1-\tau$ with markups of $\frac{1}{1-\tau}$. Both sectors have equal input shares, $\lambda_{11} + \lambda_{12} = \lambda_{21} + \lambda_{22} = \lambda$, and sector shares of output, $\beta_1 = \beta_2 = \frac{1}{2}$, and productivity is the same in both sectors, $A_1 = A_2 = A$.

The total effect of τ on output is given by:

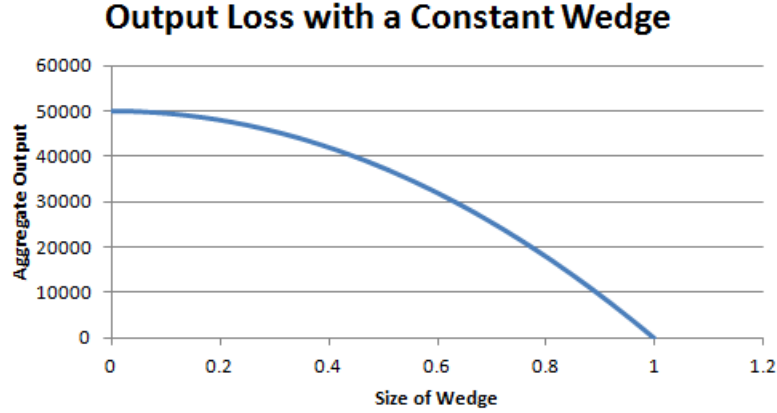
$$\log Y = \log(1 - \lambda(1 - \tau)) + \frac{\lambda}{1 - \lambda} \log(1 - \tau) + Constant \quad (2.11)$$

$$\frac{\partial \log Y}{\partial \tau} = \frac{-\lambda \tau}{(1 - \lambda(1 - \tau))(1 - \lambda)(1 - \tau)} \quad (2.12)$$

where all log's are natural logs. A decrease in the wedge, τ leads to a $\frac{\lambda \tau}{(1 - \lambda(1 - \tau))(1 - \lambda)(1 - \tau)} \%$ increase on output.

Discussion of Proposition 1: The primary conclusions from Proposition 1 are that 1) an decrease in the markup has an positive effect on output and 2) the impact on

Figure 2.1: Output Loss with a Constant Wedge



output of decreasing markups is greater with higher markups and higher input shares. The first result that lower markups have a positive increase in logged output is not surprising. The second deserves more discussion. The higher the input share, λ , the greater the amplification effect from increasing productivity in a sector. Higher intermediates share lead to not only the direct productivity effect, but the decreasing cost of inputs and hence the multiplier effect. Finally, the higher the friction, the greater effect on logged output. That is large distortions due to markups are much more costly in terms of lost percentage output, than smaller frictions.

For example, plugging $\lambda = .5$ into (2.11) the effect of reducing the friction from $\tau = .2$ to $\tau = .1$ has a 3.1% increase in output while decreasing from $\tau = .3$ to $\tau = .2$ has a 5.3% increase in output.

Proposition 2-Effect of Variation in Markups: Suppose that the market power and

frictions are not equal: $\frac{\sigma_1-1}{\sigma_1}(1-\tau_1) \neq \frac{\sigma_1-1}{\sigma_1}(1-\tau_2)$, defining $(1-\tilde{\tau}_1) \equiv \frac{\sigma_1-1}{\sigma_1}(1-\tau_1)$, and $(1-\tilde{\tau}_2) \equiv \frac{\sigma_2-1}{\sigma_2}(1-\tau_2)$. Markups are $\frac{1}{1-\tilde{\tau}_1}$ and $\frac{1}{1-\tilde{\tau}_2}$ for sectors 1 and 2 respectively. Further, suppose input coefficients are all equal, $\lambda_{11} = \lambda_{12} = \lambda_{21} = \lambda_{22} = \frac{1}{4}$.¹²

The effect of misallocation where markups differ across sectors results in the following total output:

$$\log Y = \log\left(1 - \frac{1}{4}(1-\tilde{\tau}_1) - \frac{1}{4}(1-\tilde{\tau}_2)\right) + \frac{1}{2}\log(1-\tilde{\tau}_1) + \frac{1}{2}\log(1-\tilde{\tau}_2) + \text{constant} \quad (2.13)$$

The marginal effect of a decrease in markups in sector 1 on percentage change in output is given by:

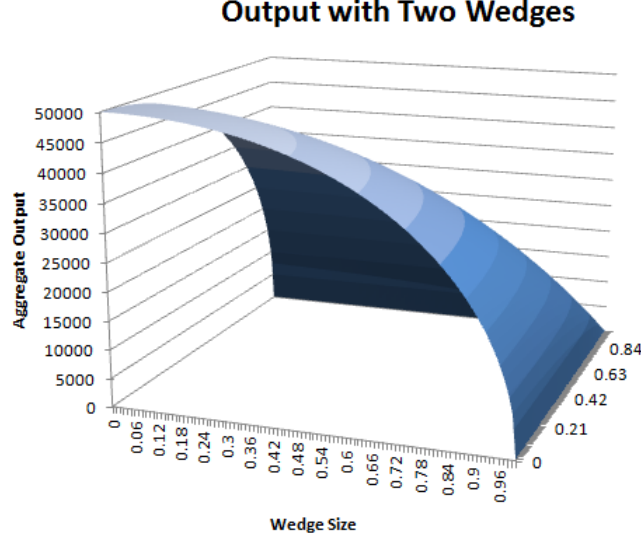
$$\frac{\partial \log Y}{\partial \tau_1} = \frac{-\frac{3}{8}\tau_1 - \frac{1}{8}\tau_2}{\left(1 - \frac{1}{4}(1-\tilde{\tau}_1) - \frac{1}{4}(1-\tilde{\tau}_2)\right)(1-\tilde{\tau}_1)} \quad (2.14)$$

Further, if $\tau_1 + \tau_2 = \tau$, (2.13) is maximized when $\tau_1 = \tau_2 = \frac{1}{2}\tau$.

Discussion of Proposition 2: Three conclusions result from the special case in Proposition 2. First, the higher the wedge, τ (with the markup reflecting $\frac{1}{1-\tau}$), being lowered, the greater the impact on output. Second, the higher the wedge on the unaltered sector, the higher the impact on output of lowering the wedge. The misallocation effect has a compounding effect, where the effect of decreasing a wedge on increasing output is greater when the unaffected sector has a higher friction. Third, in this symmetric case, conditional on a certain level of wedges in the economy, output is maximized when markups are equal between sectors.

¹²By construction $\alpha_1 + \epsilon_1 = 1 - \lambda_{11} = \lambda_{12} = .5$ and $\alpha_2 + \epsilon_2 = 1 - \lambda_{21} = \lambda_{22} = .5$. However no assumptions are needed on α and ϵ .

Figure 2.2: Output Loss with Two Wedges

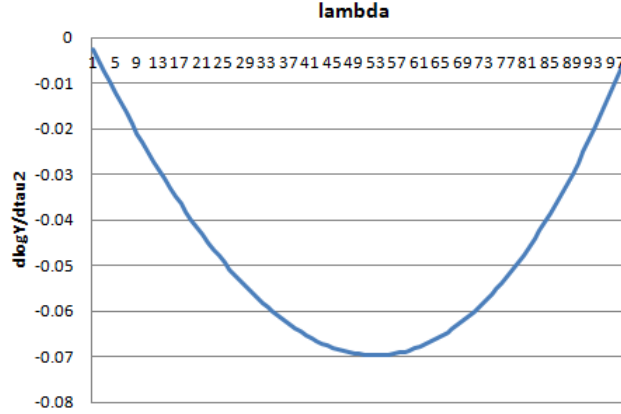


Proposition 3-One Input Sector, One Output Sector: Suppose that the market power and frictions are not equal: $\frac{\sigma_1-1}{\sigma_1}(1-\tau_1) \neq \frac{\sigma_1-1}{\sigma_1}(1-\tau_2)$, defining $(1-\tilde{\tau}_1) \equiv \frac{\sigma_1-1}{\sigma_1}(1-\tau_1)$, and $(1-\tilde{\tau}_2) \equiv \frac{\sigma_2-1}{\sigma_2}(1-\tau_2)$. Markups are $\frac{1}{1-\tilde{\tau}_1}$ and $\frac{1}{1-\tilde{\tau}_2}$ for sectors 1 and 2 respectively. Suppose sector 1 is solely an output sector, and sector 2 is solely an input sector, $\lambda_{12} = \lambda$, $\lambda_{11} = \lambda_{21} = \lambda_{22} = 0$, $\beta_1 = 1$, & $\beta_2 = 0$. Finally, assume the labor and capital shares are $\alpha_1 = \frac{1}{3}(1-\lambda)$, $\epsilon_1 = \frac{2}{3}(1-\lambda)$, $\alpha_2 = \frac{1}{3}$, $\epsilon_2 = \frac{2}{3}$.

The effect of changing the wedge results in the following change in total output:

$$\frac{d \log Y}{d \tilde{\tau}_1} = 0$$

Figure 2.3: Proposition 3: $\frac{d\log Y}{d\tilde{\tau}_2}$ for Different Levels of Input Dependence, λ



$$\frac{d\log Y}{d\tilde{\tau}_2} = -\frac{\lambda(1-\lambda)\tilde{\tau}_2}{(1-\tilde{\tau}_2)^2}$$

Discussion of Proposition 3: There are a few things to note about the results for one input sector and one output sector. The first is that the wedge on the final good does not lead to any misallocation, which brings us back to the original Lerner (1934) conclusion that only variation of markups on final goods affects output, not the level. Because the markup on the final good only distorts the final good choice between sectors, and because there is only one final good, the markup on the final goods sector does not affect misallocation.

The second is that there is no interdependence between the two wedges. The level of the final good wedge does not affect the misallocation of the intermediate

good wedge. This is because the impact of the misallocation arising from the input wedge is the result of the final goods sector underusing inputs, compared to capital and labor. This is only dependent on the cost of the input sector relative to capital and labor.

Finally, the effect of the wedge has a monotonic effect on aggregate output. This arises as the final good sector has to use a smaller and smaller portion of inputs as the markup rises, which has a stronger effect on the aggregate output. It also depends on the input dependence, λ , because it is affected by a factor of $\lambda(1 - \lambda)$, the higher input dependence peaks at $\lambda = 0.5$. Very small λ obviously decreases the impact of the input wedge. However, a very large λ leads to less misallocation between sectors because as λ converges to 1, a higher wedge on the input sector is equivalent to a higher wedge on the final good.

2.7 Markups and Misallocation: Theoretical Implications

2.7.1 Sector Prices and Markups

Here, I solve for the markups in terms of input prices. Prices for sector s is determined by its input prices, frictions, and market power:

$$p_s = \frac{\sigma_s}{\sigma_s - 1} \frac{1}{(1 - \tau_s)} p_s^e(r, w, p_1, p_2) \quad (2.15)$$

where p_s^e is the efficient price for sector s conditional on input prices and techno-

logical efficiency:

$$p_s^e = \left(\frac{r}{\alpha_s}\right)^{\alpha_s} \left(\frac{w}{\epsilon_s}\right)^{\epsilon_s} \left(\frac{p_1}{\lambda_{s1}}\right)^{\lambda_{s1}} \left(\frac{p_2}{\lambda_{s2}}\right)^{\lambda_{s2}} \frac{1}{A_s} \quad (2.16)$$

2.7.2 Aggregate Markup and Misallocation of Production

In the model, misallocation operates through two distinct channels. I call the first the resource allocation channel, and the second the relative prices channel. First, scarce capital or labor may be allocated to sectors which are not the most productive, but are the ones least subject to market power or frictions. Frictions restrict the incentive to produce, leading to a portion of output being redistributed to consumers and market power restricts production to drive up the profit from that sector output. In this channel, the size of the wedge in a given sector relative to the wedges in other sectors is the relevant measure.

Secondly, a separate form of misallocation may be due to firms substituting away from using other sector's products as inputs and towards capital and labor leading to an inefficiently low level of intermediate inputs. In this second channel, the relevant measure is not simply the distribution of logged markups represented by ω^Q , but the distribution of aggregate markups, represented by $(I - B)^{-1}\omega^Q$. Higher levels of aggregate markups lead to sectors substituting away from using other firms outputs as intermediates and inefficiently substituting capital and labor. Variation in these aggregate markups also affects misallocation by causing final goods consumers and sectors which use other sectors' goods as inputs to substitute towards sectors with lower aggregate markups.

Here I define the aggregate markup as the markup on final goods' price above the price in the equilibrium with perfect competition and no frictions in all sectors. I introduce these aggregate frictions to offer a way to estimate not only the wedge directly on a sector, but also the wedges in their input markets. In the presence of large heterogeneity in both the inputs share of output and the markups between sectors, aggregate wedges may be substantially different than sector wedges.

Definition: Aggregate markup is the markup of actual price over price conditional on perfect competition in the absence of any sector frictions.

I calculate the aggregate markup by taking logs of prices, and recursively the prices for p_s . Where p^u is the efficient price based on frictionless perfect competition in all sectors, the aggregate markup is:

$$\begin{aligned}
\log p_s = & \log\left(\frac{\sigma_s}{\sigma_s - 1} \frac{1}{(1 - \tau_s^Q)}\right) \\
& + \lambda_{s1} \left(\log\left(\frac{\sigma_1}{\sigma_1 - 1} \frac{1}{(1 - \tau_1^Q)}\right) \right. \\
& \quad \left. + \lambda_{11} \left(\log\left(\frac{\sigma_1}{\sigma_1 - 1} \frac{1}{(1 - \tau_1^Q)} + \dots \right) + \lambda_{12} \left(\log\left(\frac{\sigma_2}{\sigma_2 - 1} \frac{1}{(1 - \tau_2^Q)} + \dots \right) + \dots \right) \right. \right. \\
& \quad \left. + \lambda_{s2} \left(\log\left(\frac{\sigma_2}{\sigma_2 - 1} \frac{1}{(1 - \tau_2^Q)}\right) \right. \right. \\
& \quad \left. \left. + \lambda_{21} \left(\log\left(\frac{\sigma_1}{\sigma_1 - 1} \frac{1}{(1 - \tau_1^Q)} + \dots \right) + \lambda_{22} \left(\log\left(\frac{\sigma_2}{\sigma_2 - 1} \frac{1}{(1 - \tau_2^Q)} + \dots \right) + \dots \right) \right) \right) \\
& + \log p_s^u
\end{aligned} \tag{2.17}$$

Stacking these logged prices into a vector, in matrix form they converge to:

$$\rho = \log(\mu) + B \log(\mu) + B^2 \log(\mu) + \dots = (I - B)^{-1} \log(\mu)$$

where ρ is the aggregate markup vector, $\log \mu$ as the vector of logged markups with entries $\log(\frac{\sigma_s}{\sigma_s - 1} \frac{1}{(1 - \tau_s)})$ and B is the matrix with $b_{sj} = \lambda_{sj}$.

$$p = \rho + p^u \tag{2.18}$$

Here, p represents the vector of logged actual prices, and p^u is the vector of logged prices in frictionless perfect competition in all sectors.

Notice that the vector $\log \mu$ is simply the negative of the vector ω^Q , $\log \mu = -\omega^Q$. The aggregate markup term $(I - B)^{-1} \log(\mu)$ is equal to the negative of the primary factor affecting output: $(I - B)^{-1} \omega^Q$. This term represents the misallocation affecting the price channel.

Relationship of Aggregate Markup to Multiplier Here, I briefly review the relationship between the aggregate markup to the multiplier. These are closely related but distinct concepts. The multiplier for the domestic model is given by Equation 2.10:

$$\psi = \beta'(I - B)^{-1} \mathbf{1} \tag{2.19}$$

where $(1 - \tau)^\psi$ measures part of the effect of the level of wedges on aggregate output.

The aggregate wedge is given by:

$$\log(1 - \tau^A) = (I - B)^{-1} \omega^Q \quad (2.20)$$

The key factor in determining both is the Leontief inverse matrix, defined to be $(I - B)^{-1}$. This matrix often used in the input-output literature is the matrix whose ij^{th} entry represents the effect of a productivity shock (or decrease in the wedge) in sector j on sector i 's output.

The underlying idea behind both is similar. An increase in the monopoly power or frictions faced by a given sector, leads to an increase in the effective wedge not only in that sector, but all sectors which are dependent on it as an input, and sectors which use those sectors' goods as inputs etc. This leads to a multiplier effect of an individual wedge. The aggregate wedge reflects the wedge driven between the price of a sector and the price that would prevail if perfect competition were available in every sector. The transformation from sector wedges to aggregate wedges is determined by the Leontief inverse.

The multiplier is the estimate of how changing the average level of wedges or productivity would affect the aggregate output. An increase in productivity for all sectors of 1% leads to an increase in aggregate output of $\psi\%$. However, because the wedges also affect the reallocation term ξ in Equation 2.10, aggregate output will increase by the multiplier, but also be partially offset by the changes to the reallocation term.

2.7.3 Misallocation of Capital and Labor

This section evaluates the determinants of the relative allocation of capital and labor.

From equations (61) and (62), the sectoral labor and capital allocation are given by:

$$\frac{H_s}{H} = \frac{\frac{\sigma_s-1}{\sigma_s}(1 - \tau_s^Q)\epsilon_s\gamma_s}{\frac{\sigma_1-1}{\sigma_1}(1 - \tau_1)\epsilon_1\gamma_1 + \frac{\sigma_2-1}{\sigma_2}(1 - \tau_2)\epsilon_2\gamma_2}$$

$$\frac{K_s}{K} = \frac{\frac{\sigma_s-1}{\sigma_s}(1 - \tau_s^Q)\alpha_s\gamma_s}{\frac{\sigma_1-1}{\sigma_1}(1 - \tau_1)\alpha_1\gamma_1 + \frac{\sigma_2-1}{\sigma_2}(1 - \tau_2)\alpha_2\gamma_2}$$

It is straightforward to show that for all $\frac{\sigma_1-1}{\sigma_1}\tau_1 = \frac{\sigma_2-1}{\sigma_2}\tau_2$, the capital (and labor) employed in sector 1 is the same as the optimal frictionless allocation, $\frac{\sigma_1-1}{\sigma_1}\tau_1 = \frac{\sigma_2-1}{\sigma_2}\tau_2 = 0$. The result is that for misallocation of labor and capital (for a fixed capital stock) across sectors, only the variation in wedges matters. Despite this, the effect of that misallocation on output, described in the term ω , still depends on the Leontief inverse matrix, $(I - B)^{-1}$, in determining the effects of misallocation on output through the term $(I - B)^{-1}\omega$.

2.8 Estimation

In the empirical portion, I estimate the effect on output for a set of countries of switching the vector of wedges to the US' level of wedges. To do this, I estimate the parameters of the aggregate output equation using the international model, (69) for 39 countries.¹³

¹³This is the international equivalent to equation, (2.9). Appendix .9 contains the derivation of this equation.

$$\log Y = \frac{\beta' \omega_y + \beta'(I - B)^{-1}(a + \omega^Q + \omega + \epsilon \log H + \alpha \log K)}{1 - \beta'(I - B)^{-1} \lambda^*} \quad (2.21)$$

The part of this equation which is affected by markups is

$$\log Y = \frac{\beta' \omega_y + \beta'(I - B)^{-1}(\omega^Q + \omega)}{1 - \beta'(I - B)^{-1} \lambda^*} + \text{constant} \quad (2.22)$$

To estimate the impact of the vector of a change in markups on output, I need to estimate the parameters, β , B , and \bar{B} as well as the variables, ω_y , ω^Q , ω , and γ .¹⁴ β represents shares of final goods output from a certain sector, B represents the matrix of sector shares and \bar{B} represents the sector shares modified by the sector wedge. I estimate all of the variables in terms of the underlying parameters from equilibrium equations in the previous section.

2.8.1 Data

To do this, I use the European Commission World Input Output Database (WIOD) has national accounts and Socio-economic accounts data including input-output data for all OECD countries as well as Brazil, China, Cyprus, India, Indonesia, Malta, Latvia, Lithuania, Romania, Russia, Taiwan. Socio-economic accounts for each country include data on sector-level Gross Output, Gross Output prices, Intermediate Inputs, Intermediate Input prices, Accumulated Capital Stock, Capital stock prices, Labor compensation, and Hours engaged. National Input Output tables are included

¹⁴In the international version of the model, B corresponds to only the domestic input-output table. International inputs are given by \bar{B} and the vector of each sector's total international input shares is given by, $\lambda^* = \bar{B}\mathbf{1}$.

for all of countries included.

International price data used to construct an instrument is drawn from the World Bank Global Economic Monitor (GEM) Commodity Prices Database. Appendix D contains details on the sectors and aggregates used.

2.8.2 Estimation of Markups, $\mu_s \equiv \frac{\sigma_s}{\sigma_s - 1} \frac{1}{(1 - \tau_s^Q)}$

I estimate of markups in two steps. The first step is an instrumental variable approach to estimate markups for each sector in each country. The second is the imposition of bounds requiring consistency with constraints on structural parameters for each sector.

To estimate the markups, I use a similar methodology as Hall (1988). The main difference is that I use gross output as the dependent variable and integrate inputs as a factor of production.¹⁵ For the production function,

$$Q_{st} = A_{st}F(K_{st}, H_{st}, M_{st}) \quad (2.23)$$

Under the assumption of constant returns to scale this is expressed as

$$\frac{Q_{st}}{K_{st}} = A_{st}f\left(\frac{H_{st}}{K_{st}}, \frac{M_{st}}{K_{st}}\right) \quad (2.24)$$

The elasticity of output with respect to the change of a labor input is given by

¹⁵The gross output as opposed to value added approach was shown to be less biased in Basu & Fernald (1995) and Basu & Fernald (1997)

$\frac{w_t H_{it}}{mc_{it} Q_{it}}$. This can be seen from the original maximization equation (3)

$$\epsilon_{st} = \mu_s \frac{w_t H_{st}}{p_t Q_{st}}$$

where $\mu_s = \frac{p_s}{mc_s}$ is the markup over marginal cost. The elasticity conditions for intermediate inputs are similarly derived.

This equation can be expressed as

$$\Delta q_{st} = \Delta a_{st} + \mu_s (\tilde{\epsilon}_{st} \Delta h_{st} + \tilde{\lambda}_{st} \Delta m_{st}) \quad (2.25)$$

where Δq_{st} is the logged difference of the output to capital ratio, Δh_{st} is the logged difference of the labor to capital ratio, μ_s is the markup of $\frac{p_s}{mc_s}$, $\tilde{\epsilon}_{st}$ is the observed labor share of gross output, $\tilde{\lambda}_{st}$ is the observed intermediate share of gross output. $\Delta a_{st} = \chi_s + u_t$, and χ_s is the rate of Hicks-neutral technical progress and u_t is the productivity shock with mean 0.¹⁶

For each country sector, I estimate the equation:

¹⁶I find this by taking logs and differences:

$$\Delta q_{st} = \Delta a_{st} + \Delta \log f\left(\frac{H_{st}}{K_{st}}, \frac{M_{st}}{K_{st}}\right) \approx \Delta a_{st} + \Delta \log f^1\left(\frac{H_{st}}{K_{st}}, \frac{M_{st}}{K_{st}}\right) + \Delta \log f^2\left(\frac{H_{st}}{K_{st}}, \frac{M_{st}}{K_{st}}\right) \quad (2.26)$$

multiplying and dividing the last term by $\Delta \log \frac{H_{st}}{K_{st}}$ and noting that $\frac{\Delta \log f^1(\frac{H_{st}}{K_{st}}, \frac{M_{st}}{K_{st}})}{\Delta \log \frac{H_{st}}{K_{st}}} = \mu_s \tilde{\epsilon}_{st}$ and $\frac{\Delta \log f^2(\frac{H_{st}}{K_{st}}, \frac{M_{st}}{K_{st}})}{\Delta \log \frac{M_{st}}{K_{st}}} = \mu_s \tilde{\lambda}_{M,st}$. This comes from (3) to (6).

These expressions can be used to solve for the markup as:

$$\mu_s = \frac{\Delta q_{st} - \chi_s - u_t}{\tilde{\epsilon}_{st} \Delta h_{st} + \tilde{\lambda}_{st} \Delta m_{st}} \quad (2.27)$$

However, the main problem here is that neither χ_s nor u_t is observable. I need instrumental variables correlated with output through labor or intermediate use, but not correlated with the technical change or productivity parameters χ_s and u_t .

$$\Delta q_t = \phi_0 + \phi_1 Est_t \quad (2.28)$$

with $Est_t = \tilde{\epsilon}_{st}\Delta h_{st} + \tilde{\lambda}_{st}\Delta m_{st}$ is the estimated change in output based on input changes, ϕ_1 is the estimate for markups μ_s , ϕ_0 is the estimate for χ_s .

Each of the 39 countries has 34-36 sectors yielding over 1300 sector regressions. For each regression only time series variation is used to estimate the markup observed over 15 years (1995-2009). Because the observations are differences, each regression has 14 observations. Each regression is run with heteroskedasticity and autocorrelation robust standard errors using the Newey west correlation matrix with 12 lags.

The regression assumes the markup is constant over time within a sector. The constant term is the estimated the secular productivity growth in the sector for the period. While both the markup and the productivity growth will likely vary, the heteroskedasticity and autocorrelation robust standard errors include an error term structure allow an autocorrelated error term which absorbs any predictive effect the previous year's residual has on future years in the sample.

Instrument Construction For the first stage, I would like to identify the markup of price over marginal cost associated with a particular sector driven by frictions and market power. However, changes in productivity shocks also drive changes in input use, marginal cost, and price. As such I need an instrument exogenous with respect to these productivity shocks, but which change the costs to a sector.

I use three instruments based on price changes for

- a basket of international price changes weighted by each sector’s use of specific international inputs
- a basket of domestic price changes based on each sector’s domestic intermediate inputs relative to national changes in prices and
- a basket of changes in wages for a sector based on its relative weights of high, medium, and low skilled employees given national changes in wages for high medium and low skilled employees relative to national changes in wages. ¹⁷

The assumption needed is that international price changes, that the price changes affecting a domestic sector relative to national price changes, and that wage changes affecting a specific sector relative to national wage changes are uncorrelated with the sector productivity shock. These are plausible if the sectors are relatively small compared to the entire economy.

I use the instruments relative to national price changes in wages and prices respectively for a few reasons. The first is that markups are driven opposite directions based on supply versus demand changes (Nekarda and Ramey, 2013). The second reason is because the aggregation bias which arises from using sector-level estimates as opposed to firm-level estimates is due to the reallocation between firms within an sector. This bias depends on the presence of correlation between the markup and the cyclicity of the sector (Basu & Fernald, 1997). Because demand changes have been shown to have substantial reallocation effects (Basu & Fernald, 1997) and be consistently procyclical (Nekarda & Ramey, 2013), I try to isolate supply changes.

¹⁷The latter two instruments are similar to Bartik instruments introduced in Bartik (1991)

I construct this basket of international prices according to each sector's use of that international input in their production. The change in prices is a weighted average of the change in prices in the international prices with the weights according to the share of international inputs in sectors with international price data.

$$\Delta \bar{P}_i^{agg} = \sum_{j=1}^M \frac{\bar{E}_{ij} \Delta \bar{P}_j}{\bar{T}_i} = \sum_{j=1}^M s_{ij} \Delta \bar{P}_j$$

where $\Delta \bar{P}_i$ is the percent change in the price of the basket of goods used by sector i as inputs from sectors with internationally available prices, \bar{E}_{ij} is sector i's expenditure on international inputs from sector j, $\Delta \bar{P}_j$ is the percent change price level for international prices in sector j, \bar{T}_i is sector i's total international expenditure on sectors with internationally available prices, $s_{ij} = \frac{\bar{E}_{ij}}{\bar{T}_i}$ is sector i's weight according to the expenditures share on sector j based on all sectors available, M is the number of sectors with internationally available prices.

The normalized basket of price changes for domestic goods is given by

$$\Delta P_i^{agg} = \sum_{j \neq i}^N \frac{E_{ij} \Delta P_j}{T_i} - \Delta \bar{P} = \sum_{j \neq 1}^M s_{ij} \Delta P_j - \Delta \bar{P}$$

where the primary difference is that for domestic goods I use all N sectors with the exception of sector i, whereas with international inputs, there are limited sectors with international price data available, and prices are normalized by the GDP deflator, $\Delta \bar{P}$.

Finally, the predicted wage changes based on national trends for a given sector

is given by

$$\Delta W_i = s_{il}\Delta w_l + s_{im}\Delta w_m + s_{ih}\Delta w_h - \bar{w}$$

where s_{ij} is the share of total labor expenditure on $j \in (l, m, h)$ low, medium, or high skilled labor respectively, and \bar{w} is the national wage changes weighted by national shares of low, medium and high skilled labor.

Markup Bounds In the context of the model, markups are used both as parameters on their own and also to estimate the structural parameters for each sector (α_s , ϵ_s , λ_{sj} , and λ_{sj}^*). ϵ , the elasticity of output with respect to labor, is estimated by the labor share of gross output multiplied by the markup. λ is estimated similarly for domestic intermediate share of total inputs,. λ^* is international intermediate share of total inputs. For implausibly large markups the ϵ , λ , and λ^* can sum to more than one, leaving a negative α . For this reason, I use an upper bound of μ .

Given the assumption that the structural parameters sum to one and from the first order conditions:

$$1 = \epsilon_s + \alpha_s + \sum_{j=1}^N \lambda_{sj} + \sum_{j=1}^N \lambda_{sj}^* = \mu_s(\tilde{\epsilon}_s + \tilde{\alpha}_s + \tilde{\lambda}_s + \tilde{\lambda}_s^*) \quad (2.29)$$

where $\tilde{\epsilon}_s$ is the labor share of gross output, $\tilde{\alpha}_s$ is the capital share of gross output, $\tilde{\lambda}_s$ is the total domestic input share of gross output, $\tilde{\lambda}_s^*$ is the total international input share of gross output. This gives the condition that:

$$\mu_s = \frac{p_t Q_{st}}{r_t K_t + w_t H_{st} + \sum_{j=1}^N p_{jt} m_{sjt} + \sum_{j=1}^N p_{jt}^* m_{sjt}^*} \quad (2.30)$$

The upper bound on markups is found from the geometric mean of the markups over average costs with a relatively low rate of return on capital (2%),

$$\bar{\mu}_s = \Pi_{t=1995}^{2009} \left(\frac{p_{st}Q_{st}}{w_t H_{st} + 0.02K_{st} + \sum_{j=1}^N p_{jt}m_{sjt} + \sum_{j=1}^N p_{jt}^*m_{sjt}^*} \right)^{\frac{1}{15}} \quad (2.31)$$

The key assumptions needed for this bound is the assumption of the elasticities are equal to the labor shares of output times the markup and the CRS assumption, both of which are an assumption central to the markups literature arising from Hall (1988). The bound in effect just comes from the 0.02% lower bound on the long-term return on capital.¹⁸

Similarly, an implausibly low markup tends to underweight ϵ and λ and overweight α . It is difficult to know what is the highest expected return on capital. However, theoretically market power cannot drive the markup below one, only a subsidy can justify markups less than one because otherwise firms have a loss the margin. Because tax data is available for most countries, I use the lower bound:

$$\underline{\mu}_s = \Pi_{t=1995}^{2009} \left(\frac{1}{1 - \tau_{st}} \right)^{\frac{1}{15}} \quad (2.32)$$

where τ_{st} is the tax share of output for sector s in period t . This lower bound corresponds to the perfect competition environment in which the only distortion is the net tax.

¹⁸The estimate of α_s is sensitive to this assumption, but the estimates of markup are in general not.

Aggregate Markup Construction Aggregate markups for each sector are estimated, as in (2.7.2), by:

$$\rho = (I - B)^{-1} \log(\mu) \quad (2.33)$$

where \tilde{m} is the vector of logged aggregate markups by sector, I is the identity vector, B is the undistorted input-output matrix, and m is the vector of logged markups by sector. Further, to construct the average of the aggregate markup for a country I weight the aggregate markup by the sectors' share of final goods:

$$\rho^C = \beta'(I - B)^{-1} \log(\mu) \quad (2.34)$$

where ρ^C is the weighted aggregate markup for a given country with weights according to each sector's share of final goods and exports.

2.8.3 Parameter Estimation

ϵ_s is the share of total input expenditure used on labor for sector s divided by the markup $\epsilon_s = \frac{\tilde{\epsilon}_s}{\mu_s}$. As before, $\tilde{\epsilon}_s$ is the labor share of gross output from a sector.

λ_{sj} is the share of total domestic input costs from sector j goods in sector s defined by $\lambda_{sj} = \frac{\tilde{\lambda}_{sj}}{\mu_s}$ where $\tilde{\lambda}_{sj}$ is the expenditure from sector s on sector j 's output as a share of gross output from sector s .

λ_{sj}^* is the share of total international input costs from sector j goods in sector s defined by $\lambda_{sj}^* = \frac{\tilde{\lambda}_{sj}^*}{\mu_s}$ where $\tilde{\lambda}_{sj}^*$ is the expenditure from sector s on sector j 's output as a share of gross output from sector s .

α_s is the share of expenditure on capital defined by the constant returns to scale

as $\alpha_s = 1 - \epsilon_s - \lambda_s - \lambda_s^*$.

Finally, the vector of productivity, a , can be determined by estimating the original production function with the previously estimated structural parameters:

$$Q_s = A_s \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) H_s^{\epsilon_s} K_s^{\alpha_s} \Pi_{j=1}^N M_{sj}^{\lambda_{sj}} \Pi_{j=1}^N M_{sj}^{*\lambda_{sj}^*}$$

β are the shares of final goods output and exports from each sector. These are measured as the gross output from sector s minus the intermediate consumption from other sectors of sector s ' output divided by the total final goods and output

$$\frac{Q_s - p_s \sum_{i=1}^N m_{is}}{\sum_{s=1}^N (Q_s - p_s \sum_{i=1}^N m_{is})}.$$

\bar{B} is the domestic input-output matrix in shares of total output per sector.

B is the undistorted domestic input-output matrix which is just the domestic input-output matrix left multiplied by the diagonal matrix with the markups on the diagonal:

$$B = \begin{pmatrix} \mu_1 & 0 & \dots & 0 \\ 0 & \mu_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \mu_N \end{pmatrix} \bar{B}$$

γ is defined by:

$$\gamma \equiv (I - \bar{B})^{-1} \beta$$

ω_y is the vector of $\log(\frac{\beta_s}{\gamma_s})$.

2.8.4 Change in Output with US-level Markups

The final step is to estimate for a given country, all of the vectors β , ω^Q , ω , ω_y , and B with both the vector of markups from the country and the vector of markups from the US to estimate the impact of decreasing markups to US levels on total output. So that the impact of reducing markups in a given country to US level is:

$$\Delta \log Y^C = \frac{\beta'^C (\omega_y^{C,US} - \omega_y^C) + \beta'^C (I - B^C)^{-1} (\omega^{QUS} + \omega^{C,US} - \omega^{QC} - \omega^{C,US})}{1 - \beta'^C (I - B^C)^{-1} \lambda^*} \quad (2.35)$$

Here, all variables which have the superscript C are variables using data from country C . All variables with the US superscript are variables calculated with markups and input-output tables calculated from US data. Variables using C, US superscripts are calculated using markup parameters from the US, but all other structural parameters from country C .

2.9 Results

The primary approach in the measurement of wedges between sectors involves instrumenting for markups using three instruments:

- changes in international input prices,
- changes in domestic input prices net of the GDP deflator,¹⁹ and

¹⁹Each sector has changes in input prices weighted by each sector's input use and excluding inputs from itself as described in the previous section.

- changes in a sector's predicted wage changes net of the national wage change

Each regression is run with heteroskedasticity and autocorrelation robust standard errors using the Newey west correlation matrix with 12 lags.

Each of the 39 countries has 34-36 sectors yielding over 1300 sector regressions. For each regression only time series variation is used to estimate the markup observed over 15 years (1995-2009). The regression assumes the markup is constant over time within a sector. The constant term is the estimated the secular productivity growth in the sector for the period. While both the markup and the productivity growth will likely vary, the heteroskedasticity and autocorrelation robust standard errors include an error term structure allow an autocorrelated error term which absorbs any predictive effect the previous year's residual has on future years in the sample.

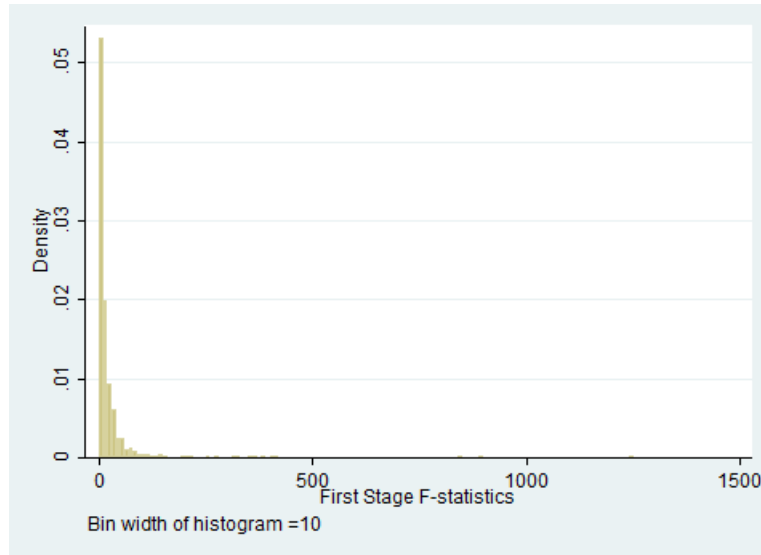
2.9.1 Measurement of Markups: First Stage

I will review the first stage results here with respect to the strength of the instrument, endogeneity tests, and overidentification tests.

Strength of First Stage The first stage statistics are reported in Figure 2.4 with bin width of 10. Staiger and Stock (1997) suggest instruments are weak if the first-stage F-statistic is less than 10 for a single endogenous regressor. Here approximately 53% of the F-statistics are below 10, with the remainder being greater than 10.

Endogeneity Tests I report endogeneity tests to verify that instrumentation is needed. In both of these cases, significant test statistics indicate that the endogenous (right-

Figure 2.4: Histogram of First Stage F-Statistics



hand side) regressor is in fact endogenous. In Figures 2.5 and 2.6 I report the histogram of the p-values for the heteroskedasticity and auto-correlation (HAC) score statistic, and the p-values for the regression based F-statistic (Wooldridge, 1995).

The two tests give somewhat contradictory results. For the regression-based F-statistic test, approximately 30 percent of the regressions had p-values which would reject the null hypothesis that the endogenous variable was exogenous at the 95% level, suggesting that for a significant portion of the regressions OLS may be preferable. However, for the HAC score test, less than 5 percent of the regressions had p-values for which we could reject that the endogenous variable was in fact endogenous at the 95% level, justifying instrumentation.

Figure 2.5: Histogram of P-values of Regression-based F-statistic Test

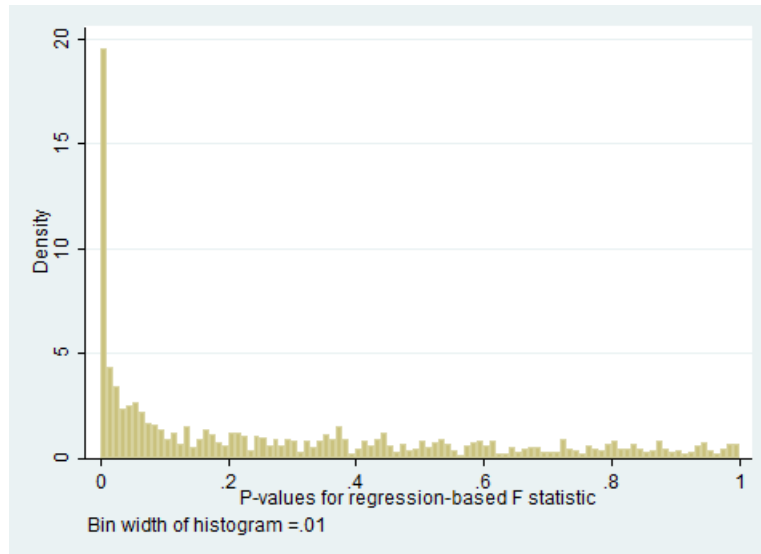
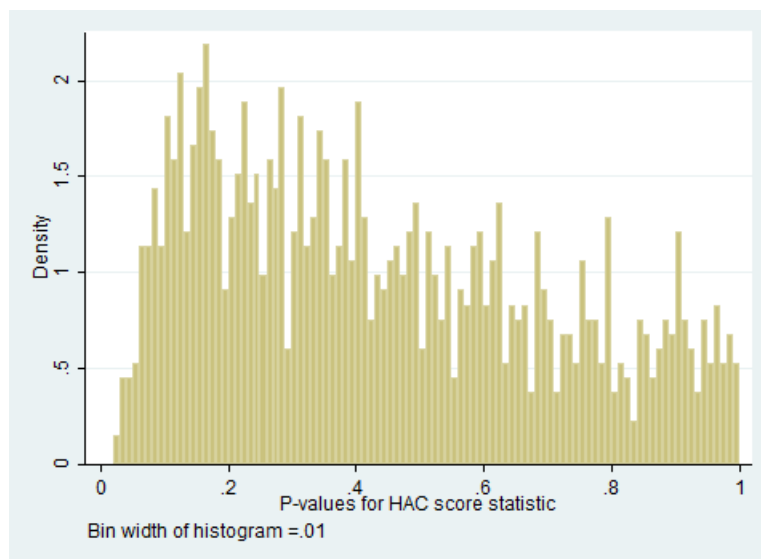


Figure 2.6: Histogram of P-values of HAC Score Test



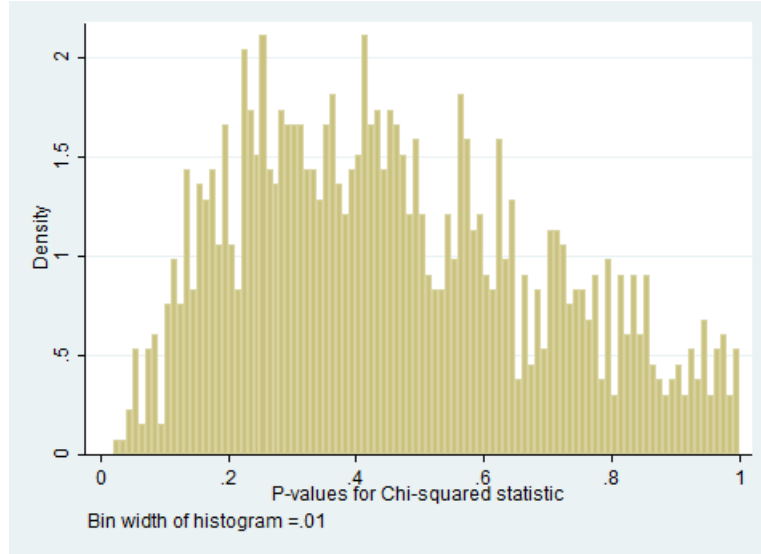
Overidentification Test Overidentification tests measure the validity of the exclusion restriction of the instruments conditional on the assumption that the other instruments are valid. The international basket of inputs is plausibly exogenous. However, the other two instruments require discussion.

The first instrument measures the how much prices increase for a sector relative to the GDP deflator. Endogeneity of the instrument would require that price changes in a sector's input sectors relative to the rest of the economy be correlated with the productivity shock of the sector. This is possible, but not necessarily immediately obvious the source. A demand increases for a sectors' goods may be correlated with productivity increases in its input sectors more than the rest of the economy.

The second instrument measures how much demand for a sector's composition of labor. The instrument is the wage changes of a particular sector as compared to wage changes in the country as a whole. Here it is in theory possible for demand for a particular sector to be more correlated with other sectors which have a similar labor skill composition as it. Demand for very high skilled sectors may be positively correlated with other very high skilled sectors, but it is not immediately obvious that this is the case. The overidentification tests are built to test the exclusion restriction conditional on the other instruments being valid.

The results of the overidentification test are reported in Figure 2.7. Because I use three instruments, I can test for overidentification using the χ -squared score test from Wooldridge (1995). The null hypothesis is that instruments are valid, and the alternative is that instruments are not valid. Results suggest that for the vast majority of cases, the instruments are valid.

Figure 2.7: Histogram of P-values of χ -squared Score Test



Comparison of Markup Estimates to Markup Bounds In Figures 2.8, 2.9, 2.10, & 2.11, I will show where the bounds fall in comparison to the estimates for the US, China, India, and Turkey as examples.²⁰ I include all other countries' estimates in Appendix .10.

2.9.2 Markups by Country

This section reviews summary statistics regarding the markup estimates by country and income. Included in Table 2.2 and Figure 2.12 are the average markups and their standard deviation by country with sectors weighted by 2009 value added

²⁰I include the US because it is the level of markups to which other countries are being compared. I include China and India because of their status as very large developing countries. I include Turkey because it has the highest estimates of markups largely driven by sector 29, Real Estate.

Figure 2.8: US Measured Markups as compared to Markup Bounds

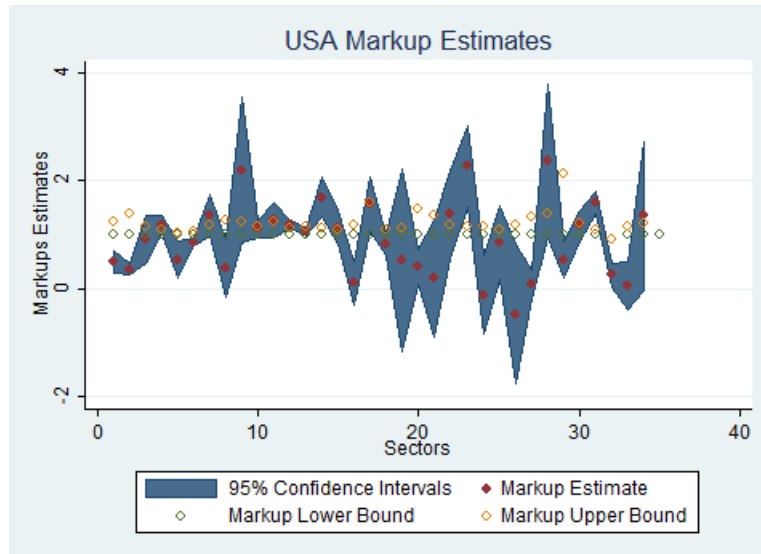


Figure 2.9: India Measured Markups as compared to Markup Bounds

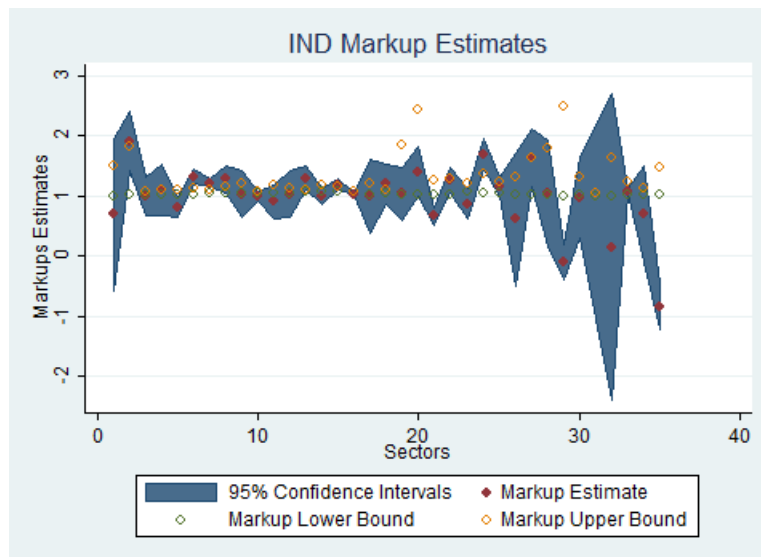


Figure 2.10: Turkey Measured Markups as compared to Markup Bounds

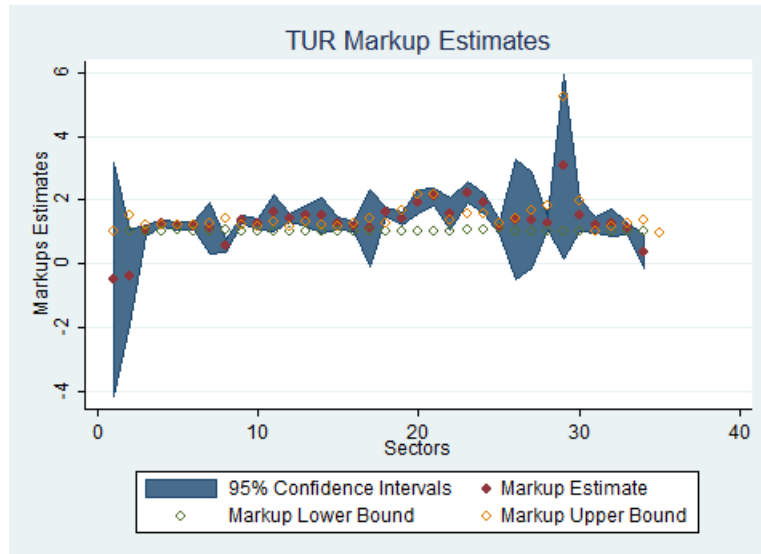
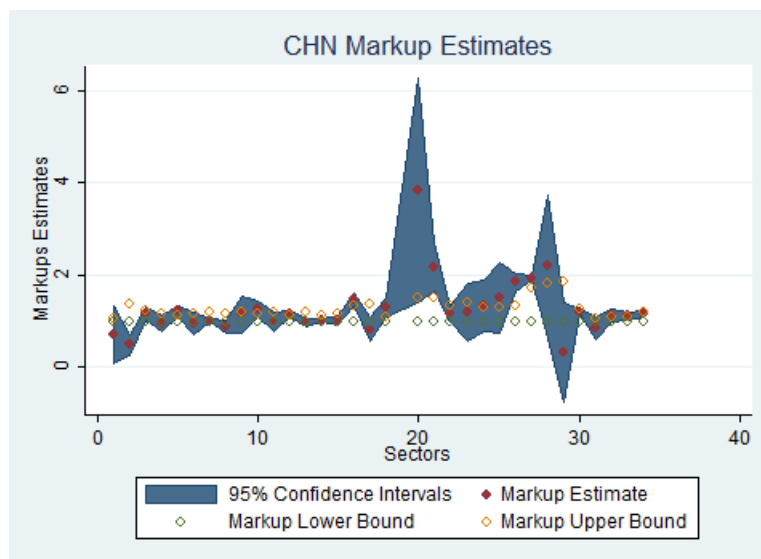


Figure 2.11: China Measured Markups as compared to Markup Bounds



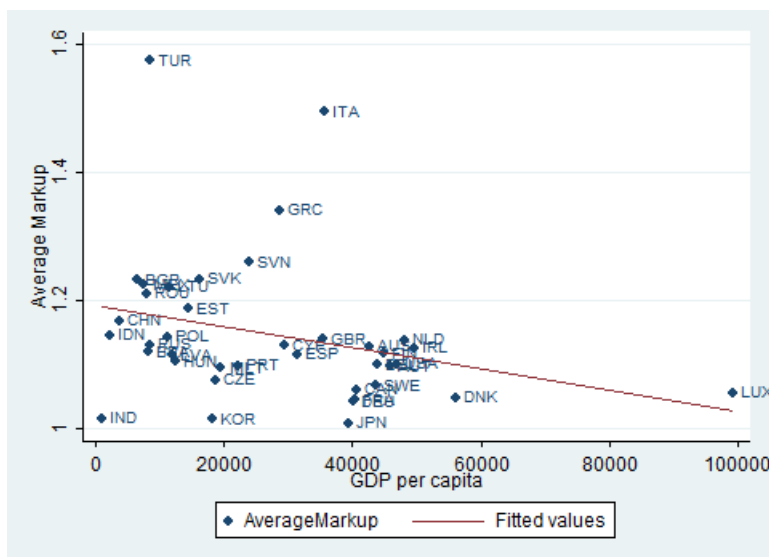
shares. Listed in order of their GDP per capita. As expected there is a strong negative correlation between the markups and the GDP per capita. Among developed countries, only Slovenia, Greece, and Italy have average markups higher than 1.2. Developing countries have generally higher markups with Bulgaria, Mexico, Romania, Turkey, Lithuania, Estonia, and Slovakia, all having markups well above 1.2. There are, however, numerous cases with low markups including India, Indonesia, China, Poland, and Hungary.²¹

There are numerous reasons that may keep markups low despite monopoly power existing in a country. The most straightforward explanation is that monopoly power is not an obstacle to aggregate productivity, but the low aggregate productivity may be driven by factors that drive up the costliness of inputs (red tape that uses management time, bad infrastructure driving up the use of labor, poor quality capital inputs with lower productivity, trade barriers, etc). Another explanation is that barriers to labor flexibility may both allow workers to keep some of the profits driving down the markup as well as may act as a barrier to the ability of firms to change their labor supplies (Domowitz Hubbard and Petersen, 1988). Finally, while the average markup may reflect the loss in productivity due to underuse of inputs, the standard deviation of markups may be the more important factor in determining misallocation between sectors.

I also estimate the weighted standard deviation according to the value added shares, in Table 2.2 and Figure 2.13. The variation in markups between sectors is the more important metric exacerbating misallocation between sectors in the econ-

²¹I draw the line between "developed" and "developing" somewhat arbitrarily at \$18,000 GDP per capita. By this measure there are 15 developing countries, and 24 developed countries.

Figure 2.12: Average Markup and GDP per Capita

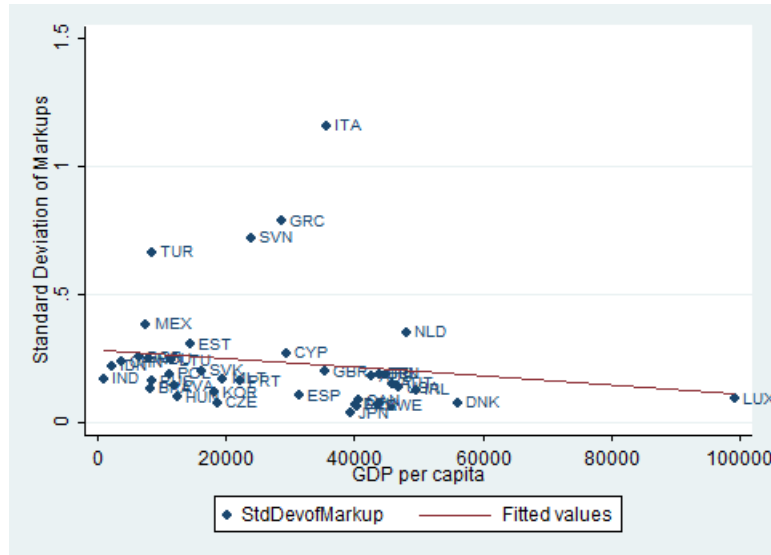


omy. Of the developing countries, Indonesia, China, Bulgaria, Mexico, Romania, Turkey, Lithuania, and Estonia all have standard deviations above 0.20. For developed countries, only Slovenia, Greece, Italy, Cypress, and the Netherlands have standard deviations above 0.20.

The standard deviation of markups is a our first summary statistic representing misallocation between sectors, and is the key factor in determining in driving misallocation of labor and capital between sectors. This in combination with the average markup may offer some clues as to what factors are most limiting to certain countries.

For example, Estonia has a much lower average markup than Slovakia, but a much higher standard deviation of markups. This may indicate that in Estonia while some sectors are very competitive others are very restricted, and that the flow of capital

Figure 2.13: Standard Deviation of Markups and GDP per Capita



and labor may be particularly distorted towards those with the low markups. The overall relatively low level of average markup may indicate that the concern over high markups may be restricted to only a few sectors and is not an economy wide problem that disincentivizes use of inputs in general. However, these higher markups may cause greater misallocation compared to when markups are widely distributed.

2.9.3 Results by Sector

The mean and standard deviation in markups by sector are also important to potentially identify sectors with substantial market power, or particular sectors which are subject to either very high or low average markups or standard deviation.

Table 2.2: Markups Summary Statistics by Country

Country	GDP per capita	μ	σ
IND	1147	1.02	0.17
IDN	2272	1.15	0.22
CHN	3749	1.17	0.23
BGR	6524	1.23	0.25
MEX	7690	1.22	0.38
ROU	8069	1.21	0.25
BRA	8373	1.12	0.13
RUS	8616	1.13	0.16
TUR	8626	1.57	0.66
POL	11295	1.14	0.19
LTU	11649	1.22	0.24
LVA	12082	1.11	0.14
HUN	12635	1.10	0.10
EST	14542	1.19	0.30
SVK	16196	1.23	0.20
KOR	18339	1.01	0.12
CZE	18881	1.08	0.08
MLT	19636	1.09	0.17
PRT	22153	1.10	0.16
SVN	24051	1.26	0.72
GRC	28695	1.34	0.78
CYP	29428	1.13	0.27
ESP	31368	1.12	0.11
GBR	35455	1.14	0.20
ITA	35724	1.49	1.16
JPN	39473	1.01	0.04
DEU	40270	1.04	0.07
FRA	40488	1.04	0.06
CAN	40764	1.06	0.08
AUS	42722	1.13	0.18
SWE	43640	1.07	0.07
BEL	43834	1.10	0.19
FIN	44838	1.12	0.19
AUT	45872	1.10	0.15
USA	46999	1.10	0.13
NLD	48174	1.14	0.35
IRL	49708	1.13	0.13
DNK	56227	1.05	0.08
LUX	99282	1.06	0.09

μ is the average markups of each sector weighted by value added. σ is the weighted standard deviation of markups according to value added. GDP per capita data is from 2009 and drawn from the World Bank World Development Indicators.

Average Markups A number of sectors have relatively high markups of greater than 1.2. Real estate, Wholesale trade, Telecommunications, and Financial Intermediation all stand out as particularly subject to high markups. This in general follows sectors which might be expected to be subject to monopoly power, large equilibrium size establishment. The one exception may be Real estate which may be due to the particularly speculative nature of real estate and substantial demand differentiation between non-homogenous products.

Standard Deviation of Markups Here, standard deviation is the standard deviation within a sector between countries. These reflect sectors which are very subject to monopoly power in some countries, but very competitive in others. Sectors which stand out as having high standard deviation (higher than 0.20) are Real Estate, Renting machinery and equipment, Telecommunications, Financial Intermediation, Wholesale and Retail trade.

Real Estate is by far the sector with the highest standard deviation. The reason for the variation in real estate has to do with both the underlying aspects of real estate as both very volatile and subject to both market power and business cycles. These mostly follow priors as to sectors which are subject to substantial market power which drives up both the average and standard deviations of markups.

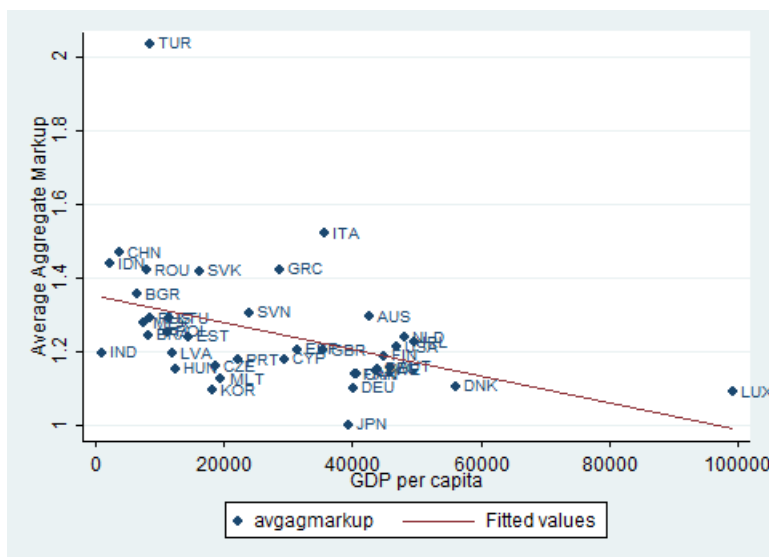
Also of note in Table 2.2 is which sectors are considerably more subject to markups in developing countries than in developed countries. While real estate seem to follow fairly closely between developed and developing economies, Financial intermediation Telecommunications, Wholesale, and Retail trade all show much higher monopoly power in developing countries than in developed countries. The

Table 2.3: Markups Comparison by Sector: Developed vs Underdeveloped

Sector	GDPsh	μ_{Dev}	σ_{Dev}	μ_{Und}	σ_{Und}	μ	σ
Agric, hunting, forestry, fishing	0.04	1.03	0.18	1.01	0.21	1.02	0.19
Mining and quarrying	0.02	1.20	0.43	1.12	0.21	1.17	0.36
Food, beverages, and tobacco	0.03	1.05	0.05	1.08	0.08	1.06	0.06
Textile and textile products	0.01	1.06	0.05	1.09	0.08	1.07	0.07
Leather and footwear	0.00	1.05	0.05	1.06	0.07	1.06	0.06
Wood and Products of Wood	0.01	1.05	0.05	1.11	0.09	1.08	0.08
Pulp, Paper, Printing, Publishing	0.01	1.08	0.06	1.12	0.10	1.09	0.08
Coke, ref petrol, nuclear fuel	0.01	1.05	0.07	1.11	0.16	1.07	0.12
Chemicals and chemical	0.02	1.12	0.10	1.11	0.08	1.12	0.09
Rubber and plastics	0.01	1.08	0.06	1.09	0.07	1.08	0.06
Other non-metallic mineral	0.01	1.12	0.06	1.13	0.11	1.12	0.08
Basic metals and fabricated metal	0.02	1.08	0.04	1.11	0.06	1.09	0.05
Machinery nec	0.01	1.07	0.03	1.10	0.08	1.08	0.06
Electrical and optical equipment	0.02	1.06	0.04	1.10	0.09	1.07	0.07
Transport equipment	0.01	1.04	0.09	1.12	0.09	1.07	0.10
Manufacturing nec; recycling	0.01	1.04	0.04	1.10	0.10	1.07	0.07
Electricity, gas, and water supply	0.03	1.12	0.18	1.11	0.12	1.12	0.16
Construction	0.07	1.07	0.07	1.15	0.11	1.10	0.09
Sale/repair of vehicles; retail gas	0.02	1.13	0.13	1.22	0.21	1.16	0.16
Wholesale trade, except vehicles	0.06	1.09	0.11	1.40	0.32	1.21	0.26
Retail trade, except vehicles	0.05	1.07	0.07	1.35	0.33	1.18	0.25
Hotels and Restaurants	0.03	1.06	0.07	1.15	0.14	1.09	0.11
Other Inland transport	0.03	1.05	0.10	1.19	0.17	1.10	0.15
Other Water transport	0.00	1.10	0.10	1.13	0.21	1.11	0.15
Other Air transport	0.00	1.05	0.05	1.09	0.12	1.07	0.08
Supporting transport activities	0.02	1.07	0.12	1.15	0.16	1.10	0.14
Post and telecommunications	0.02	1.11	0.16	1.34	0.27	1.20	0.24
Financial intermediation	0.06	1.11	0.14	1.32	0.27	1.19	0.22
Real estate activities	0.09	1.48	0.94	1.51	0.57	1.49	0.81
Renting m&eq	0.09	1.13	0.24	1.21	0.27	1.16	0.25
Public admin, defence; soc security	0.07	1.02	0.05	1.02	0.10	1.02	0.07
Education	0.05	1.00	0.06	1.05	0.06	1.02	0.06
Health and social work	0.06	1.02	0.03	1.06	0.05	1.04	0.04
Community and personal services	0.04	1.08	0.09	1.07	0.08	1.08	0.08
Households with employees	0.00			0.99	0.04	0.99	0.04

GDPsh is the average value added share of GDP for a given sector. μ_{Dev} is developed country markups, the unweighted average for a sector of all countries with GDP per capita of greater than \$18,000. σ_{Dev} is the unweighted standard deviation between countries of their markup by sector. μ_{Und} & σ_{Und} are unweighted average and standard deviation of markups for countries with GDP per capita less than \$18,000, μ & σ are unweighted average and standard deviation of markups for all countries.

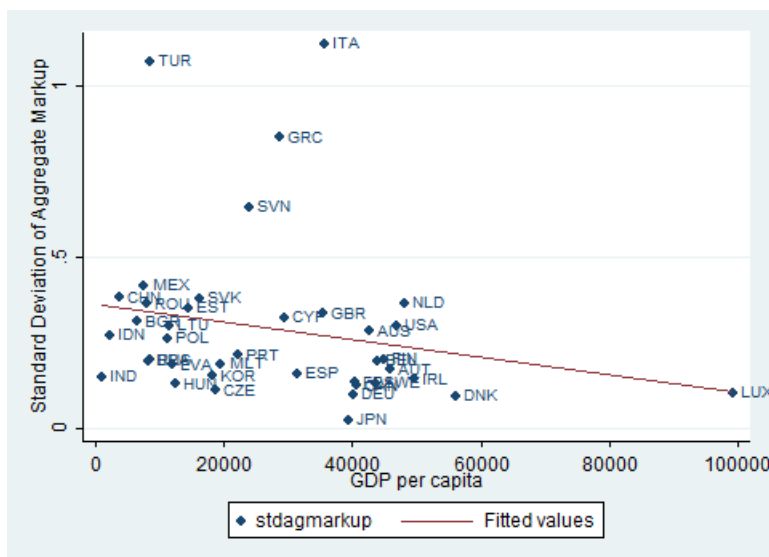
Figure 2.14: Average Aggregate Markup and GDP per Capita



main exception which has higher markups in developed countries than in developing countries is Mining and Quarrying. This may simply be a representation of higher likelihood of state owned mining and quarrying companies in developing countries which may drive down profits and markups.

Average Aggregate Markup by Country The results by country seem to follow a similar pattern as average markups, but it reveals a slightly different picture. Indonesia and China, which both had very low average markups have relatively high aggregate markups which are higher than any developed country's. The aggregate markup picture seems to point at a more crucial measure of the aggregate effect of all the markups in the country and the particular harm when sectors which are used as inputs are particularly subject to markups.

Figure 2.15: Standard Deviation of Aggregate Markup and GDP per Capita



Also, the developed-developing country comparison looks substantially different with the lowest developing country aggregate markup being India (1.20), Latvia (1.19) and Hungary (1.15), with a majority of developed countries having aggregate markups lower than 1.22 (exceptions are Italy (1.52), Greece(1.42), Slovenia(1.30), Australia(1.29), Ireland(1.22), and the Netherlands(1.24)). Turkey's aggregate markup is very high at 2.04, and this is largely driven by real estate which had a very large markup during that period. India still maintains a relatively low average aggregate markup, pointing heavily in the direction that markups and monopoly power are not the constraining factor, most likely other constraints to doing business are more important.

Aggregate Markup Standard Deviation by Country The standard deviation of aggregate markups is highly correlated with the level of aggregate markups. However, there are some important exceptions. Mexico, despite having slightly lower markups as compared to countries at the same level of GDP per capita, has a higher standard deviation, pointing to likely a higher misallocation between sectors.

Among developed countries, Greece Slovenia, and Italy both have large dispersion in aggregate markups pointing to likely misallocation of resources away from high markup sectors and towards low markup sectors. Japan stands out in its extremely low markups, but this is more likely a product of deflation in Japan coinciding with the period covered by the data (1995-2009) rather than pointing to a purely structural competitive environment.

2.9.4 Aggregate Markup by Sector

Results for aggregate markups by sector follow the same general pattern as the average markup. Real estate(1.71), Financial Intermediation(1.49), Wholesale trade(1.45), and Telecommunications (1.36) are all still high, but added to these sectors with high markups is Renting machinery and equipment(1.58) and Electricity, Gas and Water supply (1.34). This is of special policy concern in that nearly all of these sectors are primarily used as inputs to other sectors and important public goods for the functioning of the economy.

Aggregate Markups The theory would predict that the distribution of aggregate markups would match up more closely to the distribution of output than average

Table 2.4: Comparison of Average Markup and Average Aggregate Markup

Country	$\bar{\rho}$	σ_{ρ}	μ	σ_{μ}	GDPpc
IND	1.20	0.15	1.02	0.17	1147
IDN	1.44	0.27	1.15	0.22	2272
CHN	1.47	0.38	1.17	0.23	3749
BGR	1.36	0.31	1.23	0.25	6524
MEX	1.28	0.42	1.22	0.38	7690
ROU	1.42	0.36	1.21	0.25	8069
BRA	1.24	0.20	1.12	0.13	8373
RUS	1.29	0.20	1.13	0.16	8616
TUR	2.04	1.07	1.57	0.66	8626
POL	1.25	0.26	1.14	0.19	11295
LTU	1.29	0.30	1.22	0.24	11649
LVA	1.19	0.19	1.11	0.14	12082
HUN	1.15	0.13	1.10	0.10	12635
EST	1.24	0.35	1.19	0.30	14542
SVK	1.42	0.38	1.23	0.20	16196
KOR	1.09	0.15	1.01	0.12	18339
CZE	1.16	0.11	1.08	0.08	18881
MLT	1.12	0.19	1.09	0.17	19636
PRT	1.18	0.21	1.10	0.16	22153
SVN	1.30	0.64	1.26	0.72	24051
GRC	1.42	0.85	1.34	0.78	28695
CYP	1.18	0.32	1.13	0.27	29428
ESP	1.21	0.16	1.12	0.11	31368
GBR	1.20	0.34	1.14	0.20	35455
ITA	1.52	1.12	1.49	1.16	35724
JPN	1.00	0.02	1.01	0.04	39473
DEU	1.10	0.10	1.04	0.07	40270
FRA	1.14	0.13	1.04	0.06	40488
CAN	1.14	0.12	1.06	0.08	40764
AUS	1.29	0.28	1.13	0.18	42722
SWE	1.15	0.13	1.07	0.07	43640
BEL	1.15	0.20	1.10	0.19	43834
FIN	1.19	0.20	1.12	0.19	44838
AUT	1.16	0.17	1.10	0.15	45872
USA	1.21	0.30	1.10	0.13	46999
NLD	1.24	0.36	1.14	0.35	48174
IRL	1.22	0.14	1.13	0.13	49708
DNK	1.11	0.09	1.05	0.08	56227
LUX	1.09	0.10	1.06	0.09	99282

$\bar{\rho}$ is the average aggregate markups are calculated by the weighted average of aggregate markups according to their final goods and exports share of total final goods and exports. σ_{ρ} is the weighted standard deviation of aggregate markups weighted according to their final goods and exports share of total final goods and exports. μ is the country's average markup weighted by value added. σ_{μ} is the standard deviation of the markup weighted by value added.

Table 2.5: Aggregate Markup by Sector

Sector	ρ	σ_ρ	β
Agric, hunting, forestry, fishing	1.15	0.29	0.04
Mining and quarrying	1.29	0.45	0.02
Food, beverages, and tobacco	1.16	0.20	0.03
Textile and textile products	1.11	0.12	0.01
Leather and footwear	1.07	0.07	0.00
Wood and Products of Wood	1.13	0.13	0.01
Pulp, Paper, Printing, Publishing	1.20	0.15	0.01
Coke, ref petrol, nuclear fuel	1.16	0.18	0.01
Chemicals and chemical	1.22	0.20	0.02
Rubber and plastics	1.13	0.11	0.01
Other non-metallic mineral	1.18	0.13	0.01
Basic metals and fabricated metal	1.24	0.21	0.02
Machinery nec	1.12	0.09	0.01
Electrical and optical equipment	1.13	0.13	0.02
Transport equipment	1.12	0.16	0.01
Manufacturing nec; recycling	1.08	0.08	0.01
Electricity, gas, and water supply	1.34	0.28	0.03
Construction	1.25	0.17	0.07
Sale/repair of vehicles; retail gas	1.22	0.20	0.02
Wholesale trade, except vehicles	1.45	0.44	0.06
Retail trade, except vehicles	1.34	0.38	0.05
Hotels and Restaurants	1.14	0.16	0.03
Other Inland transport	1.30	0.45	0.03
Other Water transport	1.14	0.20	0.00
Other Air transport	1.09	0.10	0.00
Supporting transport activities	1.21	0.22	0.02
Post and telecommunications	1.36	0.38	0.02
Financial intermediation	1.49	0.48	0.06
Real estate activities	1.71	0.99	0.09
Renting m&eq	1.58	0.50	0.09
Public admin, defence; soc security	1.04	0.08	0.07
Education	1.03	0.07	0.05
Health and social work	1.04	0.05	0.06
Community and personal services	1.15	0.11	0.04
Households with employees	1.00	0.01	0.00

ρ is the average of aggregate markups weighted by their share of final goods and exports. σ_ρ is the standard deviation of aggregate markups weighted by their share of final goods and exports. β is the average sector share of final goods and exports.

markups. The results confirm this. For purely illustrative purposes I report the regressions of average markup, average aggregate markup, standard deviation of markup and the standard deviation of aggregate markups GDP per capita. I use GDP per capita as the independent variable because the average markups, average aggregate markups, standard deviation of markups and the standard deviation of aggregate markups are generated variables. The standard errors are bootstrapped.

For the individual regressions, the R-squared for the regression of average markup on GDP per capita jumps from 0.083 to 0.176 when regressing GDP per capita on average aggregate markup. The R-squared increases from .022 when regressing GDP per capita on the standard deviation of markups to 0.045 when using the standard deviation of aggregate markups.

While alone these results would not necessarily be strong evidence of the importance of markups for development, it does indicate that GDP per capita correlates more closely with aggregate markups than average markups, and more closely with standard deviation of aggregate markups than standard deviation of markups.

2.9.5 Output Growth Results

The final part of the results are estimates for how much output would grow if countries shifted from their markups to US levels of markups given a fixed level of aggregate capital. This is calculated by replacing a country's markups by the level of markups in the US. This is the benefit solely from the misallocation between sectors.

Among developing countries, all countries have a predicted increase in aggregate TFP as a result of switching to US levels of markups. The largest is Turkey with a

Table 2.6: Regressions of GDP per capita on Markup Variables

VARIABLES	(1) AvgMarkup	(2) AggMarkup	(3) StdMarkup	(4) StdAggMarkup
GDPpc	-1.68e-06** (7.32e-07)	-3.65e-06** (1.45e-06)	-1.69e-06 (1.38e-06)	-2.57e-06 (1.67e-06)
Constant	1.193*** (0.0330)	1.354*** (0.0544)	0.283*** (0.0427)	0.365*** (0.0635)
Observations	39	39	39	39
R-squared	0.083	0.176	0.022	0.045

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

27% increase in TFP, Indonesia with a 17% increase in TFP, and Romania with a 16% increase in TFP.

Among developed countries, most countries face relatively small changes in TFP. The largest increase in developed countries is Slovenia and Italy, which increase by 9% each as a result of switching to US level of markups. The biggest contraction is in Luxembourg, which would face a 28% contraction in aggregate TFP at US levels and distribution of markups.

This estimate of increased output reflects the movement to a new steady state in the context of a fixed capital stock. Allowing the aggregate capital stock to grow amplifies the effect, but not always completely uniformly as the amplification will also depend on the estimated return on capital. The estimate of the change in total output when integrating capital accumulation varied from -1% to 24% (and 60% for Turkey) for developing countries, and from -10% to 26% for developed countries with the exception of a -37% contraction for Luxembourg.

Table 2.7: Growth in Output as a Percentage from US Levels of Markups

Country	GDPpc	ρ	σ_ρ	Δ TFP	Δ Y
IND	1147	1.20	0.15	0	-1
IDN	2272	1.44	0.27	17	24
CHN	3749	1.47	0.38	5	7
BGR	6524	1.36	0.31	7	19
MEX	7690	1.28	0.42	8	11
ROU	8069	1.42	0.36	16	24
BRA	8373	1.24	0.20	1	1
RUS	8616	1.29	0.20	1	4
TUR	8626	2.04	1.07	27	60
POL	11295	1.25	0.26	13	15
LTU	11649	1.29	0.30	10	17
LVA	12082	1.19	0.19	3	5
HUN	12635	1.15	0.13	0	-1
EST	14542	1.24	0.35	5	11
SVK	16196	1.42	0.38	12	24
KOR	18339	1.09	0.15	-1	-2
CZE	18881	1.16	0.11	-4	-5
MLT	19636	1.12	0.19	-2	-4
PRT	22153	1.18	0.21	0	0
SVN	24051	1.30	0.64	9	14
GRC	28695	1.42	0.85	8	26
CYP	29428	1.18	0.32	5	5
ESP	31368	1.21	0.16	-1	2
GBR	35455	1.20	0.34	-1	-2
ITA	35724	1.52	1.12	9	17
JPN	39473	1.00	0.02	-2	-10
DEU	40270	1.10	0.10	-3	-5
FRA	40488	1.14	0.13	-3	-5
CAN	40764	1.14	0.12	0	-2
AUS	42722	1.29	0.28	4	5
SWE	43640	1.15	0.13	0	-1
BEL	43834	1.15	0.20	-3	0
FIN	44838	1.19	0.20	2	5
AUT	45872	1.16	0.17	1	2
USA	46999	1.21	0.30	0	0
NLD	48174	1.24	0.36	4	7
IRL	49708	1.22	0.14	3	5
DNK	56227	1.11	0.09	0	-1
LUX	99282	1.09	0.10	-28	-37

ρ are the weighted average of aggregate markups weighted by sectors' share of final goods and exports. σ_ρ is the standard deviation of aggregate markups weighted by their share of final goods and exports. Δ TFP represents the growth in aggregate TFP from moving to the US levels of markups. This is a new steady state from reallocation, but does not take into account growth from aggregate capital accumulation. Δ Y is the estimate of output change with capital accumulation. All estimates are the log output change converted to percentages by $(e^x - 1) * 100$.

2.10 Conclusions

One of the major advancements in the economic growth literature has been investigating the role that within-sector misallocation of capital and labor can play in explaining differences between developed and developing countries. Here, I investigate whether misallocation between sectors may also be an important source of misallocation and to what degree markups can offer an explanation for the TFP and output gap between developed and developing countries.

The theoretical model, based on a model proposed by Jones (2011a), has given a few important theoretical conclusions. First, both frictions and market power act as a wedge between the marginal product of an input and its price which drives down aggregate productivity. This may happen through discouraging use of intermediate goods, causing firms to substitute away from intermediates dragging down sector and aggregate productivity. Further, variation in those wedges causes misallocation in two ways. Variation in wedges across sectors causes misallocation of labor, capital, and intermediate inputs. Wedges also cause misallocation of production of final goods towards those sectors with lowest aggregate markup, the markup of the sector including the markups affecting input sectors. Finally, this between-sector misallocation of resources drives down aggregate productivity. Thus, there is lower aggregate capital accumulation from the disparity in markups and aggregate markups.

This definition and measurement of aggregate markups, accounting for not only sector markups, but also the markups inherent in input sectors is a key contribution of the paper. The aggregate markups and standard deviation of aggregate are about twice as highly correlated with output differences between countries than average

markups and average standard deviation.

I measure the wedges which drive the between-sector misallocation by drawing on the large literature on markups. Measured markups are higher in developing countries, but aggregate markups are especially high in most developing countries even in some cases when markups alone are not. Further, predictions as to the benefits to reallocation are substantial, but fairly small in comparison to the degree necessary to close the TFP differences between developed and developing countries. Most developing countries have an increase in TFP of less than 18% with Turkey as an outlier at 27%. Allowing the aggregate capital stock to change yields increases of -1 to 24% (and 60% for Turkey).

Some important caveats should be noted with respect to interpreting the results. The first is that the results measure the improvement in steady state GDP, and it very well may be that some countries are not currently at their steady state. It may be argued that India, China, and several other emerging markets growing at high rates reflect that they are converging to developed country steady states. In that sense their expected steady state GDP per capita should be substantially higher than their present GDP per capita, and we should see substantially lower changes in output than if they had already reached their steady state output.

Also the conclusions of the paper should be interpreted as the between-sector misallocation effect, as both the frictions and the monopoly almost certainly have within-sector effects which may affect within-sector productivity. Importantly, the model restricts a final good to have constant shares of each sector output, so it is likely a lower bound on the effect of between-sector misallocation since by construction it

requires shares of output by sector to remain constant.

Chapter 3

Cross Country Income Accounting and Between-Sector Misallocation

3.1 Introduction

The growth accounting literature has estimated the relative contributions of capital and labor from aggregate productivity. I add to this literature in two substantial ways. First, the input-output structure of the model developed in the previous chapter allows an estimation not simply of the direct effect of the capital and human capital stock in aggregate, but also how changes in capital and human capital stock affect aggregate output through the interdependence of sectors. Second, it allows separation of three effects, that were previously implicitly in the aggregate total factor productivity: the sector level productivity, the misallocation of resources between sectors measured by markups, and the underlying demand for sectors' final goods

and exports.

A broad literature has arisen to identify differing potential explanatory factors which may go to explain this productivity factor. Lagos (2006) shows how labor frictions and their distribution may play a role in determining aggregate TFP. Basu and Fernald (2002) provide a distinction between aggregate productivity and aggregate technology. Buera, Kaboski, and Shin (2009) show that a large portion of between country income differences can be explained by capital frictions and their concomitant inefficiencies building on a large literature measuring the effect of credit market imperfections. Within-sector misallocation has been a source of substantial loss of sector productivity (Hsieh and Klenow, 2009; Restuccia and Rogerson 2008; Peters 2013; Bartlesman, Haltiwanger, and Scarpetta, 2013).

Here I use the model developed to estimate the percentage change to a country's income from five sources: capital, human capital, productivity, between-sector misallocation, and sectoral demand parameters.

Previous approaches to cross-country income accounting was done under the assumption of perfect competition and no interdependence of sectors. Under the assumption of perfect competition, Cobb-Douglas parameter on capital is substantially higher than if markups are taken into account. Viewed from the imperfect competition lens, much of the frequently discussed high returns to capital in developing countries may be driven by factors which drive misallocation. Here we can review those analyses and estimate to what degree accounting for wedges reflected in markups may give a more refined picture as to what drives income differences.

Additionally, the interdependence of sectors, when by each sector's inputs used

as factors of production for other sectors, drives a multiplier effect from increases in productivity, human capital, capital stock and decreases in wedges. An increase in the productivity of a given sector leads to an increase in inputs from other sectors, leading to further productivity gains from sectors consuming their intermediates, etc. Accounting for these cross sector dependence allows differences in human capital stocks, and sector productivity to explain much more than they would in a traditional income accounting exercise.

First, I report the levels of human capital stock, capital stock, productivity, and sectoral demand parameters. Second, I calculate the hypothetical exercises for how countries' output would change if they shifted to US levels of sector productivity, capital stock per hour worked, human capital stock per hour worked, wedges and sectoral demand parameters. Third, I estimate the multipliers for productivity, capital, and human capital. Finally, I estimate to what degree the cross-country income differences are explained by differences in capital, human capital, misallocation, and sector-level productivity.

3.2 Income Difference Accounting

In this section, I review the theoretical impact of moving to US levels of capital stock per capita, and human capital stock per capita productivity, wedges, and sectoral demand parameters. To do this, I use the international version of the model developed in the previous chapter. The equilibrium output equation is given by equation (69):

$$\log Y = \frac{\beta' \omega_y + \beta'(I - B)^{-1}(a + \omega^Q + \omega + \epsilon \log H + \alpha \log K)}{1 - \beta'(I - B)^{-1} \lambda^*} \quad (3.1)$$

The exponential version of this equation is:

$$Y = A^\psi (1 - \tau)^\psi H^{\psi_H} K^{\psi_K} \xi \quad (3.2)$$

where the multipliers are given by

$$\begin{aligned} \psi &= \frac{\beta'(I - B)^{-1} \mathbf{1}}{1 - \beta'(I - B)^{-1} \lambda^*} \\ \psi_H &= \frac{\beta'(I - B)^{-1} \epsilon}{1 - \beta'(I - B)^{-1} \lambda^*} \\ \psi_K &= \frac{\beta'(I - B)^{-1} \alpha}{1 - \beta'(I - B)^{-1} \lambda^*} \end{aligned}$$

and ξ is given by

$$\begin{aligned} \log(\xi) &= \beta' \omega_y + \beta'(I - B)^{-1}(\omega + \tilde{\eta}_a + \tilde{\eta}_\tau) \\ A \eta_{as} &= A_s \\ (1 - \tau) \eta_{\tau i} &= \frac{\sigma_i - 1}{\sigma_i} (1 - \tau_i) \end{aligned}$$

where A is the weighted average of the productivity: $\log(A) = \beta_1 \log(A_1) + \beta_2 \log(A_2)$.

τ is the weighted average of the markups: $\log(1 - \tau) = \beta_1 \log(\frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1)) +$

$\beta_2 \log(\frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2))$. $\tilde{\eta}_a$ and $\tilde{\eta}_\tau$ are vectors of the logged η_{as} and $\eta_{\tau s}$ terms.

Table 3.1: Variables in the Model

Vector/Matrix	Element	Explanation
β	β_s	The vector of shares of final goods and export production
α	α_s	The vector of shares of capital shares by sector
ϵ	ϵ_s	The vector of shares of labor shares by sector
λ^*	$\lambda_s^* = \sum_{j=1}^N \lambda_{sj}^*$	The vector of shares of imported inputs by sector
γ	$\frac{p_s Q_s}{Y}$	The ratio of gross output from sector s to GDP
B	λ_{sj}	The undistorted domestic input-output matrix
\bar{B}	$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{sj}$	The distorted input-output matrix
θ_s^K	$\frac{\alpha_s \gamma_s}{\sum_{j=1}^N \frac{\sigma_j - 1}{\sigma_j} (1 - \tau_j^Q) \alpha_j \gamma_j}$	The allocation term for capital
θ_s^H	$\frac{\epsilon_s \gamma_s}{\sum_{j=1}^N \frac{\sigma_j - 1}{\sigma_j} (1 - \tau_j^Q) \epsilon_j \gamma_j}$	The allocation term for human capital
ω^K	$\alpha_s \log(\theta_s^K)$	Sectoral allocation term for capital
ω^L	$\epsilon_s \log(\theta_s^H)$	Sectoral allocation term for human capital
ω^m	$\sum_{j=1}^N \lambda_{sj} \log(\frac{2s}{\gamma_j} \lambda_{sj})$	Sectoral allocation term for domestic intermediates
ω^Q	$\log(\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q))$	Vector of frictions and market power
ω	$\omega^K + \omega^L + \omega^m$	Sum of allocation terms
ω_y	$\log(\frac{\beta_s}{\gamma_s})$	Shares of final goods, exports, and GFCF to total sector output
a	$\log(A_s)$	Vector of logged sector productivity
$\tilde{\eta}_a$	$\log(\eta_{as})$	Vector of the logged variance of productivities
$\tilde{\eta}_\tau$	$\log(\eta_{\tau s})$	Vector of the logged variance of frictions and market power

From this equation I estimate the effect of changing a given parameter of the model. I compare different hypotheses for what drives income differences by comparing differences between countries according to changing different parameters of the model. The six different potential sources of difference are:

1. differences in human capital stock ($\frac{H}{L}$)
2. differences in physical capital stock ($\frac{K}{L}$)
3. sector level productivity (a)
4. differences in structural allocation of production (β)
5. wedges driving between-sector misallocation (τ)
6. differences in sector level parameters ($\alpha, \epsilon, \lambda, \lambda^*$).

I will estimate the effect of moving to US levels of the first five sets of parameters.

Changes in H To estimate the effect of switching to US levels of human capital stock, I estimate:

$$\Delta \log Y^C = \frac{\beta'^C (I - B^C)^{-1} \epsilon^C (\log(\bar{h}^{US}) - \log(\bar{h}^C))}{1 - \beta'^C (I - B^C)^{-1} \lambda^*} \quad (3.3)$$

where \bar{h}^C is the average level of human capital in the country of interest, \bar{h}^{US} is the average level of human capital per hour in the US, and L is the total number of hours worked.

I estimate the total human capital stock using the perpetual inventory method with regard to education spending. The 1995 estimate of human capital is given by 1995 education spending divided by .05 (assumed to be the depreciation rate of human capital), with each year after that assuming a 5% depreciation rate and adding the yearly education spending. I estimate average human capital by dividing the total human capital by the hours worked.

Changes in Capital Stock, K To estimate the effect of switching to US levels of physical capital stock per hour worked, I estimate:

$$\Delta \log Y^C = \frac{\beta'^C (I - B^C)^{-1} \alpha^C (\log(\bar{k}^{US}) - \log(\bar{k}^C))}{1 - \beta'^C (I - B^C)^{-1} \lambda^*} \quad (3.4)$$

where \bar{k}^C is the average level of capital per hour worked in the country of interest, \bar{k}^{US} is the average level of capital per hour worked in the US. Capital stock is measured

in US 1995 dollars.¹

Changes in A To estimate the effect of switching to US levels of productivity between sectors, I estimate:

$$\Delta \log Y^C = \frac{\beta'^C (I - B^C)^{-1} (a^{US} - a^C)}{1 - \beta'^C (I - B^C)^{-1} \lambda^*} \quad (3.5)$$

where a^C is the logged vector of sector productivity for the country of interest, a^{US} is the logged vector of sector productivity for the US.

The productivity is found by calculating

$$\log(A_s) = \log Q_s - \log(K_s) - \log(H_s) - \log(M_s) \quad (3.6)$$

where Q_s , K_s and M_s are measured in 1995 US dollars for all countries, Q_s is the value of output deflated by the markup in sector s , and H_s represents the total human capital adjusted hours worked.

Changes in β To estimate the effect of switching to US levels of structural allocation of production, I estimate:

$$\Delta \log Y^C = \left(\frac{\beta'^{US}}{1 - \beta'^{US} (I - B^C)^{-1} \lambda^*} - \frac{\beta'^C}{1 - \beta'^C (I - B^C)^{-1} \lambda^*} \right) *$$

¹Sector-level capital stocks and hours engaged are available in the socioeconomic accounts in the World Input Output Database as in Chapter 2. Foreign exchange rates are implicit in the SEA and the national input-output tables because the former are in local currency and the latter are in dollars. The measure of capital stock by hour engaged is the aggregate capital stock divided by total hours engaged country.

$$(\omega_y^C + (I - B^C)^{-1}(a^C + \omega^{CQ} + \omega^C + \epsilon^C \log H^C + \alpha^C \log K^C)) \quad (3.7)$$

where {C, US} represent the country of interest or the US respectively.

Changes in Wedges (τ) These are included exactly as found in the previous chapter.

This evaluates the effect of moving to US levels of markups.

$$\Delta \log Y^C = \frac{\beta'^C (\omega_y^{C,US} - \omega_y^C) + \beta'^C (I - B^C)^{-1} (\omega^{QUS} + \omega^{C,US} - \omega^{QC} - \omega^{C,US})}{1 - \beta'^C (I - B^C)^{-1} \lambda^*} \quad (3.8)$$

Discussion of Theoretical Implications of Moving to US Parameters Each of these sets of parameters represents a different potential aspect of barriers to development and disaggregating the effect between them allows us to better identify both the barriers to development and how they manifest. Though each of the six factors are related they are distinct concepts and may help in identifying how best to understand barriers to development generally and in specific cases.

The first thing to note about the general framework is that the first three factors (human capital, capital, and productivity) increase output in similar ways. An increase in human capital increase output in sectors in accordance to their dependence on human capital, ϵ . An increase in capital increases output in sectors dependent on their capital shares, α . An increase in productivity will increase the level of output for given levels of capital, human capital, and inputs.

Each of these changes propagates through the economy in similar ways. The Leontief inverse matrix, $(I - B)^{-1}$, determines how increase in productivity for a

set of sectors will propagate through the economy and affect the overall output of all sectors. The ij^{th} component of the Leontief inverse determines how an increase in productivity in a given sector, j affects the output of sector i . β reflects the weighting of final goods and exports by sector. The international multiplier term $\frac{1}{1-\beta'C(I-B^C)^{-1}\lambda^*}$ reflects how much output as a whole increases from sector dependence on international trade.²

Each of these first three sets of parameters have direct and uniformly positive impacts on output. As long as the US has higher levels of human capital, capital, and productivity than the compared country, the effect will be positive. The multipliers on the three factors differ only insofar as sectors differ in their human capital or capital parameters.

The latter two terms, the sectoral demand parameters (β) and wedges (τ), have more complex effects. Both determine between-sector allocation of production. The wedge term $\frac{\sigma_s}{\sigma_s-1} \frac{1}{(1-\tau_s^Q)}$ affects both demand of final goods and intermediate goods. It represents a bias away from reflecting the true demand from business and from consumers. Further, it causes misallocation because with the level of markups will cause business to substitute away from intermediate inputs substituting either capital or labor as compared to the efficient allocation. Estimation of the effect of this term gives us how much the level and distribution of markups lead to positive reallocation and increase in production.

The β term reflects the final goods and export demand for products. This perhaps heroically assumes that demand between sectors does not change, and tests what is

²This multiplier effect depends on the balanced trade assumption. An increase in productivity in sectors at home allow the purchase of more foreign inputs.

the effect of moving to US levels of underlying distribution of sector demand. A priori it may be that developed countries are developed not only because of high capital, human capital and productivity, but also because they have specialized in the sectors which have higher productivity across countries. This tests how much other countries output would change if they had the same underlying demand and production allocation as the US. This may also be a more longer term estimate of the effects of structural change in the absence of productivity changes.

Finally, it is important to note that these predictions need not sum to US levels of output. The estimates of the effect of switching to US levels of K , H , a , and τ are conditional on the levels of β . Similarly, the estimate of moving to US levels of β is conditional on K , H , a , and τ .

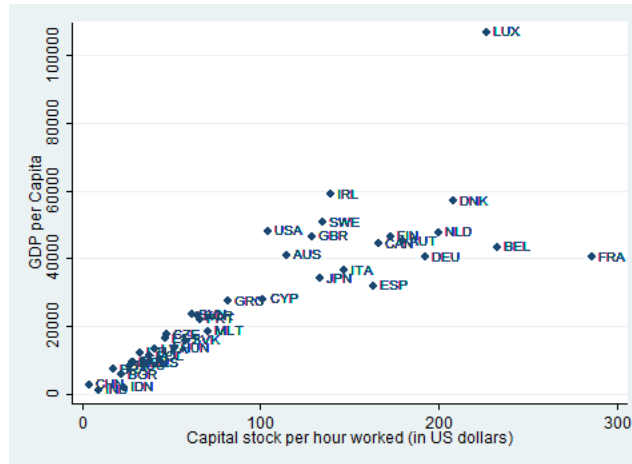
3.3 Data

Data used is the same as used in Chapter 2. The primary source of data is the European Commission World Input Output Database, which includes both National Input Output Tables and Socioeconomic Tables including sector level data for 39 countries. To construct the instruments used to measure the markups in the previous chapter additional data is used from the World Bank World Development Indicators.

3.4 Results

First I will review some of the preliminary results on differences in measured variables. Figure 3.1 shows that differences in capital stock per hour worked are very closely

Figure 3.1: Capital Stock per Hour Worked and GDP per Capita

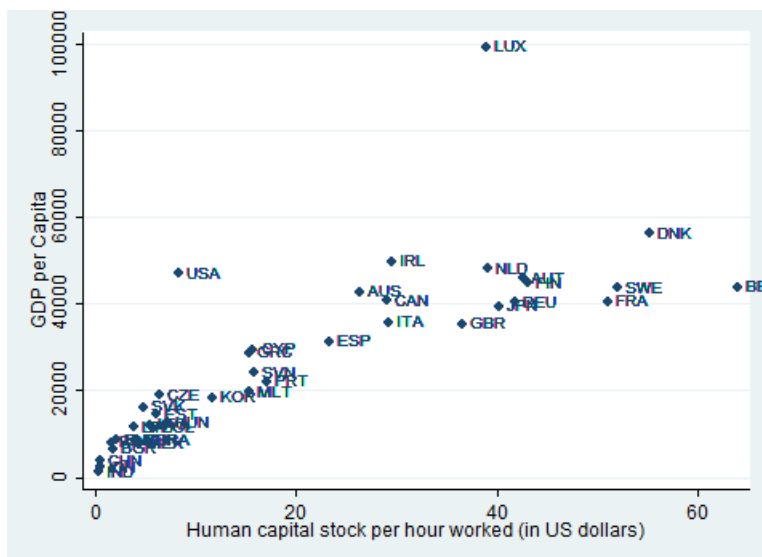


aligned to GDP per capita.

Figure 3.2 shows differences in human capital per hour worked are very closely aligned to GDP per capita.

Figure 13 plots countries' average productivity weighted by the sector value added. Here the correlation between GDP per capita and productivity is still positive, but is much less strong than the capital and human capital stock. The distribution of countries suggests that some countries may have micro level productivity sufficient to be developed but may be hindered by other barriers such as frictions or low productivity in disproportionately important sectors. Also of note here, is that the US is an outlier with very high weighted sector-level productivity. One possible explanation may be that this measure of human capital stock may take too much credit for factors which are better thought of as productivity. The weak relationship justifies further estimates of whether other measures of human capital differences

Figure 3.2: Human Capital Stock per Hour Worked and GDP per Capita

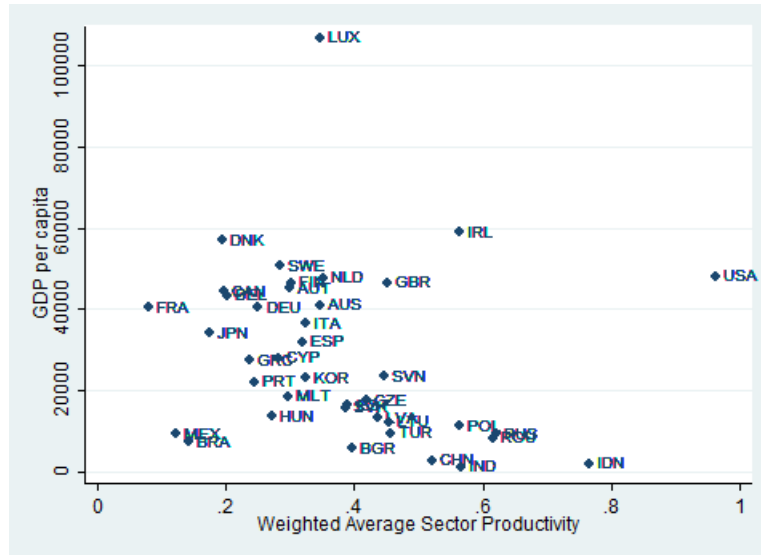


between countries give similar results.³

I report the correlation between sector TFP and β in figure 3.4 as a loose measure of the potential gains from structural reallocation towards more productive sectors. There is only a loosely positive link between this correlation and GDP per capita. The dispersed results suggest that while some countries are specialized in their most productive sectors, and for others the opposite is true. The lack of a strong positive relationship between GDP per capita and the correlation between β and TFP suggests that most countries do not primarily develop by increasing their production in

³It should also be noted that the US' high productivity may be in part caused by the very low measured total human capital stock. In the US education expenditure per hour worked seems far lower than would be expected for a country with its GDP and on par with middle income countries. If it is understated, it will cause inflated estimates for sector productivity because of the lower human capital use if this measure doesn't accurately capture US human capital stock per hour worked.

Figure 3.3: Average Weighted Productivity and GDP per Capita



their most productive sectors, but by making all sectors more productive. This also offers confirmation of McMillan & Rodrik (2011) observation that structural change does not necessarily move towards the most productive sectors.

The results from the comparative estimation of shifting to US levels of parameters in Table 3.2 gives a clear picture as to the relative importance of each of the factors. Human capital and capital stock convergence are important factors and potentially increase output of the poorest countries in the sample by up to 776 percent for human capital per hour worked and up to 177 percent for capital stock per hour worked, but it is clear that the results here confirm what the growth accounting literature has found that there is still a large amount of the cross-country income differences that are unexplained by these two factors.

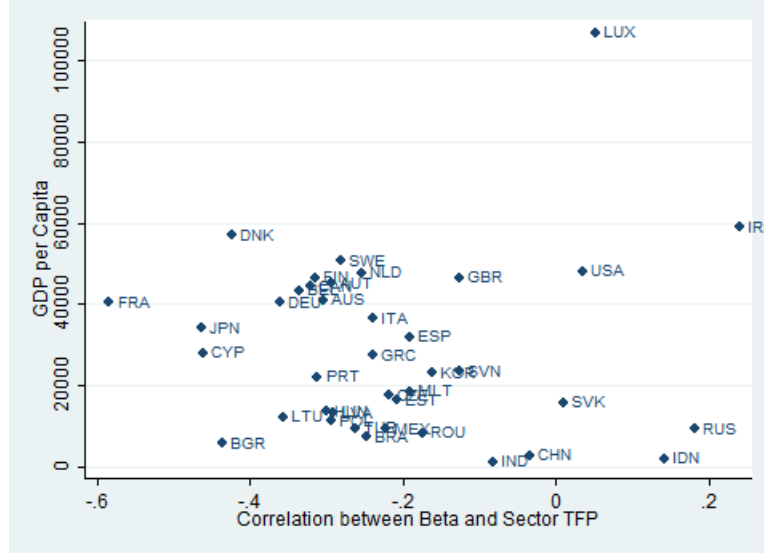
By far the largest and most consistently positive effect is driven by the differences

Table 3.2: Expected Percentage Change in Output from moving to US parameters

Country	GDPpc	H	K	TFP	β	τ
IND	1147	530	132	217	-44	0
IDN	2272	776	62	136	-14	17
CHN	3749	485	177	358	16	5
BGR	6524	259	60	318	382	7
MEX	7690	36	90	280	213	8
ROU	8069	276	41	148	44	16
BRA	8373	32	67	341	76	1
RUS	8616	199	40	168	-42	1
TUR	8626	53	47	265	255	27
POL	11295	33	24	200	181	13
LTU	11649	72	41	208	322	10
LVA	12082	38	40	368	111	3
HUN	12635	11	17	484	994	0
EST	14542	27	22	376	314	5
SVK	16196	44	29	702	1495	12
KOR	18339	-23	8	284	242	-1
CZE	18881	19	26	438	690	-4
MLT	19636	-33	14	337	311	-2
PRT	22153	-41	9	364	118	0
SVN	24051	-40	10	259	298	9
GRC	28695	-32	9	241	-5	8
CYP	29428	-40	1	202	-24	5
ESP	31368	-55	-10	302	79	-1
GBR	35455	-73	-4	231	45	-1
ITA	35724	-60	-6	279	269	9
JPN	39473	-61	-9	278	26	-2
DEU	40270	-71	-13	253	319	-3
FRA	40488	-75	-24	414	116	-3
CAN	40764	-57	-13	279	182	0
AUS	42722	-62	-2	318	70	4
SWE	43640	-78	-5	370	220	0
BEL	43834	-83	-19	635	740	-3
FIN	44838	-71	-11	309	91	2
AUT	45872	-73	-12	315	181	1
USA	46999	0	0	0	0	0
NLD	48174	-75	-14	400	426	4
IRL	49708	-62	-8	248	361	3
DNK	56227	-77	-15	349	120	0
LUX	99282	-73	-29	559	1057	-28

GDPpc is GDP per capita. H reflects the percentage change from changing to US levels of human capital per hour worked. K reflects the percent change in output from changing to US levels of capital stock per hour worked. A reflects the percentage change from moving to US levels of sector level productivity. β reflects the percentage change in output from moving to US levels of sectoral demand parameters. τ reflects change in log output from moving to US levels of wedges. All estimates are logged changes adjusted to percentage terms, $(e^x - 1) * 100$.

Figure 3.4: GDP per capita and the Correlation between Sector TFP and β



in sector-level productivity. Sector-level productivity includes both the firm level productivity and the efficiency of within sector allocation between firms. The latter has been robustly shown to be an important factor in sector productivity (Restuccia & Rogerson, 2008; Hsieh & Klenow, 2009; Bartelsman, Haltiwanger, & Scarpetta, 2009). Also important to note, the US may have somewhat inflated effects of productivity and deflated estimates of human capital due to the comparatively small expenditure on education. However, even if the US had human capital expenditure commensurate with its GDP per capita, the picture would remain similar albeit with smaller estimates for switching to US productivity and higher effects from switching to US levels of human capital per worker.

Moving to US levels of structural allocation of demand β has the most varied effects. For some countries, the effects of reallocation are massive, Hungary faces a

1400%+ predicted growth. Of course, estimates like these become inaccurate if a small productive sector is unable to scale up to a very large sector at the same level of productivity. Other countries, such as India, face contraction from shifting to US levels of structural allocation of demand. However, on the whole, most countries face a substantial increase in output from shifting to US levels of β suggesting that at least in the US' case, it has specialized in its most productive sectors.

Finally, the misallocation arising from wedges reflected in markups are given in the last column. These suggest consistently positive but small effects from switching to US levels of markups and frictions.

3.5 Multipliers

One of the most interesting results from the previous section's hypothetical exercises is that the estimated impact of switching to US levels of capital, human capital, productivity, and sector demand are so large. Taken together, switching to US levels of human capital, capital, and sector-level productivity close most of the gap between developing countries and the US. This is not a standard result. This section will first compare the current setup to standard income accounting exercises and discuss the main driver of the large income gains: the multipliers. Second, I will review why the multipliers calculated here are larger than the ones calculated by Jones (2011a).

Previous income accounting exercises have sought to identify the aggregate equation:

$$Y = AK^\alpha L^{1-\alpha} \quad (3.9)$$

While the model developed has an aggregate output equation of similar form in Equation 3.2, one crucial difference is that there is a multiplier on the productivity term, and the capital and labor exponents no longer sum to 1.⁴

Inherent in the standard growth accounting exercises is the assumption that there is no multiplier on productivity, human capital, or capital. The multipliers in the model are generated because an increase in productivity in one sector will lead to not only within-sector productivity increases, but also productivity increases in sectors which depend on inputs from those sectors. The lower prices in a given sector will increase the equilibrium output in dependent sectors because of the lower prices arising from the original productivity increase. As this productivity increase propagates through other sectors, the aggregate effect is determined by the multiplier. Therefore, integrating the multiplier.

For the international version of the model, the equation used for estimation is:

$$Y = A^\psi (1 - \tau)^\psi H^{\psi_H} K^{\psi_K} \xi \quad (3.10)$$

⁴For non-zero intermediate use, they will always sum to greater than 1.

The multipliers are given by

$$\begin{aligned}\psi &= \frac{\beta'(I - B)^{-1}\mathbf{1}}{1 - \beta'(I - B)^{-1}\lambda^*} \\ \psi_H &= \frac{\beta'(I - B)^{-1}\epsilon}{1 - \beta'(I - B)^{-1}\lambda^*} \\ \psi_K &= \frac{\beta'(I - B)^{-1}\alpha}{1 - \beta'(I - B)^{-1}\lambda^*}\end{aligned}$$

ψ is the multiplier on the productivity level and the wedge.⁵ ψ_H is the human capital multiplier. ψ_K is the capital multiplier.

I report the multipliers in Table 3.3. For the productivity multiplier, a 1% increase in all sectors' productivity will lead to a $\psi\%$ increase in total output. For the human capital multiplier, a 1% increase in aggregate human capital stock will lead to a $\psi_H\%$ increase in total output. A 1% increase in aggregate physical capital stock will lead to a $\psi_K\%$ increase in aggregate output.

The second important result is that the multipliers calculated here are substantially higher than the multiplier calculated in Jones (2011a). The productivity multiplier falls generally between 2 and 3.5. Jones (2011a) finds multipliers of between 1.5 and 2.5.

The difference between the multiplier calculated here and the ones calculated in Jones (2011a) arises from correcting for markups. Markups greater than or equal to 1 will by construction lead to a lower capital share and commensurately higher

⁵Though the multiplier is the same on both the productivity and the wedge, the misallocation term ξ also depends on the wedge, and offsets some of the effect of the $(1 - \tau)^\psi$ term.

Table 3.3: Productivity, Human Capital, and Capital Multipliers

Country	GDPpc	ψ_{dom}	ψ_{int}	ψ	ψ_H	ψ_K
IND	1147	2.14	1.18	2.52	0.56	0.35
IDN	2272	2.15	1.39	2.98	0.78	0.33
CHN	3749	2.77	1.22	3.37	0.66	0.31
BGR	6524	2.03	1.63	3.32	0.82	0.30
MEX	7690	1.63	1.27	2.08	0.48	0.48
ROU	8069	2.00	1.42	2.85	0.80	0.25
BRA	8373	1.90	1.10	2.09	0.60	0.29
RUS	8616	2.26	1.16	2.64	0.81	0.31
TUR	8626	2.10	1.27	2.67	0.58	0.30
POL	11295	2.03	1.35	2.73	0.82	0.21
LTU	11649	1.56	1.50	2.35	0.71	0.30
LVA	12082	1.90	1.50	2.86	0.76	0.35
HUN	12635	1.71	1.66	2.85	0.77	0.23
EST	14542	1.78	1.66	2.96	0.77	0.24
SVK	16196	2.00	1.84	3.68	0.68	0.43
KOR	18339	1.88	1.25	2.35	0.74	0.16
CZE	18881	1.98	1.57	3.11	0.71	0.30
MLT	19636	1.42	1.61	2.29	0.67	0.34
PRT	22153	1.78	1.30	2.30	0.72	0.20
SVN	24051	1.71	1.48	2.54	0.80	0.18
GRC	28695	1.61	1.24	2.00	0.64	0.35
CYP	29428	1.50	1.33	2.00	0.81	0.26
ESP	31368	1.96	1.23	2.41	0.76	0.24
GBR	35455	1.97	1.23	2.43	0.87	0.18
ITA	35724	2.01	1.21	2.43	0.74	0.19
JPN	39473	1.86	1.07	1.99	0.61	0.40
DEU	40270	1.76	1.25	2.19	0.77	0.22
FRA	40488	1.96	1.24	2.43	0.76	0.27
CAN	40764	1.72	1.28	2.20	0.67	0.30
AUS	42722	2.31	1.22	2.82	0.83	0.25
SWE	43640	1.82	1.37	2.51	0.82	0.21
BEL	43834	1.79	1.69	3.03	0.86	0.27
FIN	44838	1.86	1.31	2.43	0.75	0.23
AUT	45872	1.67	1.38	2.31	0.80	0.24
USA	46999	2.08	1.12	2.33	0.80	0.30
NLD	48174	1.82	1.58	2.86	0.90	0.23
IRL	49708	1.63	1.77	2.90	0.76	0.30
DNK	56227	1.64	1.35	2.22	0.77	0.23
LUX	99282	1.53	2.27	3.48	0.84	0.43

GDPpc is GDP per capita. ψ_{dom} is the multiplier arising from domestic good use, $\beta'(I - B)^{-1}\mathbf{1}$. ψ_{int} is the multiplier arising from international input use, $\frac{1}{1 - \beta'(I - B)^{-1}\lambda^*}$. ψ is the total multiplier equal to the product of the domestic and international multipliers. ψ_H is the human capital multiplier, $\beta'(I - B)^{-1}\epsilon$. ψ_K is the capital multiplier, $\beta'(I - B)^{-1}\alpha$.

intermediate and labor share. Because the primary determinant of the size of the multiplier is the intermediate goods share, these higher measured intermediate shares lead to a higher estimated multiplier for productivity and for the human capital stock. The capital multiplier will increase due to the intermediate share increase, but decrease due to the lower capital share, so the effect is indeterminate.⁶

Because of this, even if between-sector misallocation accounted for a relatively limited share of the output gap, accounting for markups may still illumine cross-country income accounting. Incorporating the wedges driving prices up allows for distinguishing the capital share of inputs from the markups arising from market power and other frictions. Correcting for the markup allows more accurate measurement of the intermediate input dependence which determines the multiplier. Accounting for this, underlying differences in human capital, physical capital, and sector-level productivity can explain most of the between country output differences.

Also, of general interest is how these results relates to the rest of the misallocation literature. Hsieh & Klenow (2009) famously found 40-60% increase in sector output for India and 30-50% increase in sector output for China if capital and labor were allocated as efficiently within sector as the US. While their result was limited to manufacturing in China and India, it is interesting to see how these within-sector reallocation gains would affect the economy as a whole in the presence of the multiplier.

In the current setup, the sector-level productivity reflects not only firm productivity, but also the efficiency of the allocation between firms within a given sector.

⁶The capital and human capital multipliers were not reported in Jones(2011a)

Hsieh & Klenow's result is equivalent to an increase in the productivity parameter in the current model. If we assume that those within-sector reallocation benefits are relatively consistent across non-manufacturing sectors, the effect on the average A from Equation 3.10 would be to increase by a factor of 1.4 for China and 1.5 for India. The multiplier is 3.37 for China, and 2.52 for India. This means that for China, the aggregate effect of that within-sector reallocation is a 211% increase in output ($1.4^{3.37} - 1 = 2.11$). For India, the aggregate effect of the within-sector reallocation would be 178% increase in output ($1.5^{2.52} - 1 = 1.78$).

3.6 Predictions' Explanatory Power on Income Gaps

In this section, I test whether the multipliers give reliable estimates of how much income gaps can be explained by human capital, capital, sector level productivity, and wedges. In Table 3.4, I report how much of the productivity gap would be closed if human capital stock per capita, capital stock, sector-level productivities, and wedges were to shift to US parameter levels. I list both the predicted factor by which output would increase based on moving to US levels of capital, human capital, wedges, and productivity, and the actual factor by which GDP between countries is different. Finally, for ease of comparison, I estimate the predicted GDP change divided by the actual gap. A factor of 2 reflects a predicted output of 2 times US levels of GDP.

If the model and assumptions are accurate, the predicted effect of switching to US levels of human capital, capital, wedges, and sector productivities, should be

generally similar to the US. Importantly, I do not include changes to US levels of β because changes to US β 's are conditional on given levels of the other four parameters. For this reason, it is not expected that countries will have the exact US level of output. If countries happen to be specialized in sectors the US is very productive in, the country may have a predicted GDP much larger than the US'.

The results indicate that for most countries, the predicted output from moving to US levels of human capital per hour worked, capital per hour worked, wedges, and productivities, is generally believable. It does seem that for developing countries the results are more disperse and for a few (Slovakia, China, Bulgaria, and the Czech Republic) have predicted effects that may be too large to be taken literally.

For most countries, the predicted effect completely closes the gap between the US. For 6 of 39 countries the predicted is less than US' level of output. This may be an indicator that the multiplier may have been too large. One possibility may have been that the upper bound for markups may have assumed too low a required return to capital. The byproduct of a low return to capital, is a lower capital share and a higher input share, which increases the multiplier for countries with markups which hit the upper bound.

Aside from the four countries with very high predictions, it is surprising how consistently the predicted change in a countries output reaches the level of US output. The finding that all of the income gap can be explained by the fundamentals of capital, human capital, wedges, and sector-level productivity is novel. It is important to emphasize that nothing in the model has forced this to be true. The GDP per capita is based on aggregated data while the capital, human capital, and sector-level

Table 3.4: Predicted Change from H, K, a, and τ vs. Actual Income Differences

Country	GDPpc	Predicted	Gap	Pred/US
IND	1147	46.16	40.97	1.13
IDN	2272	38.92	20.69	1.88
CHN	3749	78.03	12.54	6.22
BGR	6524	25.89	7.20	3.59
MEX	7690	10.53	6.11	1.72
ROU	8069	15.24	5.82	2.62
BRA	8373	9.77	5.61	1.74
RUS	8616	11.33	5.46	2.08
TUR	8626	10.47	5.45	1.92
POL	11295	5.61	4.16	1.35
LTU	11649	8.23	4.03	2.04
LVA	12082	9.33	3.89	2.40
HUN	12635	7.57	3.72	2.03
EST	14542	7.68	3.23	2.38
SVK	16196	16.73	2.90	5.76
KOR	18339	3.19	2.56	1.25
CZE	18881	7.78	2.49	3.13
MLT	19636	3.26	2.39	1.36
PRT	22153	3.03	2.12	1.43
SVN	24051	2.57	1.95	1.32
GRC	28695	2.73	1.64	1.67
CYP	29428	1.90	1.60	1.19
ESP	31368	1.63	1.50	1.09
GBR	35455	0.86	1.33	0.65
ITA	35724	1.53	1.32	1.16
JPN	39473	1.29	1.19	1.09
DEU	40270	0.87	1.17	0.74
FRA	40488	0.95	1.16	0.82
CAN	40764	1.43	1.15	1.24
AUS	42722	1.62	1.10	1.47
SWE	43640	0.99	1.08	0.92
BEL	43834	1.00	1.07	0.93
FIN	44838	1.08	1.05	1.03
AUT	45872	0.99	1.02	0.96
USA	46999	1.00	1.00	1.00
NLD	48174	1.11	0.98	1.14
IRL	49708	1.25	0.95	1.32
DNK	56227	0.89	0.84	1.07
LUX	99282	0.92	0.47	1.94

GDPpc is GDP per capita. Predicted gives the predicted factor by which the economy would increase from moving to US levels of human capital stock per hour worked, capital stock per hour worked, wedges, and sector-level productivity. Gap measures the actual GDP per capita divided by the US GDP per capita. Pred/US measures the predicted final output as a share of the US' output.

productivity have been taken from sector-level data and the wedges measured in previous sectors. The multiplier is estimated purely based on the intermediate goods shares and sector demand parameters.

3.7 Conclusion

An extensive growth accounting literature has decomposed output differences into capital, labor, and aggregate productivity with most of the income differences being explained by this aggregate productivity term. More recently a variety of approaches have been used to identify the determinants of this productivity term. Explanatory roles have been identified for human capital, distribution of labor shocks, within-sector misallocation, and firm level productivity.

One important role which has been identified is specialization in less productive sectors, which may be due to between-sector misallocation or underlying demand (Caselli, 2005; McMillan & Rodrik, 2011; Jones 2011a). I extend this potential explanation by developing a model built on Jones (2011a) and using it to develop a income accounting framework which allows estimating the hypothetical effect of moving to US parameters of levels. The model allows identification of the effect of wedges representing markups and frictions which distort price signals to both final goods consumers and businesses which use other sectors goods as inputs. Additionally, it allows for differentiation of between-sector misallocation driven by these markups from underlying demand for sectors' final goods and exports.

In this chapter, I estimate the explanatory power of traditional sources of cross-

country income differences: capital stock, human capital stock, sector-level productivity, as well as sector wedges and sectoral demand parameters. The input-output structure allows identification of not only how individual sectors will respond to an increase in capital stock, human capital stock, or productivity shocks, but how those increases will affect the economy as a whole through other sectors' dependence on their inputs.

The results indicate that human capital stock, capital stock, and sector level productivities still dominate the between country difference in income. Between these three main factors, switching to US level sector productivities has the biggest and most consistently positive impact with most countries seeing a very positive effect with developing countries facing increases of 136 to 702 percent. All developing countries faced an increase from moving to US levels of human capital per hour worked and capital stock per hour worked with output increasing by up to 776% with movements to US levels of human capital and 177% from moving to US levels of capital stock.

The between-sector misallocation effect arising from markups as compared to the US is consistently positive for developing countries, but relatively small, with the largest impact being a 27% increase. However, the impact of moving to US levels of underlying demand for final goods and exports is large and varied. The largest positive effects have greater 1400% increase in output, and the most negative effect having a 44% collapse in output. In the countries with large potential gains from shifting to US levels of final goods and export demand, this may reflect that certain aspects of the economy are functioning very well, but are restricted from growing.

On the other hand, for countries which faced zero or negative impacts of moving to US levels of final goods and exports demand (such as India and Indonesia) it may reflect that there are country wide issues may be limiting the productivity of sectors across the board or may suffer from low productivity in precisely the sectors in which the US has the largest shares.

Finally, I analyze the role of the multiplier in explaining cross country income differences. The first important result is that taken together, differences in human capital stock, capital stock, wedges, and sector productivities explain almost all of income differences when the multipliers are taken into account. The multipliers found here are not taken into account in traditional income accounting exercises and including them allows traditional factors to explain all of income differences.

The second key conclusion regarding the multipliers is that the multipliers adjusted for markups are significantly higher (perhaps too high) than found in Jones (2011a). This arises by construction in that accounting for markups greater than 1 leads to a lower estimated capital share of inputs and commensurately higher labor and intermediate shares. Because the multiplier is primarily dependent on intermediate shares, multipliers are larger than those found in Jones.

These results point us definitively in the direction of the multiplier as the central factor in explaining output differences between countries. Perhaps surprisingly, it seems that the central factors of capital, labor, wedges, and sector productivities are all that is needed in an input-output framework. While accounting for wedges between sectors has not driven a large part of the results in explaining differences between countries, it has played a vital role in the measurement of intermediate

dependence. Accounting for markups leads necessarily to lower capital shares, and higher intermediate and labor shares, and consequently to a higher multiplier. It is this substantially higher multiplier than originally found in Jones (2011a) which allows human capital, capital, and productivity to close the income gap between countries.

Chapter 4

Conclusion

This dissertation set out to illuminate theoretically and empirically the role of between-sector misallocation in determining income differences between countries. Chapter 2 provided the framework to evaluate how wedges aggregate throughout the economy depending on sectors' intermediate dependence. This framework allowed estimation of misallocation arising from these wedges measured from markups. This misallocation happened through three channels. First, the level of aggregate wedges, the accumulated effect of both the final sector wedge and the input sector wedges determined the level of misallocation arising from firms inefficiently substituting away from intermediate inputs in general. Second, the variation of aggregate wedges caused inefficient movement away from those sectors with particularly high aggregate wedges. Finally, the variation in wedges determined how capital and labor stocks were allocated between sectors.

Chapter 2 continued to estimate the level and standard deviation of these wedges

measured as markups. The *prima facie* case for the importance of both the level and standard deviation of aggregate wedges is made with basic regressions which indicate that the mean and standard deviation of aggregate markups are about twice as highly correlated with GDP per capita than simply average levels of markups and standard deviations of markups. These results also indicate that the level of the aggregate markup and average markups are much more important than the standard deviation of the aggregate markup and standard deviation of markup. This suggests that between the channels through which misallocation happens, the inefficient substitution away from intermediate inputs in general is more important as a barrier to development than inefficient substitution away from certain sectors towards other sectors or the misallocation of capital and labor between sectors.

Chapter 2 concludes with estimates of the total output effect for 39 countries of moving to US levels of markups. Developing countries face a positive but muted effect. Turkey stood out due to a very high markup in real estate and faced a hypothetical 27% increase in TFP and a 60% increase when factoring in capital accumulation associated with that increase. However, the remainder of developing countries faced increases between 0 and 17% increases in output and 0 to 24% increase in output when internalizing capital accumulation. These effects, while notable and consistently positive are relatively small when compared to the 3 to 20 fold per capita income differences between these countries and the US.

Chapter 3 expands this exercise to encompass hypothetical shifts to US levels of human capital per worker hour, capital stock per worker hour, sector level productivity, and demand parameters in the context of the input-output model. Measure-

ments of human capital, capital and sector productivity which correct for sector level markup are very correlated with GDP per capita as expected.

The hypothetical exercise find large and very consistent effects of human capital and capital stock increases of up to 776% for moving to US human capital stock per hour worked with the largest gains ($> 200\%$ increases) happening in the poorest countries in the sample, and up to 177% for movement to US capital stock per hour worked. For developed countries, most faced a predicted contraction from moving to US levels of capital stock per hour and human capital stock per hour. Shifting to US levels of sector level productivity had the most consistently large effects of 100-700% increases.

Changing to US levels of structural demand parameters which determine the relative weighting of each sector had the most varied results. While most developing countries faced an increase by moving to the US sectoral demand, the results were very heterogeneous. Slovakia increased more than 14 fold while India and Russia faced 40-50% contractions when shifting to US levels of sector weightings. The majority of countries, however, faced an increase from moving to US sector demand parameters.

These results point to a more textured picture of the character of development. For certain countries such as Slovakia and Hungary, certain sectors are already producing at developing country standards, and may justify a deeper understanding of why specialization has not moved towards those productive sectors. For other countries, such as India and Indonesia, there seems to be no benefit and actually a contractionary effect from mimicking developed country distribution of production

between sectors. It may be of first order concern to understand why those sectors are so low productivity to begin with, but may also indicate that barriers to development are broadly affecting all sectors.

This dissertation has sought to measure markups reflecting wedges in certain sectors and place them in the context of an economy where sectors depend on each other's inputs to produce a final product. This has played two important roles in contributing to the cross-country income accounting literature. First, it has found that the between-sector misallocation measured by estimating the sector wedges in the context of an input-output model plays an important albeit complementary role as a barrier to development. Second, accounting for sector wedges allows for more accurate measurement of the roles of capital stock, human capital stock, sector-level productivity, and demand for sector output. It is this latter role which has played a bigger role in resolving the mystery of why traditional growth accounting has been unable to explain large income differences between countries.

Perhaps the most interesting result arising from the dissertation is the role of the multipliers in explaining cross-country income differences. Taken together, the estimates of output changes arising from human capital stock per hour worked, capital stock per hour worked, sector wedges, and sector-level productivity almost completely explain the income gap between developing and developed countries and the US.

This result was driven by estimates of the multiplier on productivity, human capital, and capital stocks which was much larger than had previously been measured. The higher multiplier was driven by correcting input shares for markups. For markups

greater than one, the uncorrected capital share will overestimate the true capital coefficient and underestimate the labor and intermediate coefficients. Because the size of the multipliers are driven primarily by the intermediate dependence of sectors, adjusting for markups leads to higher multipliers.

While the dissertation set out to measure between-sector misallocation, the most important result may be that multipliers which are corrected for markups are much larger, and that with these larger multipliers, core factors of capital, human capital, and productivity differences may go much further towards resolving the mystery of the determinants income differences between countries than previously thought.

Appendices

.1 Derivation of Equilibrium Conditions

Maximizing (2.4) subject to (2.5), the first order conditions are:

$$\frac{p_1 y_1}{Y} = \beta_1 \quad (1)$$

$$\frac{p_2 y_2}{Y} = \beta_2 \quad (2)$$

To solve the firms' maximization problem, I first must find the price as a function of quantity from (2.2) and (2.3).

This maximization for firm i gives:

$$\frac{\sigma_s - 1}{\sigma_s} (q_{s_i}^{\frac{\sigma_s - 1}{\sigma_s}})^{\frac{\sigma_s}{\sigma_s - 1} - 1} \frac{\sigma_s}{\sigma_s - 1} q_{s_i}^{\frac{\sigma_s - 1}{\sigma_s} - 1} - \lambda p_{s_i} = 0$$

$$(q_{s_i}^{\frac{\sigma_s - 1}{\sigma_s}})^{\frac{1}{\sigma_s - 1}} = \lambda p_{s_i} q_{s_i}^{\frac{1}{\sigma_s}}$$

$$Q_s = (q_{s_i}^{\frac{\sigma_s-1}{\sigma_s}})^{\frac{\sigma_s}{\sigma_s-1}} = (\lambda p_{s_i})^{\sigma_s} q_{s_i}$$

$$Q_s (\lambda p_{s_i})^{-\sigma_s} = q_{s_i}$$

Plugging this into the definition of Q_s :

$$Q_s = \left(\int (Q_s (\lambda p_{s_i})^{-\sigma_s})^{\frac{\sigma_s-1}{\sigma_s}} di \right)^{\frac{\sigma_s}{\sigma_s-1}}$$

which reduces to

$$\lambda^{\sigma_s} = \left(\int ((p_{s_i})^{-\sigma_s})^{\frac{\sigma_s-1}{\sigma_s}} di \right)^{\frac{\sigma_s}{\sigma_s-1}}$$

Reducing this the price index for sector s output is:

$$p_s \equiv \frac{1}{\lambda} = \left(\int (p_{s_i}^{1-\sigma_s} di) \right)^{\frac{1}{1-\sigma_s}}$$

So that price of firm i's output in terms of firm i's quantity produced is:

$$p_{s_i} = \left(\frac{Q_s}{q_{s_i}} \right)^{\frac{1}{\sigma_s}} p_s$$

Plugging this price function into the original firms' maximization equation, (2.1)

I now maximize

$$\max_{q_{1_i}, K_{1_i}, H_{1_i}, m_{1_i1}, m_{1_i2}} (1 - \tau_1) p_s Q_1^{\frac{1}{\sigma_1}} q_{1_i}^{\frac{\sigma_1-1}{\sigma_1}} - p_1 m_{1_i1} - p_2 m_{1_i2} - r K_{1_i} - w H_{1_i}$$

$$s.t. \quad q_{1_i} = A_1 K_{1_i}^{\alpha_1} H_{1_i}^{\epsilon_1} m_{1_i1}^{\lambda_{11}} m_{1_i2}^{\lambda_{12}}$$

taking p_s and Q_s as given.

Because the firms within a sector are identical so $q_{s_i} = Q_s$ for each sector, s , the equilibrium conditions reduce to (because $Q_1^{\frac{1}{\sigma_1}} q_{1_i}^{\frac{\sigma_1-1}{\sigma_1}-1} = Q_1^{\frac{1}{\sigma_1}} Q_1^{\frac{\sigma_1-1}{\sigma_1}-1} = 1$):

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \epsilon_s \frac{p_s Q_s}{H_s} = w \quad (3)$$

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \alpha_s \frac{p_s Q_s}{K_s} = r \quad (4)$$

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{s1} \frac{p_s Q_s}{m_{s1}} = p_1 \quad (5)$$

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{s2} \frac{p_s Q_s}{m_{s2}} = p_2 \quad (6)$$

Here the σ_s represents the elasticity of substitution for firms output between a sector which determines the markup, τ_s is the fraction of output which is lost due to a friction which could represent corruption, theft, rent seeking etc. These two drive a wedge between the price of the input and the marginal revenue product from the input.

Plugging in the first order conditions for domestic inputs into (2.6)

$$Q_j = y_j + m_{1j} + m_{2j}$$

$$Q_j = y_j + \frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)\lambda_{1j}\frac{p_1 Q_1}{p_j} + \frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2)\lambda_{2j}\frac{p_2 Q_2}{p_j} \quad (7)$$

Using (1), this is:

$$p_j Q_j = Y\beta_j + \frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)\lambda_{1j}p_1 Q_1 + \frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2)\lambda_{2j}p_2 Q_2$$

So that the solution to these equations when stacked is:

$$\begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix} \equiv \begin{pmatrix} \frac{p_1 Q_1}{Y} \\ \frac{p_2 Q_2}{Y} \end{pmatrix} = \begin{pmatrix} 1 - \frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)\lambda_{11} & -\frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2)\lambda_{21} \\ -\frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)\lambda_{12} & 1 - \frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2)\lambda_{22} \end{pmatrix}^{-1} \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix} \quad (8)$$

Combining the first order conditions, equation (8) with the equality from (1) that

$\frac{p_i}{p_j} = \frac{\beta_i}{\beta_j} \frac{y_j}{y_i}$. The equilibrium input quantities are:

$$\frac{H_s}{H} = \frac{\frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q)\epsilon_s \gamma_s}{\frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)\epsilon_1 \gamma_1 + \frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2)\epsilon_2 \gamma_2} \equiv \frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q)\theta_s^H \quad (9)$$

$$\frac{K_s}{K} = \frac{\frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q)\alpha_s \gamma_s}{\frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)\alpha_1 \gamma_1 + \frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2)\alpha_2 \gamma_2} \equiv \frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q)\theta_s^K \quad (10)$$

$$m_{s1} = \frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q)\lambda_{sj}\frac{\gamma_s Q_1}{\gamma_1} \equiv \frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s^Q)\theta_{s1}^m Q_1 \quad (11)$$

$$m_{s2} = \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{sj} \frac{\gamma_s Q_2}{\gamma_2} \equiv \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \theta_{s2}^m Q_2 \quad (12)$$

Plugging these into the production equation:

$$Q_s = A_s \left(\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \right) (\theta_s^H H)^{\epsilon_s} (\theta_s^K K)^{\alpha_s} (\theta_{s1}^m Q_1)^{\lambda_{s1}} (\theta_{s2}^m Q_2)^{\lambda_{s2}} \quad (13)$$

so that taking natural logs and stacking into vectors:

$$q = a + \omega^Q + \omega + \epsilon \log H + \alpha \log K + Bq \quad (14)$$

where α and ϵ are vectors of coefficients, the matrix B is the undistorted input-output table with entries as the coefficients for inputs. a is the vector of logged sector productivity. ω^Q is the vector of sector frictions and markups, and $\omega \equiv \omega^H + \omega^K + \omega^m$ is the collection of allocation terms: $\omega_s^K = \alpha_s \log(\theta_s^K)$, $\omega_s^H = \epsilon_s \log(\theta_s^H)$, $\omega_s^m = \lambda_{s1} \log(\theta_{s1}^m) + \lambda_{s2} \log(\theta_{s2}^m)$.

The solution is

$$q = (I - B)^{-1} (a + \omega^Q + \omega + \epsilon \log H + \alpha \log K) \quad (15)$$

Here q , a , ω^Q , ω , ϵ and α are 2x1 vectors, I and B are 2x2 matrices, and $\log K$ and $\log H$ are scalars.

$$\begin{pmatrix} q_1 \\ q_2 \end{pmatrix} = \begin{pmatrix} 1 - \lambda_{11} & -\lambda_{12} \\ -\lambda_{21} & 1 - \lambda_{22} \end{pmatrix}^{-1} \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1 - 1}{\sigma_1} 1 - \tau_1) \\ \log(\frac{\sigma_2 - 1}{\sigma_2} 1 - \tau_2) \end{pmatrix} \right) \quad (16)$$

$$+ \begin{pmatrix} \alpha_1 \log(\theta_1^K) + \epsilon_1 \log(\theta_1^H) + \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \alpha_2 \log(\theta_2^K) + \epsilon_2 \log(\theta_2^H) + \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log K + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L$$

From the definition of γ_s and (1), $y_s = \frac{\beta_s Q_s}{\gamma_s}$. In logs, this becomes:

$$y = \omega_y + q$$

where ω_y is the vector of $\log(\frac{\beta_s}{\gamma_s}) = \log(\frac{p_s y_s}{p_s Q_s})$, the ratios of final good and export production to the gross production.

From the definition of Y ,

$$\log Y = \beta' y = \beta' \omega_y + \beta' q$$

where y is the vector of logged final consumption and exports, and β is the vector of β_s .

The final output in logs is given by

$$\log Y = \beta' \omega_y + \beta' (I - B)^{-1} (a + \omega^Q + \omega + \epsilon \log H + \alpha \log K) \quad (17)$$

Taking the antilogs of (17), output is given by

$$Y = A^\psi (1 - \tau)^\psi H^{\psi_H} K^{\psi_K} \xi \quad (18)$$

where the multipliers are given by

$$\psi = \beta'(I - B)^{-1}\mathbf{1}$$

$$\tilde{\epsilon} = \beta'(I - B)^{-1}\epsilon$$

$$\tilde{\alpha} = \beta'(I - B)^{-1}\alpha$$

and ξ is given by

$$\log(\xi) = \beta'\omega_y + \beta'(I - B)^{-1}(\omega + \tilde{a} + \tilde{\eta}_\tau)$$

$$A\eta_{as} = A_s$$

$$(1 - \tau)\eta_{\tau s} = \frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s)$$

where A is the weighted average of the productivity: $\log(A) = \beta_1 \log(A_1) + \beta_2 \log(A_2)$, and τ is the weighted average of the markups: $\log(1 - \tau) = \beta_1 \log(\frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)) + \beta_2 \log(\frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2))$. $\tilde{\eta}_a$ and $\tilde{\eta}_\tau$ are vectors of the logged η_{as} and $\eta_{\tau s}$ terms.

.2 Derivation of Equilibrium Conditions: Relaxing Final Goods

Cobb-Douglas Assumption

To verify how sensitive the results are to the assumption of the Cobb-Douglas form of final goods output, I use the general constant elasticity of substitution form, allowing final goods to be complements or substitutes.

Maximizing:

$$\max_{y_1, y_2} Y - p_1 y_1 - p_2 y_2 \quad (19)$$

$$s.t. \quad Y = (\beta_1 y_1^{\frac{\sigma-1}{\sigma}} + \beta_2 y_2^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} \quad (20)$$

σ represents the elasticity of substitution between the final goods from each sector. If σ is less than 1, the final goods are complements, with the estimate converging to the Leontief production function as σ goes to 0. If σ is greater than 1, they are substitutes, converging to the linear, perfect substitutes function as σ goes to ∞ .

the first order conditions are:

$$\frac{p_1 y_1}{Y} = \beta_1^\sigma p_1^{1-\sigma} \quad (21)$$

$$\frac{p_2 y_2}{Y} = \beta_2^\sigma p_2^{1-\sigma} \quad (22)$$

The firms' maximization problem proceeds similarly to the original derivation giving us the same first order conditions (3)-(6). Aggregation continues similarly until (7):

$$Q_j = y_j + \frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{1j} \frac{p_1 Q_1}{p_j} + \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{2j} \frac{p_2 Q_2}{p_j}$$

Using (21), this is:

$$p_j Q_j = Y \beta_j^\sigma p_j^{1-\sigma} + \frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{1j} p_1 Q_1 + \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{2j} p_2 Q_2$$

So that the solution to these equations when stacked is:

$$\begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix} \equiv \begin{pmatrix} \frac{p_1 Q_1}{Y} \\ \frac{p_2 Q_2}{Y} \end{pmatrix} = \begin{pmatrix} 1 - \frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{11} & -\frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{21} \\ -\frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{12} & 1 - \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{22} \end{pmatrix}^{-1} \begin{pmatrix} \beta_1^\sigma p_j^{1-\sigma} \\ \beta_2^\sigma p_j^{1-\sigma} \end{pmatrix} \quad (23)$$

Combining the first order conditions and equation (23). The equilibrium input quantities are:

$$\frac{H_s}{H} = \frac{\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \epsilon_s \gamma_s}{\frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \epsilon_1 \gamma_1 + \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \epsilon_2 \gamma_2} \equiv \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \theta_s^H \quad (24)$$

$$\frac{K_s}{K} = \frac{\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \alpha_s \gamma_s}{\frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \alpha_1 \gamma_1 + \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \alpha_2 \gamma_2} \equiv \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \theta_s^K \quad (25)$$

$$m_{s1} = \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{sj} \frac{\gamma_s Q_1}{\gamma_1} \equiv \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \theta_{s1}^m Q_1 \quad (26)$$

$$m_{s2} = \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{sj} \frac{\gamma_s Q_2}{\gamma_2} \equiv \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \theta_{s2}^m Q_2 \quad (27)$$

Plugging these into the production equation:

$$Q_s = A_s \left(\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \right) (\theta_s^H H)^{\epsilon_s} (\theta_s^K K)^{\alpha_s} (\theta_{s1}^m Q_1)^{\lambda_{s1}} (\theta_{s2}^m Q_2)^{\lambda_{s2}} \quad (28)$$

so that taking natural logs and stacking into vectors:

$$q = a + \omega^Q + \omega + \epsilon \log H + \alpha \log K + Bq \quad (29)$$

where α and ϵ are vectors of coefficients, the matrix B is the undistorted input-output table with entries as the coefficients for inputs. a is the vector of logged sector productivity. ω^Q is the vector of sector frictions and markups, and $\omega \equiv \omega^H + \omega^K + \omega^m$ is the collection of allocation terms: $\omega_s^K = \alpha_s \log(\theta_s^K)$, $\omega_s^H = \epsilon_s \log(\theta_s^H)$, $\omega_s^m = \lambda_{s1} \log(\theta_{s1}^m) + \lambda_{s2} \log(\theta_{s2}^m)$.

The solution is

$$q = (I - B)^{-1}(a + \omega^Q + \omega + \epsilon \log H + \alpha \log K) \quad (30)$$

Here q , a , ω^Q , ω , ϵ and α are 2x1 vectors, I and B are 2x2 matrices, and $\log K$ and $\log H$ are scalars.

$$\begin{pmatrix} q_1 \\ q_2 \end{pmatrix} = \begin{pmatrix} 1 - \lambda_{11} & -\lambda_{12} \\ -\lambda_{21} & 1 - \lambda_{22} \end{pmatrix}^{-1} \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1-1}{\sigma_1} 1 - \tau_1) \\ \log(\frac{\sigma_2-1}{\sigma_2} 1 - \tau_2) \end{pmatrix} \right) + \quad (31)$$

$$\begin{pmatrix} \alpha_1 \log(\theta_1^K) + \epsilon_1 \log(\theta_1^H) + \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \alpha_2 \log(\theta_2^K) + \epsilon_2 \log(\theta_2^H) + \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log K + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L$$

From the definition of γ_s and (1), $y_s = \frac{\beta_s^\sigma p_s^{1-\sigma} Q_s}{\gamma_s}$. In logs, this becomes:

$$y = \omega_y + q$$

where y is the vector of logged final consumption and exports and ω_y is the vector of $\log(\frac{\beta_s^\sigma p_s^{1-\sigma}}{\gamma_s}) = \log(\frac{p_s y_s}{p_s Q_s})$, the ratios of final good and export production to the gross production.

Here the cost of the CES function is that we no longer have the log linear specification. Because of this, we lose the intuitive results that arise from the log linear form.

From the definition of Y ,

$$Y = (\beta_1 y_1^{\frac{\sigma-1}{\sigma}} + \beta_2 y_2^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}$$

However, we can still solve this based on our previous equations.

Intuitively, the primary difference is the relationship between the shares of sector final goods output $\frac{p_s y_s}{Y}$, and their relative importance in terms of weighting, β_s . Given by the equation:

$$\frac{p_s y_s}{Y} = \beta_s^\sigma p_s^{1-\sigma}$$

From this the greater the complementarity between sectors ($\sigma < 1$), the more that the underlying weighting, β_s will be amplified for relatively large sectors compared to small sectors.

.3 Proofs of Propositions

Proof of Proposition 1: Also following Jones (2011a), the equation for γ_i is given by

$$\gamma = (I - \bar{B})^{-1}\beta$$

$$\gamma = (I - \bar{B})^{-1}\mathbf{1}\frac{1}{2}$$

These sum to

$$\gamma = \frac{1}{1 - \lambda(1 - \tau)}\mathbf{1}$$

Further, from the (2.9)

$$\log Y = \beta'\omega_y + \beta'(I - B)^{-1}(\omega^Q + \omega) + Constant$$

Since $\omega_{yi} = \log(\frac{\beta_i}{\gamma_i})$, and from (.3)

$$\beta'\omega_y = \log(1 - \lambda(1 - \tau))$$

and

$$\beta'(I - B)^{-1}\omega^Q = \beta'(I - B)^{-1}\mathbf{1}\log(1 - \tau) = \frac{\log(1 - \tau)}{1 - \lambda}$$

Also,

$$\omega = \omega_k + \omega_L + \omega_m$$

$$\omega_k = -\alpha\log(1 - \tau) + constant$$

$$\omega_L = -\epsilon \log(1 - \tau) + \text{constant}$$

$$\omega_m = \text{constant}$$

Since the coefficients sum to 1:

$$\beta'(I - B)^{-1}\omega = -\frac{\epsilon + \alpha}{1 - \lambda} \log(1 - \tau) = -\frac{1 - \lambda}{1 - \lambda} \log(1 - \tau) = -\log(1 - \tau)$$

So that the total effect of τ on output is given by

$$\log Y = \log(1 - \lambda(1 - \tau)) + \frac{\lambda}{1 - \lambda} \log(1 - \tau) + \text{Constant}$$

The partial derivative with respect to τ is

$$\frac{\partial \log Y}{\partial \tau} = \frac{\lambda}{1 - \lambda(1 - \tau)} - \frac{\lambda}{1 - \lambda} \frac{1}{1 - \tau}$$

Which reduces to:

$$\frac{\partial \log Y}{\partial \tau} = \frac{-\lambda\tau}{(1 - \lambda(1 - \tau))(1 - \lambda)(1 - \tau)}$$

Proof of Proposition 2:

$$\gamma = (I - B)^{-1}\beta = \frac{\frac{1}{2}(1 - .25(1 - \tau_2)) + .25(1 - \tau_1) + 1 - .25(\tau_1) + .25(1 - \tau_2))}{1 - \frac{1}{4}(1 - \tilde{\tau}_1) - \frac{1}{4}(1 - \tilde{\tau}_2)}$$

$$\gamma = \frac{1}{1 - \frac{1}{4}(1 - \tilde{\tau}_1) - \frac{1}{4}(1 - \tilde{\tau}_2)}$$

So that

$$\beta' \omega_y = \log(1 - \frac{1}{4}(1 - \tilde{\tau}_1) - \frac{1}{4}(1 - \tilde{\tau}_2)) + \text{constant} \quad (32)$$

The second term is given by:

$$\beta(I - B)^{-1}(\omega^Q + \omega) = \begin{pmatrix} \frac{1}{2} & \frac{1}{2} \end{pmatrix} \begin{pmatrix} \frac{3}{2} & \frac{1}{2} \\ \frac{1}{2} & \frac{3}{2} \end{pmatrix} \left(\begin{pmatrix} \log(1 - \tau_1) \\ \log(1 - \tau_2) \end{pmatrix} + \begin{pmatrix} -\frac{1}{2} \log(1 - \tau_1) \\ -\frac{1}{2} \log(1 - \tau_2) \end{pmatrix} \right) \quad (33)$$

This reduces to:

$$\beta(I - B)^{-1}(\omega^Q + \omega) = \frac{1}{2} \log(1 - \tilde{\tau}_1) + \frac{1}{2} \log(1 - \tilde{\tau}_2) + \text{constant} \quad (34)$$

So that the total output is affected by frictions through the terms:

$$\begin{aligned} \log Y &= \beta' \omega_y + \beta'(I - B)^{-1}(\omega^Q + \omega) \\ &= \log(1 - \frac{1}{4}(1 - \tilde{\tau}_1) - \frac{1}{4}(1 - \tilde{\tau}_2)) + \frac{1}{2} \log(1 - \tilde{\tau}_1) + \frac{1}{2} \log(1 - \tilde{\tau}_2) + \text{constant} \end{aligned} \quad (35)$$

which is the result.

When adding the condition $\tilde{\tau}_1 + \tilde{\tau}_2 = \tilde{\tau}$, the output equation reduces to

$$\log Y = \log(1 - \frac{1}{2}(1 - \tilde{\tau})) + \frac{1}{2} \log(1 - \tilde{\tau}_1) + \frac{1}{2} \log(1 - \tilde{\tau}_2) + \text{constant} \quad (36)$$

Maximizing this equation subject to $\tilde{\tau}_1 + \tilde{\tau}_2 = \tilde{\tau}$,

$$-\frac{1}{2} \frac{1}{(1 - \tilde{\tau}_1)} + \frac{1}{2} \frac{1}{(1 - \tilde{\tau} + \tilde{\tau}_1)} = 0 \quad (37)$$

and

$$\tilde{\tau}_1 = \tilde{\tau}_2 = \frac{1}{2} \tilde{\tau} \quad (38)$$

Proof of Proposition 3: To show Proposition 3, I estimate for sector 1 having inputs with $\lambda_{11} = 0$, and $\lambda_{12} = \lambda$ and sector 2 gaving inputs of $\lambda_{21} = \lambda_{22} = 0$. Further, we have that $\beta_1 = 1$ and $\beta_2 = 0$.

Plugging this into (2.9), our final output equation is given by:

$$\log Y = \beta' \omega_y + \beta' (I - B)^{-1} (a + \omega^Q + \omega + \epsilon \log H + \alpha \log K)$$

Substituting in for the variables in the equation:

$$\begin{aligned} \log Y = & \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix}' \begin{pmatrix} \log(\gamma_1) \\ \log(\gamma_2) \end{pmatrix} + \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix}' \begin{pmatrix} 1 - \lambda_{11} & -\lambda_{12} \\ -\lambda_{21} & 1 - \lambda_{22} \end{pmatrix}^{-1} \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)) \\ \log(\frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2)) \end{pmatrix} \right) \\ & + \begin{pmatrix} \alpha_1 \log(\theta_1^K) + \epsilon_1 \log(\theta_1^H) + \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \alpha_2 \log(\theta_2^K) + \epsilon_2 \log(\theta_2^H) + \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log K + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L \end{aligned}$$

$$\begin{aligned}
\log Y &= \begin{pmatrix} 1 \\ 0 \end{pmatrix}' \begin{pmatrix} \log(\gamma_1) \\ \log(\gamma_2) \end{pmatrix} + \begin{pmatrix} 1 \\ 0 \end{pmatrix}' \begin{pmatrix} 1 & -\lambda \\ 0 & 1 \end{pmatrix}^{-1} \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1-1}{\sigma_1}(1-\tau_1)) \\ \log(\frac{\sigma_2-1}{\sigma_2}(1-\tau_2)) \end{pmatrix} \right) \\
&+ \begin{pmatrix} \alpha_1 \log(\theta_1^K) + \epsilon_1 \log(\theta_1^H) + \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \alpha_2 \log(\theta_2^K) + \epsilon_2 \log(\theta_2^H) + \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log K + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L
\end{aligned}$$

which reduces to:

$$\begin{aligned}
\log Y &= \log(\gamma_1) + \begin{pmatrix} 1 \\ \lambda \end{pmatrix}' \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1-1}{\sigma_1}1 - \tau_1) \\ \log(\frac{\sigma_2-1}{\sigma_2}1 - \tau_2) \end{pmatrix} \right) \\
&+ \begin{pmatrix} \alpha_1 \log(\theta_1^K) + \epsilon_1 \log(\theta_1^H) + \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \alpha_2 \log(\theta_2^K) + \epsilon_2 \log(\theta_2^H) + \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log K + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L
\end{aligned} \tag{39}$$

Now I'll find $\log(\gamma_1)$ and the misallocation terms. To find gamma, I use equation (8):

$$\begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix} \equiv \begin{pmatrix} \frac{p_1 q_1}{Y} \\ \frac{p_2 q_2}{Y} \end{pmatrix} = \begin{pmatrix} 1 - \frac{\sigma_1-1}{\sigma_1}(1-\tau_1)\lambda_{11} & -\frac{\sigma_2-1}{\sigma_2}(1-\tau_2)\lambda_{21} \\ -\frac{\sigma_1-1}{\sigma_1}(1-\tau_1)\lambda_{12} & 1 - \frac{\sigma_2-1}{\sigma_2}(1-\tau_2)\lambda_{22} \end{pmatrix}^{-1} \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix}$$

Plugging in our coefficients:

$$\begin{aligned} \begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix} &= \begin{pmatrix} 1 & 0 \\ -\frac{\sigma_1-1}{\sigma_1}(1-\tau_1)\lambda & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \frac{\sigma_1-1}{\sigma_1}(1-\tau_1)\lambda & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} \\ &= \begin{pmatrix} 1 \\ \frac{\sigma_1-1}{\sigma_1}(1-\tau_1)\lambda \end{pmatrix} \end{aligned} \quad (40)$$

Plugging in the definitions of the misallocation terms and results for γ ¹:

$$\begin{pmatrix} \alpha_1 \log(\theta_1^K) \\ \alpha_1 \log(\theta_2^K) \end{pmatrix} = \begin{pmatrix} \alpha_1 \log\left(\frac{\alpha_1 \gamma_1}{\alpha_1 \gamma_1 (1-\tilde{\tau}_1) + \alpha_2 \gamma_2 (1-\tilde{\tau}_2)}\right) \\ \alpha_1 \log\left(\frac{\alpha_2 \gamma_2}{\alpha_1 \gamma_1 (1-\tilde{\tau}_1) + \alpha_2 \gamma_2 (1-\tilde{\tau}_2)}\right) \end{pmatrix} = \begin{pmatrix} \alpha_1 \log\left(\frac{\alpha_1}{\alpha_1 (1-\tilde{\tau}_1) + \alpha_2 \lambda (1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}\right) \\ \alpha_1 \log\left(\frac{\alpha_2 \lambda (1-\tau_1)}{\alpha_1 (1-\tilde{\tau}_1) + \alpha_2 \lambda (1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}\right) \end{pmatrix}$$

$$\begin{pmatrix} \alpha_1 \log(\theta_1^K) \\ \alpha_1 \log(\theta_2^K) \end{pmatrix} = \begin{pmatrix} \epsilon_1 \log\left(\frac{\epsilon_1 \gamma_1}{\epsilon_1 \gamma_1 (1-\tilde{\tau}_1) + \epsilon_2 \gamma_2 (1-\tilde{\tau}_2)}\right) \\ \epsilon_2 \log\left(\frac{\epsilon_2 \gamma_2}{\epsilon_1 \gamma_1 (1-\tilde{\tau}_1) + \epsilon_2 \gamma_2 (1-\tilde{\tau}_2)}\right) \end{pmatrix} = \begin{pmatrix} \epsilon_1 \log\left(\frac{\epsilon_1}{\epsilon_1 (1-\tilde{\tau}_1) + \epsilon_2 \lambda (1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}\right) \\ \epsilon_2 \log\left(\frac{\epsilon_2 \lambda (1-\tau_1)}{\epsilon_1 (1-\tilde{\tau}_1) + \epsilon_2 \lambda (1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}\right) \end{pmatrix}$$

$$\begin{pmatrix} \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} = \begin{pmatrix} \lambda \log\left(\frac{\gamma_1 \lambda}{\gamma_2}\right) \\ 0 \end{pmatrix} = \begin{pmatrix} \lambda \log\left(\frac{\lambda}{\lambda(1-\tilde{\tau}_1)}\right) \\ 0 \end{pmatrix} = \begin{pmatrix} \lambda \log\left(\frac{1}{1-\tilde{\tau}_1}\right) \\ 0 \end{pmatrix}$$

¹I substitute $(1 - \tilde{\tau}) = \frac{\sigma_i - 1}{\sigma_i}(1 - \tau_i)$

Our original equation (39) simplifies to:

$$\begin{aligned} \log Y = & \begin{pmatrix} 1 \\ \lambda \end{pmatrix}' \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1-1}{\sigma_1} 1 - \tau_1) \\ \log(\frac{\sigma_2-1}{\sigma_2} 1 - \tau_2) \end{pmatrix} + \begin{pmatrix} \alpha_1 \log(\frac{\alpha_1}{\alpha_1(1-\tilde{\tau}_1)+\alpha_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \\ \alpha_2 \log(\frac{\alpha_2\lambda(1-\tau_1)}{\alpha_1(1-\tilde{\tau}_1)+\alpha_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \end{pmatrix} \right) \\ & + \begin{pmatrix} \epsilon_1 \log(\frac{\epsilon_1}{\epsilon_1(1-\tilde{\tau}_1)+\epsilon_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \\ \epsilon_2 \log(\frac{\epsilon_2\lambda(1-\tau_1)}{\epsilon_1(1-\tilde{\tau}_1)+\epsilon_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \end{pmatrix} + \begin{pmatrix} \lambda \log(\frac{1}{1-\tilde{\tau}_1}) \\ 0 \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log K + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L \end{aligned}$$

Because we are only interested in the effect of changing the wedges, we can lump the aspects of the equation together:

$$\begin{aligned} \log Y = & \begin{pmatrix} 1 \\ \lambda \end{pmatrix}' \left(\begin{pmatrix} \log(1 - \tilde{\tau}_1) \\ \log(1 - \tilde{\tau}_2) \end{pmatrix} + \begin{pmatrix} \alpha_1 \log(\frac{\alpha_1}{\alpha_1(1-\tilde{\tau}_1)+\alpha_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \\ \alpha_2 \log(\frac{\alpha_2\lambda(1-\tilde{\tau}_1)}{\alpha_1(1-\tilde{\tau}_1)+\alpha_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \end{pmatrix} \right) \\ & + \begin{pmatrix} \epsilon_1 \log(\frac{\epsilon_1}{\epsilon_1(1-\tilde{\tau}_1)+\epsilon_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \\ \epsilon_2 \log(\frac{\epsilon_2\lambda(1-\tau_1)}{\epsilon_1(1-\tilde{\tau}_1)+\epsilon_2\lambda(1-\tilde{\tau}_2)(1-\tilde{\tau}_1)}) \end{pmatrix} + \begin{pmatrix} \lambda \log(\frac{1}{1-\tilde{\tau}_1}) \\ 0 \end{pmatrix} + constant \end{aligned}$$

Expanding, coupling terms, and cancelling out:

$$\begin{aligned} \log Y = & (1 - \lambda - \alpha_1 - \epsilon_1) \log(1 - \tilde{\tau}_1) + \lambda \log(1 - \tilde{\tau}_2) + \alpha_1 \log(\frac{\alpha_1}{\alpha_1 + \alpha_2\lambda(1 - \tilde{\tau}_2)}) \\ & + \lambda \alpha_2 \log(\frac{\alpha_2\lambda}{\alpha_1 + \alpha_2\lambda(1 - \tilde{\tau}_2)}) + \epsilon_1 \log(\frac{\epsilon_1}{\epsilon_1 + \epsilon_2\lambda(1 - \tilde{\tau}_2)}) + \lambda \epsilon_2 \log(\frac{\epsilon_2\lambda}{\epsilon_1 + \epsilon_2\lambda(1 - \tilde{\tau}_2)}) + constant \end{aligned}$$

Using the CRS assumption, we are left with:

$$\log Y = \lambda \log(1 - \tilde{\tau}_2) + \alpha_1 \log\left(\frac{\alpha_1}{\alpha_1 + \alpha_2 \lambda(1 - \tilde{\tau}_2)}\right) + \lambda \alpha_2 \log\left(\frac{\alpha_2 \lambda}{\alpha_1 + \alpha_2 \lambda(1 - \tilde{\tau}_2)}\right)$$

$$+ \epsilon_1 \log\left(\frac{\epsilon_1}{\epsilon_1 + \epsilon_2 \lambda(1 - \tilde{\tau}_2)}\right) + \lambda \epsilon_2 \log\left(\frac{\epsilon_2 \lambda}{\epsilon_1 + \epsilon_2 \lambda(1 - \tilde{\tau}_2)}\right) + \text{constant}$$

Taking the derivative of this with respect to $\tilde{\tau}_1$ and $\tilde{\tau}_2$:

$$\frac{d \log Y}{d \tilde{\tau}_1} = 0$$

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda \left(\frac{1}{1 - \tilde{\tau}_2} - \alpha_2 \frac{\alpha_1 + \alpha_2 \lambda}{\alpha_1 + \alpha_2 \lambda(1 - \tilde{\tau}_2)} - \epsilon_2 \frac{\epsilon_1 + \epsilon_2 \lambda}{\epsilon_1 + \epsilon_2 \lambda(1 - \tilde{\tau}_2)} \right)$$

Expanding these terms:

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda \left(\frac{(\alpha_1 + \alpha_2 \lambda)(\epsilon_1 + \epsilon_2 \lambda)(1 - \tilde{\tau}_2) - \alpha_2(\alpha_1 + \alpha_2 \lambda)(\epsilon_1 + \epsilon_2 \lambda(1 - \tilde{\tau}_2))(1 - \tilde{\tau}_2) - \epsilon_2(\epsilon_1 + \epsilon_2 \lambda)(1 - \tilde{\tau}_2)(\alpha_1 + \alpha_2 \lambda(1 - \tilde{\tau}_2))}{(1 - \tilde{\tau}_2)(\alpha_1 + \alpha_2 \lambda)(\epsilon_1 + \epsilon_2 \lambda(1 - \tilde{\tau}_2))} \right)$$

Organizing terms by $\alpha_1 \epsilon_1$, $\alpha_1 \epsilon_2$, $\alpha_2 \epsilon_1$, and $\alpha_2 \epsilon_2$ and using the CRS assumptions ($1 = \lambda + \alpha_1 + \epsilon_1$ and $1 = \alpha_2 + \epsilon_2$):

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda \left(\frac{\alpha_1 \epsilon_1 (1 - \alpha_2 (1 - \tau_2) - \epsilon_2 (1 - \tau_2)) + \alpha_1 \epsilon_2 \lambda (1 - \alpha_2 (1 - \tau_2) - \epsilon_2) + \alpha_2 \epsilon_1 \lambda (1 - \alpha_2 - \epsilon_2 (1 - \tau_2)) + \alpha_2 \epsilon_2 \lambda^2 (1 - \alpha_2 - \epsilon_2)}{(1 - \tilde{\tau}_2)(\alpha_1 + \alpha_2 \lambda)(\epsilon_1 + \epsilon_2 \lambda(1 - \tilde{\tau}_2))} \right)$$

Using the CRS assumptions ($1 = \lambda + \alpha_1 + \epsilon_1$ and $1 = \alpha_2 + \epsilon_2$):

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda \left(\frac{\alpha_1 \epsilon_1 (\alpha_2 \tau_2 + \epsilon_2 \tau_2) + \alpha_1 \epsilon_2 \lambda (\alpha_2 \tau_2) + \alpha_2 \epsilon_1 \lambda (\epsilon_2 \tau_2)}{(1 - \tilde{\tau}_2)(\alpha_1 + \alpha_2 \lambda)(\epsilon_1 + \epsilon_2 \lambda(1 - \tilde{\tau}_2))} \right)$$

This simplifies to:

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda \tilde{\tau}_2 \frac{\frac{\alpha_1 \epsilon_1}{1 - \tilde{\tau}_2} + \alpha_2 \epsilon_2 \lambda (1 - \lambda)}{(\epsilon_1 + \epsilon_2 \lambda (1 - \tilde{\tau}_2))(\alpha_1 + \alpha_2 \lambda (1 - \tilde{\tau}_2))}$$

This can be further simplified using the assumptions that the labor and capital shares are $\alpha_1 = \frac{1}{3}(1 - \lambda)$, $\epsilon_1 = \frac{2}{3}(1 - \lambda)$, $\alpha_2 = \frac{1}{3}$, $\epsilon_2 = \frac{2}{3}$

Including these, we have:

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda \tilde{\tau}_2 \frac{\frac{\frac{2}{9}(1 - \lambda)^2}{1 - \tilde{\tau}_2} + \frac{2}{9}\lambda(1 - \lambda)}{(\frac{2}{3}(1 - \lambda) + \frac{2}{3}\lambda(1 - \tilde{\tau}_2))(\frac{1}{3}(1 - \lambda) + \frac{1}{3}\lambda(1 - \tilde{\tau}_2))}$$

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda \tilde{\tau}_2 \frac{(1 - \lambda)^2 + \lambda(1 - \lambda)(1 - \tilde{\tau}_2)}{(1 - \tilde{\tau}_2)^3}$$

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\lambda(1 - \lambda) \tilde{\tau}_2 \frac{(1 - \lambda) + \lambda(1 - \tilde{\tau}_2)}{(1 - \tilde{\tau}_2)^3}$$

$$\frac{d \log Y}{d \tilde{\tau}_2} = -\frac{\lambda(1 - \lambda) \tilde{\tau}_2}{(1 - \tilde{\tau}_2)^2}$$

.4 Theoretical Markup Derivation

To see this, I solve for prices using the FOCs to solve. Taking the example of H_s and K_s ,

$$p_s = \frac{\sigma_s}{\sigma_s - 1} \frac{1}{1 - \tau_s^Q} \frac{w}{\epsilon_s} \frac{H_s}{p_s Q_s} = \frac{\sigma_s}{\sigma_s - 1} \frac{1}{1 - \tau_s^Q} \frac{1}{\alpha_s} \frac{K_s}{p_s Q_s}$$

So that ratios of factor inputs are given for example by:

$$\frac{K_s}{H_s} = \frac{w}{r} \frac{\alpha_s}{\epsilon_s}$$

with similar conditions for all combinations of inputs.

And further notice that the FOC can be written as

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) A_s \epsilon_s \left(\frac{K_s}{H_s} \right)^{\alpha_s} \left(\frac{m_{s1}}{H_s} \right)^{\lambda_{s1}} \left(\frac{m_{s2}}{H_s} \right)^{\lambda_{s2}} = \frac{w}{p_s}$$

since $\epsilon_s = 1 - \alpha_s - \lambda_{s1} - \lambda_{s2}$. Substituting in all the input ratios, and solving for p_s we have equation (2.15). This result is similar to the Hsieh & Klenow (2009) result on distortions and their consequent markups.

.5 Price Index Construction

International prices are available in the following sectors:

Table 1: Sectors Used for Basket of International Prices

Sector	International Price Aggregate
Agriculture, Hunting, Forestry and Fishing	Agr: Food Grains
Mining and Quarrying	Metals and minerals
Food, Beverages and Tobacco	Agr: Food
Textiles and Textile Products	Cotton
Wood and Products of Wood and Cork	Timber
Pulp, Paper, Paper , Printing and Publishing	Woodpulp
Coke, Refined Petroleum and Nuclear Fuel	Energy
Chemicals and Chemical Products	Fertilizers
Rubber and Plastics	Rubber
Basic Metals and Fabricated Metal	Metals and Minerals

Attention is extended to these sectors primarily for international price data availability reasons, but they also represent the sectors primarily used as inputs into domestic production sectors. To estimate the international prices, I use the World Bank Global Economic Monitor (GEM) Commodity Prices Database. This database uses specific international prices to construct aggregates in certain sectors. Table 2 describes the construction of GEM sector aggregates.

Table 2: International Aggregate Construction

International Price Aggregate	Description
Agr: Food Grains	Grains index includes barley, maize, rice and wheat.
Metals and minerals	Metals and minerals index: aluminum, copper, iron ore, lead, nickle, tin and zinc.
Agr: Food	Food index includes fats and oils, grains and other food items.
Cotton	Cotton (Cotton Outlook "CotlookA index")
Agr: Raw: Timber	Timber index includes tropical hard logs and sawnwood.
Woodpulp	Woodpulp (Sweden), softwood, sulphate, bleached, air-dry weight
Energy	Energy index, a Laspeyres Index for coal, crude oil and natural gas.
Fertilizers	Fertilizers index: natural phosphate rock, phosphate, potassium and nitrogenous products.
Rubber	Rubber (Asia), RSS3 grade, Singapore Commodity Exchange Ltd (SICOM)
Metals and Minerals	Metals and minerals index: aluminum, copper, iron ore, lead, nickle, tin and zinc.

.6 Additional First Stage Results

In this section, I include additional first stage results charting for which sectors the first stage F-statistics are the strongest, the relationship between the aggregate markup and the average F-statistic and standard deviation of the F-statistics, and the shares of markups which hit the upper or lower bounds.

Figures 1, 2, & 3 chart the relationship between the unbounded and bounded markup estimates and the first stage F-statistics.

Figures 4, 5, & 6 chart the relationship between the average markup and the share of markups at the lower or upper bound.

Figure 1: Unbounded Markup and First Stage F-Statistics

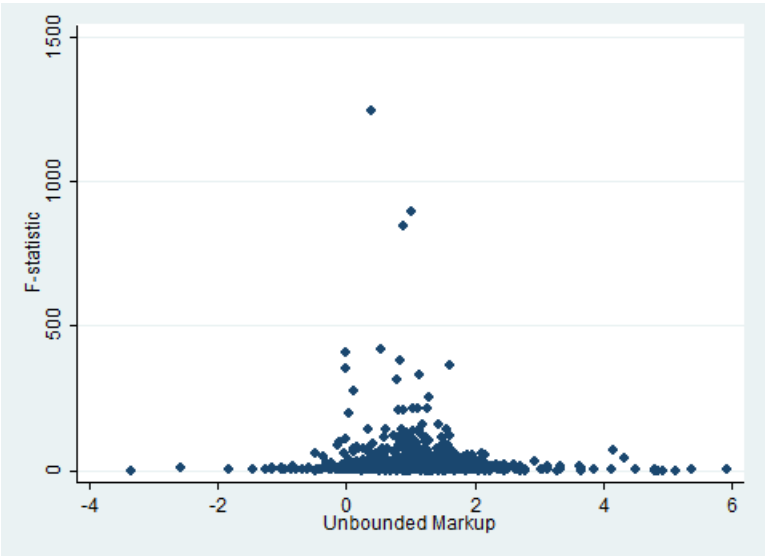


Figure 2: Average Markup and Average F-Statistics

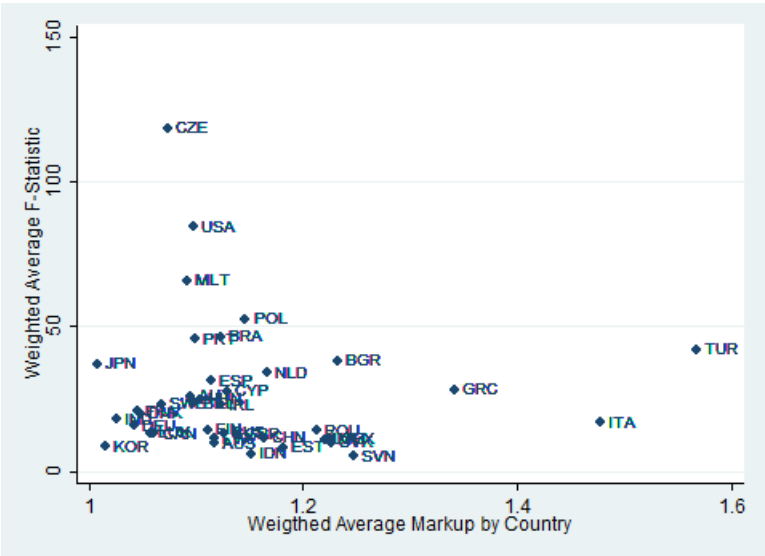


Figure 3: Average Markup and Standard Deviation of F-Statistics

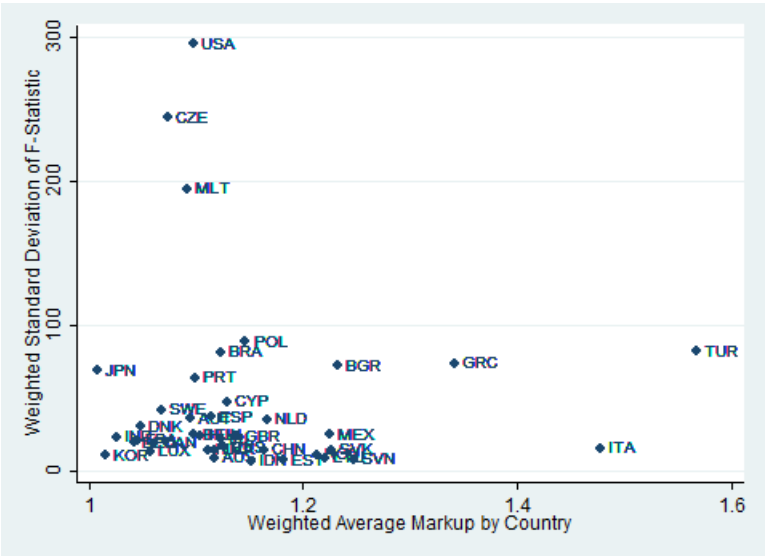


Figure 4: Average Markup and Share of Markups at Lower Bound

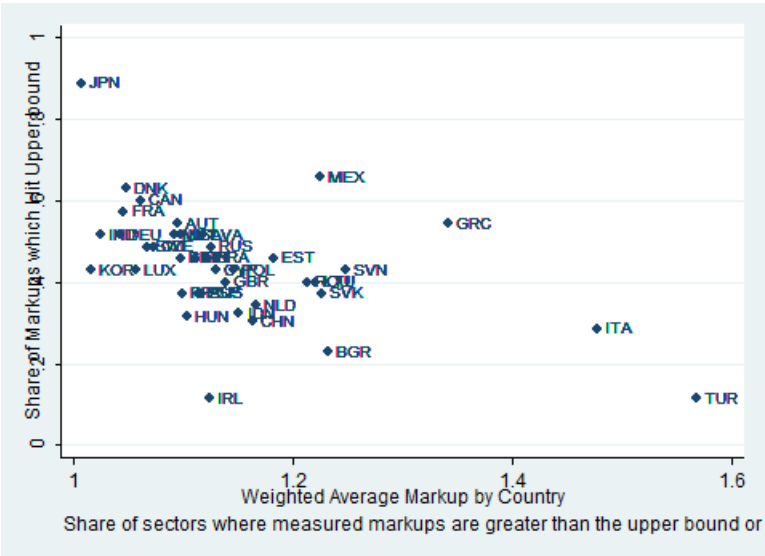
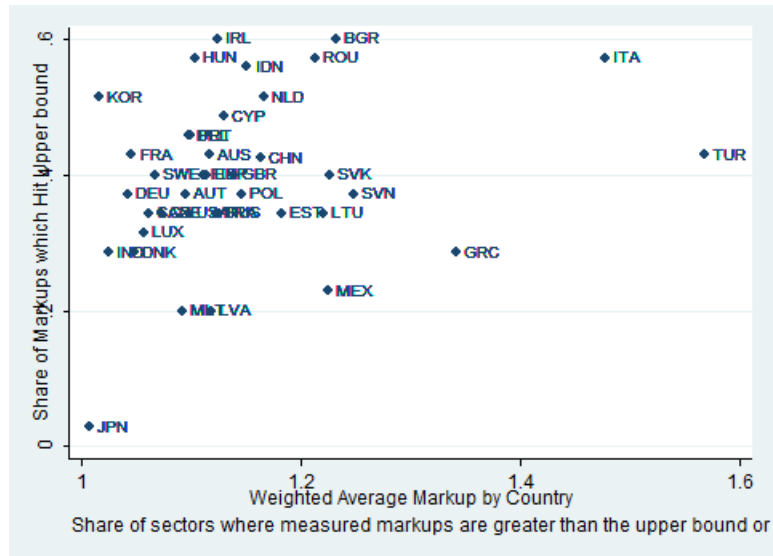


Figure 5: Average Markup and Share of Markups at Upper Bound



.7 US Markups

In this Table 3, I report the estimated bounded markups, unbounded markups, aggregate markup, share of GDP (measured as $\frac{VA}{GDP}$), and share of final goods and exports, β .

.8 Derivation of Equilibrium Conditions with Capital Accumulation

The derivation with capital accumulation follows similarly for equations (1) through (8). I deviate from the derivation starting with the equation (62). The following equations remain the same except I define the capital allocation term differently.

Combining the first order conditions, equation (8) with the equality from (1) that $\frac{p_i}{p_j} = \frac{\beta_i}{\beta_j} \frac{y_j}{y_i}$. The equilibrium input quantities are:

$$\frac{H_s}{H} = \frac{\frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\epsilon_s\gamma_s}{\frac{\sigma_1-1}{\sigma_1}(1-\tau_1)\epsilon_1\gamma_1 + \frac{\sigma_2-1}{\sigma_2}(1-\tau_2)\epsilon_2\gamma_2} \equiv \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\theta_s^H \quad (41)$$

$$K_s = \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\alpha_s\frac{\gamma_s Y}{r} \equiv \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\hat{\theta}_s^K Y \quad (42)$$

$$m_{s1} = \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\lambda_{sj}\frac{\gamma_s Q_1}{\gamma_1} \equiv \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\theta_{s1}^m Q_1 \quad (43)$$

$$m_{s1} = \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\lambda_{sj}\frac{\gamma_s Q_2}{\gamma_2} \equiv \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\theta_{s2}^m Q_2 \quad (44)$$

Table 3: US Markups

Sector	μ	μ_{unb}	ρ	GDPsh	β
Agric, hunting, forestry, fishing	1.00	0.50	1.02	0.01	0.01
Mining and quarrying	1.00	0.35	1.17	0.02	0.01
Food, beverages, and tobacco	1.00	0.90	1.04	0.01	0.03
Textile and textile products	1.08	1.18	1.13	0.00	0.00
Leather and footwear	1.00	0.53	1.00	0.00	0.00
Wood and Products of Wood	1.00	0.86	1.01	0.00	0.00
Pulp, Paper, Printing, Publishing	1.17	1.35	1.32	0.01	0.01
Coke, ref petrol, nuclear fuel	1.00	0.38	1.07	0.01	0.01
Chemicals and chemical	1.22	2.19	1.45	0.01	0.02
Rubber and plastics	1.10	1.10	1.15	0.00	0.00
Other non-metallic mineral	1.23	1.25	1.28	0.00	0.00
Basic metals and fabricated metal	1.12	1.18	1.29	0.01	0.00
Machinery nec	1.04	1.04	1.07	0.01	0.01
Electrical and optical equipment	1.12	1.69	1.18	0.02	0.02
Transport equipment	1.09	1.12	1.14	0.01	0.03
Manufacturing nec; recycling	1.00	0.10	1.01	0.00	0.01
Electricity, gas, and water supply	1.57	1.57	1.68	0.02	0.01
Construction	1.00	0.80	1.05	0.04	0.06
Sale/repair of vehicles; retail gas	1.00	0.53	1.01	0.01	0.01
Wholesale trade, except vehicles	1.00	0.40	1.15	0.06	0.04
Retail trade, except vehicles	1.00	0.19	1.04	0.06	0.07
Hotels and Restaurants	1.17	1.37	1.23	0.03	0.04
Inland transport	1.13	2.26	1.28	0.01	0.01
Water transport	1.00	-0.12	1.00	0.00	0.00
Air transport	1.00	0.85	1.01	0.00	0.01
Supporting transport activities	1.00	-0.47	1.05	0.01	0.00
Post and telecommunications	1.00	0.07	1.09	0.03	0.02
Financial intermediation	1.37	2.36	2.00	0.09	0.06
Real estate activities	1.00	0.53	1.11	0.12	0.11
Renting m&eq	1.17	1.17	1.97	0.13	0.05
Public admin, defence; soc security	1.07	1.59	1.11	0.13	0.19
Education	0.91	0.25	0.91	0.01	0.01
Health and social work	1.00	0.05	1.00	0.07	0.11
Community and personal services	1.21	1.34	1.33	0.04	0.04
Households with employees			1.00	0.00	0.00

μ is the bounded markup. μ_{unb} is the unbounded markup. ρ is the aggregate markup for the listed sector. GDPsh is the share of GDP represented by the value added in that sector. β is the share of final goods and exports reflected by that sector.

Plugging these into the production equation:

$$Q_s = A_s \left(\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \right) (\theta_s^H H)^{\epsilon_s} (\hat{\theta}_s^K Y)^{\alpha_s} (\theta_{s1}^m Q_1)^{\lambda_{s1}} (\theta_{s2}^m Q_2)^{\lambda_{s2}} \quad (45)$$

so that taking natural logs and stacking into vectors:

$$q = a + \omega^Q + \hat{\omega} + \epsilon \log H + \alpha \log Y + Bq \quad (46)$$

where α and ϵ are vectors of coefficients, the matrix B is the undistorted input-output table with entries as the coefficients for inputs. a is the vector of logged sector productivity. ω^Q is the vector of sector frictions and markups, and $\hat{\omega} \equiv \omega^H + \hat{\omega}^K + \omega^m$ is the collection of allocation terms: $\hat{\omega}_s^K = \alpha_s \log(\hat{\theta}_s^K)$, $\omega_s^H = \epsilon_s \log(\theta_s^H)$, $\omega_s^m = \lambda_{s1} \log(\theta_{s1}^m) + \lambda_{s2} \log(\theta_{s2}^m)$.

The solution is

$$q = (I - B)^{-1} (a + \omega^Q + \hat{\omega} + \epsilon \log H + \alpha \log Y) \quad (47)$$

Here q , a , ω^Q , ω , ϵ and α are 2x1 vectors, I and B are 2x2 matrices, and $\log K$ and $\log H$ are scalars. It is important to note that due to the differences in the capital allocation factor, $\hat{\omega}$ is different than the original ω .

$$\begin{pmatrix} q_1 \\ q_2 \end{pmatrix} = \begin{pmatrix} 1 - \lambda_{11} & -\lambda_{12} \\ -\lambda_{21} & 1 - \lambda_{22} \end{pmatrix}^{-1} \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1 - 1}{\sigma_1} 1 - \tau_1) \\ \log(\frac{\sigma_2 - 1}{\sigma_2} 1 - \tau_2) \end{pmatrix} \right) \quad (48)$$

$$+ \begin{pmatrix} \alpha_1 \log(\theta_1^K) + \epsilon_1 \log(\theta_1^H) + \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \alpha_2 \log(\theta_2^K) + \epsilon_2 \log(\theta_2^H) + \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log Y + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L$$

From the definition of γ_s and (1), $y_s = \frac{\beta_s Q_s}{\gamma_s}$. In logs, this becomes:

$$y = \omega_y + q$$

where ω_y is the vector of $\log(\frac{\beta_s}{\gamma_s}) = \log(\frac{p_s y_s}{p_s Q_s})$, the ratios of final good and export production to the gross production.

From the definition of Y,

$$\log Y = \beta' y = \beta' \omega_y + \beta' q$$

where y is the vector of logged final consumption and exports, and β is the vector of β_s .

The final output in logs is given by

$$\log Y = \beta' \omega_y + \beta' (I - B)^{-1} (a + \omega^Q + \hat{\omega} + \epsilon \log H + \alpha \log Y) \quad (49)$$

This now simplifies to

$$\log Y = \frac{\beta' \omega_y + \beta' (I - B)^{-1} (a + \omega^Q + \hat{\omega} + \epsilon \log H)}{1 - \beta' (I - B)^{-1} \alpha} \quad (50)$$

Taking the antilogs of (50), output is given by

$$Y = A^{\hat{\psi}}(1 - \tau)^{\hat{\psi}} H^{\hat{\epsilon}} \hat{\xi} \quad (51)$$

where the multipliers are given by

$$\hat{\psi} = \frac{\beta'(I - B)^{-1}\mathbf{1}}{1 - \beta'(I - B)^{-1}\alpha}$$

$$\hat{\epsilon} = \frac{\beta'(I - B)^{-1}\epsilon}{1 - \beta'(I - B)^{-1}\alpha}$$

and $\hat{\xi}$ is given by

$$\log(\hat{\xi}) = \frac{\beta'\omega_y + \beta'(I - B)^{-1}(\omega + \tilde{\eta}_a + \tilde{\eta}_\tau)}{1 - \beta'(I - B)^{-1}\alpha}$$

$$A\eta_{as} = A_s$$

$$(1 - \tau)\eta_{\tau s} = \frac{\sigma_s - 1}{\sigma_s}(1 - \tau_s)$$

where A is the weighted average of the productivity: $\log(A) = \beta_1 \log(A_1) + \beta_2 \log(A_2)$, and τ is the weighted average of the markups: $\log(1 - \tau) = \beta_1 \log(\frac{\sigma_1 - 1}{\sigma_1}(1 - \tau_1)) + \beta_2 \log(\frac{\sigma_2 - 1}{\sigma_2}(1 - \tau_2))$. $\tilde{\eta}_a$ and $\tilde{\eta}_\tau$ are vectors of the logged η_{as} and $\eta_{\tau s}$ terms.

.9 Derivation of Equilibrium Conditions with International Trade

There are two different conditions when moving to international trade, the production function now includes imports which are considered separate Cobb-Douglas inputs and there is now a balanced trade condition requiring the imported inputs to be equal to the value of exports.

The balanced trade condition:

$$FX = \sum_{s=1}^N \sum_{j=1}^N \tilde{p}_j \tilde{m}_{sj} \quad (52)$$

And that total GDP is divided between consumption and exports

$$Y = C + FX \quad (53)$$

Maximizing (2.4) subject to (2.5) the first order conditions are:

$$\frac{p_s c_s}{Y} = \beta_s \quad (54)$$

To solve the firms' maximization problem, we first must find the price as a function of quantity from (2.2) and (2.3).

This maximization for firm i gives:

$$\frac{\sigma_s - 1}{\sigma_s} \left(q_{s_i}^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1} - 1} \frac{\sigma_s}{\sigma_s - 1} q_{s_i}^{\frac{\sigma_s - 1}{\sigma_s} - 1} - \lambda p_{s_i} = 0$$

$$(q_{s_i}^{\frac{\sigma_s-1}{\sigma_s}})^{\frac{1}{\sigma_s-1}} = \lambda p_{s_i} q_{s_i}^{\frac{1}{\sigma_s}}$$

$$Q_s = (q_{s_i}^{\frac{\sigma_s-1}{\sigma_s}})^{\frac{\sigma_s}{\sigma_s-1}} = (\lambda p_{s_i})^{\sigma_s} q_{s_i}$$

$$Q_s (\lambda p_{s_i})^{-\sigma_s} = q_{s_i}$$

Plugging this into the definition of Q_s :

$$Q_s = \left(\int (Q_s (\lambda p_{s_i})^{-\sigma_s})^{\frac{\sigma_s-1}{\sigma_s}} di \right)^{\frac{\sigma_s}{\sigma_s-1}}$$

which reduces to

$$\lambda^{\sigma_s} = \left(\int ((p_{s_i})^{-\sigma_s})^{\frac{\sigma_s-1}{\sigma_s}} di \right)^{\frac{\sigma_s}{\sigma_s-1}}$$

Reducing this the price index for sector s output is:

$$p_s \equiv \frac{1}{\lambda} = \left(\int (p_{s_i}^{1-\sigma_s} di) \right)^{\frac{1}{1-\sigma_s}}$$

So that price of firm i's output in terms of firm i's quantity produced is:

$$p_{s_i} = \left(\frac{Q_s}{q_{s_i}} \right)^{\frac{1}{\sigma_s}} p_s$$

Plugging this price function into the original firms' maximization equation, (2.1)

we now maximize

$$\max_{q_{1_i}, K_{1_i}, H_{1_i}, m_{1_i1}, m_{1_i2}} (1 - \tau_1) p_s Q_1^{\frac{1}{\sigma_1}} q_{1_i}^{\frac{\sigma_1-1}{\sigma_1}} - \sum_{s=1}^N p_s m_{1_i s} - \sum_{s=1}^N \tilde{p}_s \tilde{m}_{1_i s} - r K_{1_i} - w H_{1_i}$$

$$s.t. \quad q_{1_i} = A_1 K_{1_i}^{\alpha_1} H_{1_i}^{\epsilon_1} m_{1_i1}^{\lambda_{11}} m_{1_i2}^{\lambda_{12}}$$

taking p_s and Q_s as given.

Because the firms within a sector are identical so $q_{s_i} = Q_s$ for each sector, s , the equilibrium conditions reduce to (because $Q_1^{\frac{1}{\sigma_1}} q_{1_i}^{\frac{\sigma_1-1}{\sigma_1}-1} = Q_1^{\frac{1}{\sigma_1}} Q_1^{\frac{\sigma_1-1}{\sigma_1}-1} = 1$):

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \epsilon_s \frac{p_s Q_s}{H_s} = w \quad (55)$$

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \alpha_s \frac{p_s Q_s}{K_s} = r \quad (56)$$

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{sj} \frac{p_s Q_s}{m_{sj}} = p_j \quad (57)$$

$$\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \lambda_{sj}^* \frac{p_s Q_s}{\tilde{m}_{sj}} = \tilde{p}_j \quad (58)$$

Here the σ_s represents the elasticity of substitution for firms output between an sector which determines the markup, τ_s is the fraction of output which is lost due to a friction which could represent corruption, theft, rent seeking etc. These two drive

a wedge between the price of the input and the marginal revenue product from the input.

Plugging in the first order conditions for domestic inputs into (2.6)

$$Q_j = y_j + \sum_{s=1}^N m_{sj} \quad (59)$$

$$Q_j = y_j + \frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{1j} \frac{p_1 Q_1}{p_j} + \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{2j} \frac{p_2 Q_2}{p_j}$$

Using (1), this is:

$$p_j Q_j = Y \beta_j + \frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{1j} p_1 Q_1 + \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{2j} p_2 Q_2$$

So that the solution to these equations when stacked is:

$$\begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix} \equiv \begin{pmatrix} \frac{p_1 Q_1}{Y} \\ \frac{p_2 Q_2}{Y} \end{pmatrix} = \begin{pmatrix} 1 - \frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{11} & -\frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{21} \\ -\frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \lambda_{12} & 1 - \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \lambda_{22} \end{pmatrix}^{-1} \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix} \quad (60)$$

Combining the first order conditions, equation (60) with the equality from (1)

that $\frac{p_i}{p_j} = \frac{\beta_i}{\beta_j} \frac{y_j}{y_i}$. The equilibrium input quantities are:

$$\frac{H_s}{H} = \frac{\frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \epsilon_s \gamma_s}{\frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1) \epsilon_1 \gamma_1 + \frac{\sigma_2 - 1}{\sigma_2} (1 - \tau_2) \epsilon_2 \gamma_2} \equiv \frac{\sigma_s - 1}{\sigma_s} (1 - \tau_s^Q) \theta_s^H \quad (61)$$

$$\frac{K_s}{K} = \frac{\frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\alpha_s\gamma_s}{\frac{\sigma_1-1}{\sigma_1}(1-\tau_1)\alpha_1\gamma_1 + \frac{\sigma_2-1}{\sigma_2}(1-\tau_2)\alpha_2\gamma_2} \equiv \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\theta_s^K \quad (62)$$

$$m_{sj} = \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\lambda_{sj}\frac{\gamma_s Q_j}{\gamma_j} \equiv \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\theta_{sj}^m Q_j \quad (63)$$

$$\tilde{m}_{sj} = \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\lambda_{sj}^*\frac{\gamma_s Y}{\tilde{p}_j} \equiv \frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\theta_{sj}^{\tilde{m}} Y \quad (64)$$

Plugging these into the production equation:

$$Q_s = A_s\left(\frac{\sigma_s-1}{\sigma_s}(1-\tau_s^Q)\right)(\theta_s^H H)^{\epsilon_s}(\theta_s^K K)^{\alpha_s}\Pi_{j=1}^N(\theta_{sj}^m Q_j)^{\lambda_{sj}}\Pi_{j=1}^N(\theta_{sj}^{\tilde{m}} Y)^{\lambda_{sj}^*} \quad (65)$$

so that taking natural logs and stacking into vectors:

$$q = a + \omega^Q + \omega + \epsilon \log H + \alpha \log K + Bq \quad (66)$$

where α and ϵ are vectors of coefficients, the matrix B is the undistorted input-output table with entries as the coefficients for inputs. a is the vector of logged sector productivity. ω^Q is the vector of sector frictions and markups, and $\omega \equiv \omega^H + \omega^K + \omega^m + \omega^{\tilde{m}}$ is the collection of allocation terms: $\omega_s^K = \alpha_s \log(\theta_s^K)$, $\omega_s^H = \epsilon_s \log(\theta_s^H)$, $\omega_s^m = \sum_{j=1}^N \lambda_{sj} \log(\theta_{sj}^m)$, $\omega_s^{\tilde{m}} = \sum_{j=1}^N \lambda_{sj}^* \log(\theta_{sj}^{\tilde{m}})$.

The solution is

$$q = (I - B)^{-1}(a + \omega^Q + \omega + \epsilon \log H + \alpha \log K + \lambda^* \log Y) \quad (67)$$

Here q , a , ω^Q , ω , ϵ and α are 2x1 vectors, I and B are 2x2 matrices, and $\log K$ and $\log H$ are scalars.

$$\begin{aligned} \begin{pmatrix} q_1 \\ q_2 \end{pmatrix} &= \begin{pmatrix} 1 - \lambda_{11} & -\lambda_{12} \\ -\lambda_{21} & 1 - \lambda_{22} \end{pmatrix}^{-1} \left(\begin{pmatrix} \log(A_1) \\ \log(A_2) \end{pmatrix} + \begin{pmatrix} \log(\frac{\sigma_1-1}{\sigma_1}1 - \tau_1) \\ \log(\frac{\sigma_2-1}{\sigma_2}1 - \tau_2) \end{pmatrix} \right) \\ &+ \begin{pmatrix} \alpha_1 \log(\theta_1^K) + \epsilon_1 \log(\theta_1^H) + \lambda_{11} \log(\theta_{11}^m) + \lambda_{12} \log(\theta_{12}^m) \\ \alpha_2 \log(\theta_2^K) + \epsilon_2 \log(\theta_2^H) + \lambda_{21} \log(\theta_{21}^m) + \lambda_{22} \log(\theta_{22}^m) \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \log K \\ &+ \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \log L + \begin{pmatrix} \lambda_1^* \\ \lambda_2^* \end{pmatrix} \log Y \end{aligned} \quad (68)$$

From the definition of γ_s and (1), $y_s = \frac{\beta_s Q_s}{\gamma_s}$. In logs, this becomes:

$$y = \omega_c + q$$

where ω_c is the vector of $\log(\frac{\beta_s}{\gamma_s}) = \log(\frac{p_s c_s}{p_s Q_s})$, the ratios of final good and export production to the gross production.

From the definition of Y ,

$$\log Y = \beta' c = \beta' \omega_c + \beta' q$$

where c is the vector of logged final consumption, and β is the vector of β_s .

The final output in logs is given by

$$\log Y = \beta' \omega_y + \beta' (I - B)^{-1} (a + \omega^Q + \omega + \epsilon \log H + \alpha \log K + \lambda^* \log Y)$$

which simplifies to

$$\log Y = \frac{\beta' \omega_y + \beta'(I - B)^{-1}(a + \omega^Q + \omega + \epsilon \log H + \alpha \log K)}{1 - \beta'(I - B)^{-1} \lambda^*} \quad (69)$$

Taking the antilogs of (69), output is given by

$$Y = A^\psi (1 - \tau)^\psi H^{\psi_H} K^{\psi_K} \xi \quad (70)$$

where the multipliers are given by

$$\begin{aligned} \mu &= \frac{\beta'(I - B)^{-1} \mathbf{1}}{1 - \beta'(I - B)^{-1} \lambda^*} \\ \psi_H &= \frac{\beta'(I - B)^{-1} \epsilon}{1 - \beta'(I - B)^{-1} \lambda^*} \\ \psi_K &= \frac{\beta'(I - B)^{-1} \alpha}{1 - \beta'(I - B)^{-1} \lambda^*} \end{aligned}$$

and ξ is given by

$$\begin{aligned} \log(\xi) &= \beta' \omega_y + \beta'(I - B)^{-1}(\omega + \tilde{\eta}_a + \tilde{\eta}_\tau) \\ A \eta_{as} &= A_s \\ (1 - \tau) \eta_{\tau i} &= \frac{\sigma_i - 1}{\sigma_i} (1 - \tau_i) \end{aligned}$$

where A is the weighted average of the productivity: $\log(A) = \beta_1 \log(A_1) + \beta_2 \log(A_2)$, and τ is the weighted average of the markups: $\log(1 - \tau) = \beta_1 \log(\frac{\sigma_1 - 1}{\sigma_1} (1 - \tau_1)) +$

$\beta_2 \log(\frac{\sigma_2-1}{\sigma_2}(1 - \tau_2))$. $\tilde{\eta}_a$ and $\tilde{\eta}_\tau$ are vectors of the logged η_{as} and $\eta_{\tau s}$ terms.

.10 Estimates of Markups as Compared to Bounds

.11 Sector Level Productivity

Figure 13 includes each of the all of the sectors in comparison to their GDP per capita. One sector stands out. Sector 29, Real estate, has very low productivity across countries. This is due to the fact that real estate has very large capital stocks as compared to output. While in effect these capital stock are more properly seen as inventory, because of the way that capital is measured, it looks like they are extremely capital intensive, which drives down the Solow residual to below 0 for all countries.

This property of real estate also drives some of the more unintuitive results. The top country in terms of GDP per capita has very high productivity on the whole, but real estate productivity is low even compared to much poorer countries due to the high real estate cost and stock. The unintuitive result that Luxembourg's output would increase by 2,500 percent, is primarily driven by this outlier.

Next are the individual sector variation in sector productivity. Some sectors' productivity follows the level of development very closely, most notably Financial Intermediation. However, there are others in which development has only a weakly positive correlation with sector productivity.

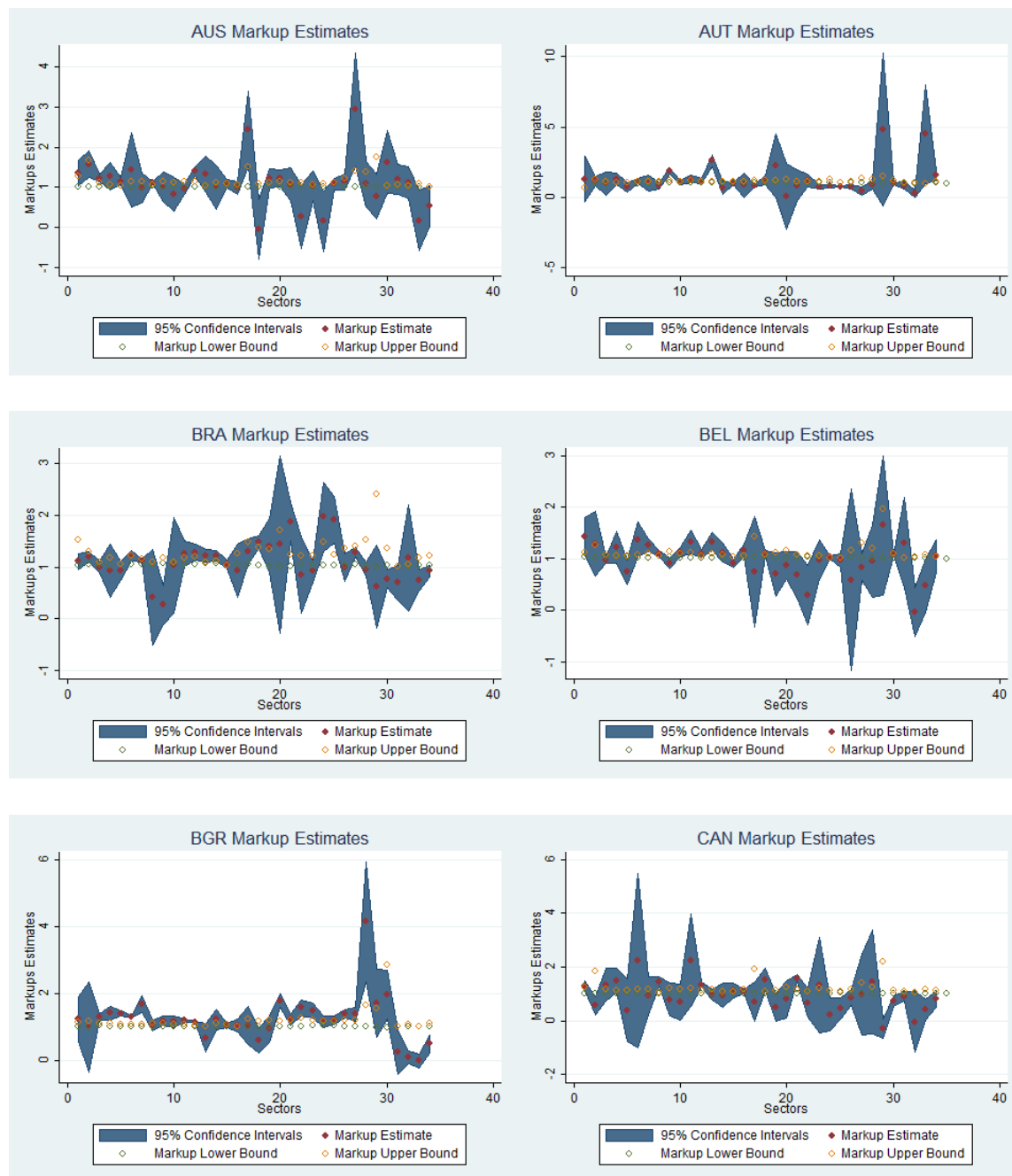


Figure 7: Plots of Markups as compared to their bounds by sector for each country

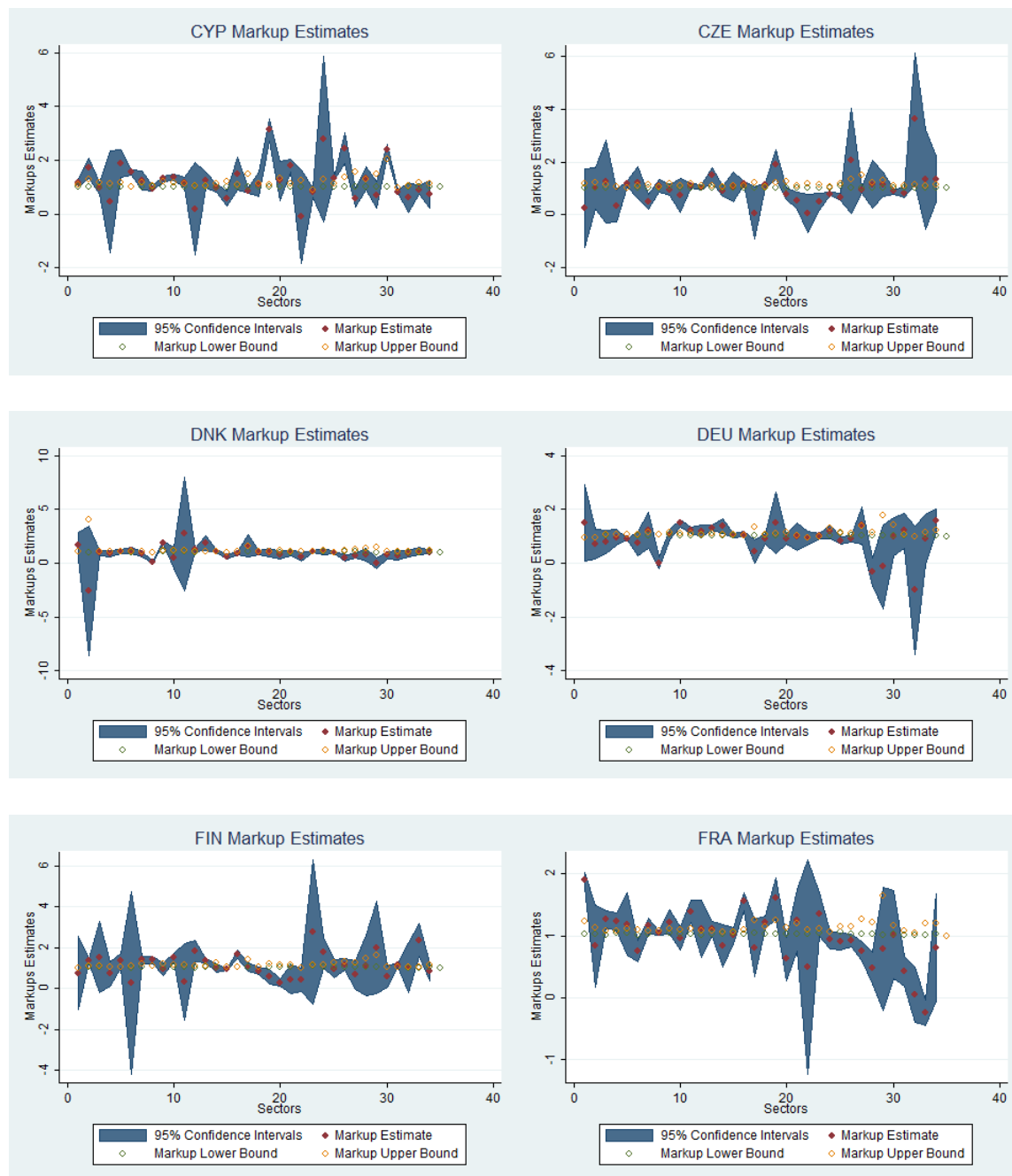


Figure 8: Plots of Markups as compared to their bounds by sector for each country

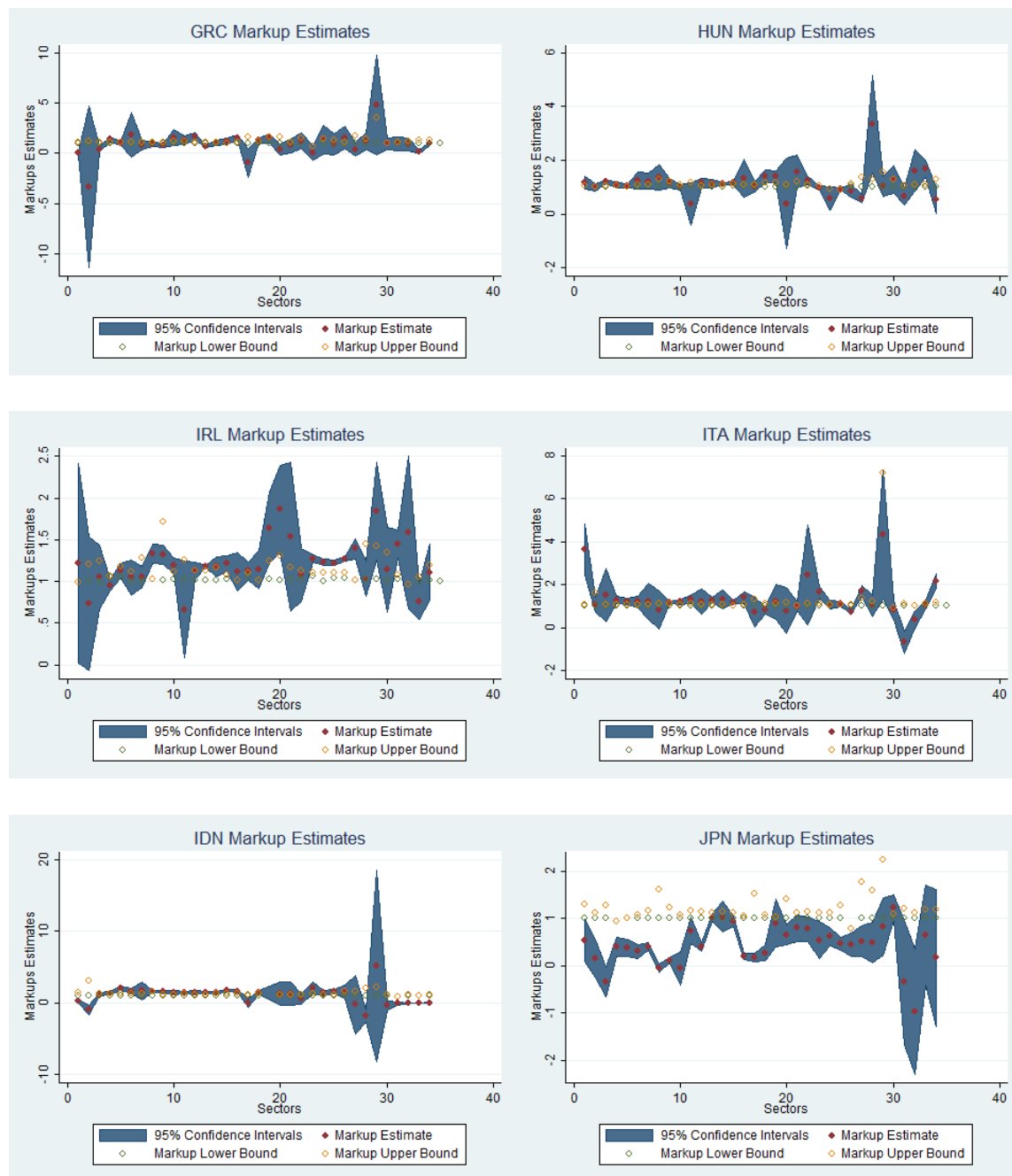


Figure 9: Plots of Markups as compared to their bounds by sector for each country

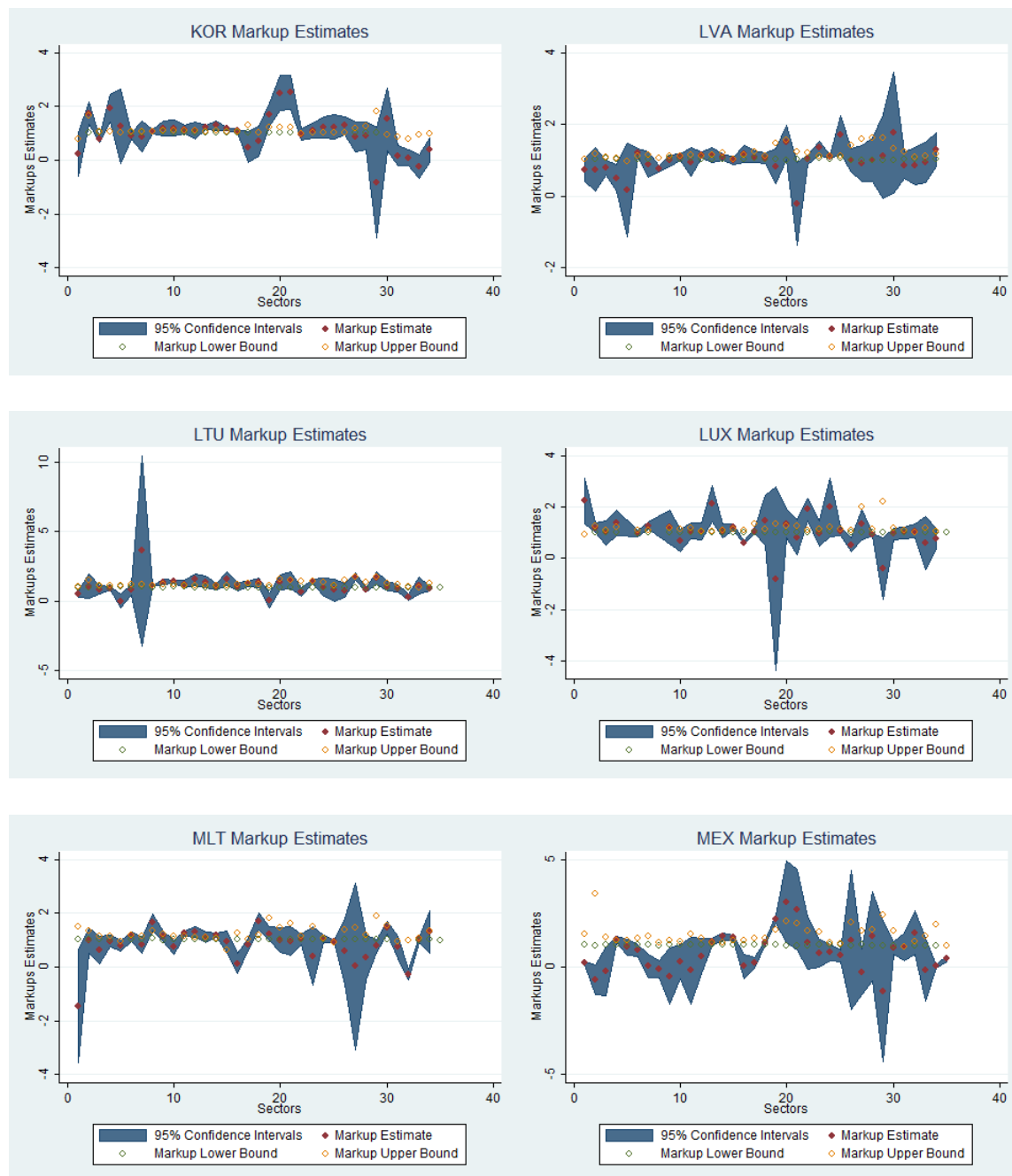


Figure 10: Plots of Markups as compared to their bounds by sector for each country

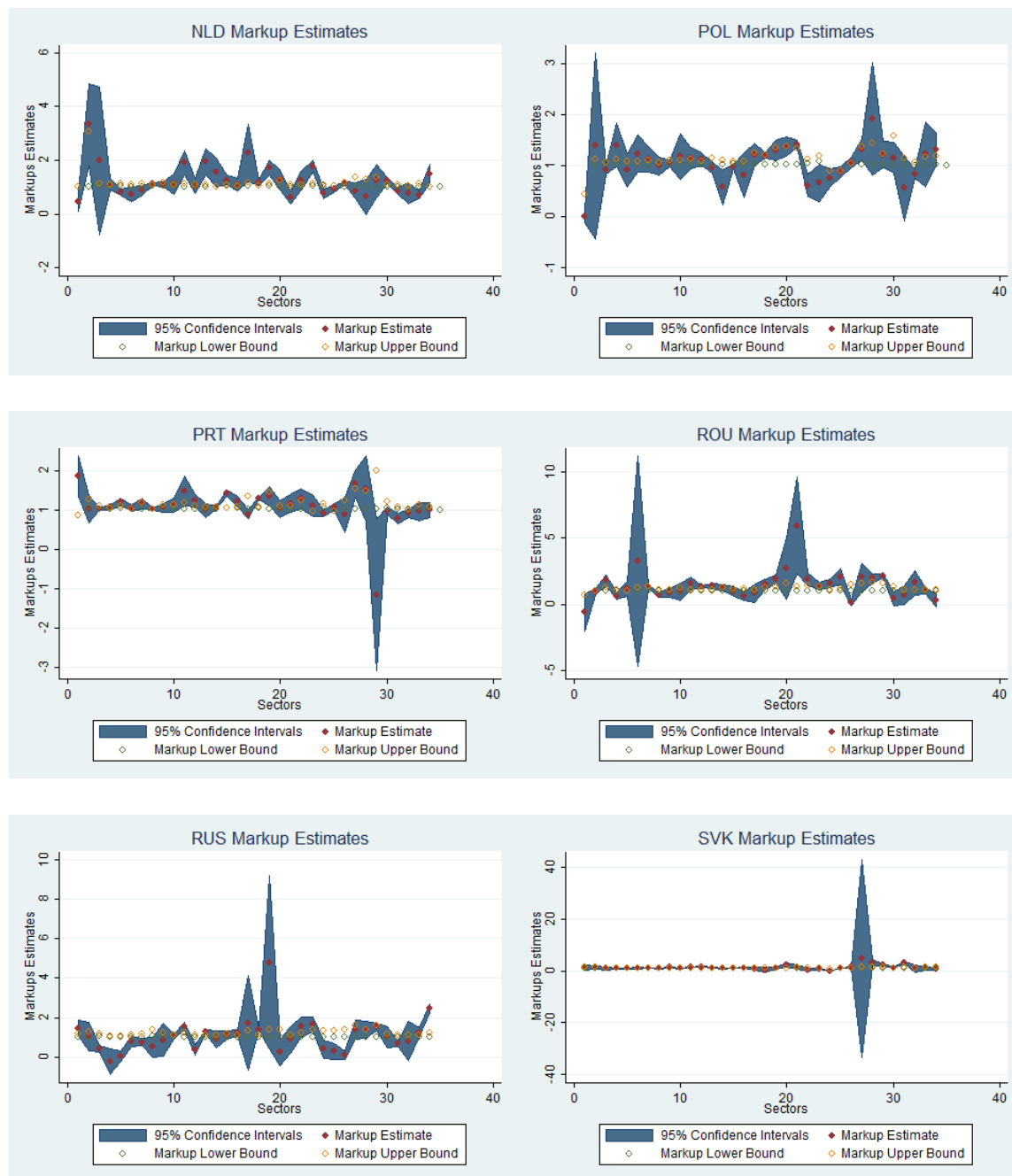


Figure 11: Plots of Markups as compared to their bounds by sector for each country

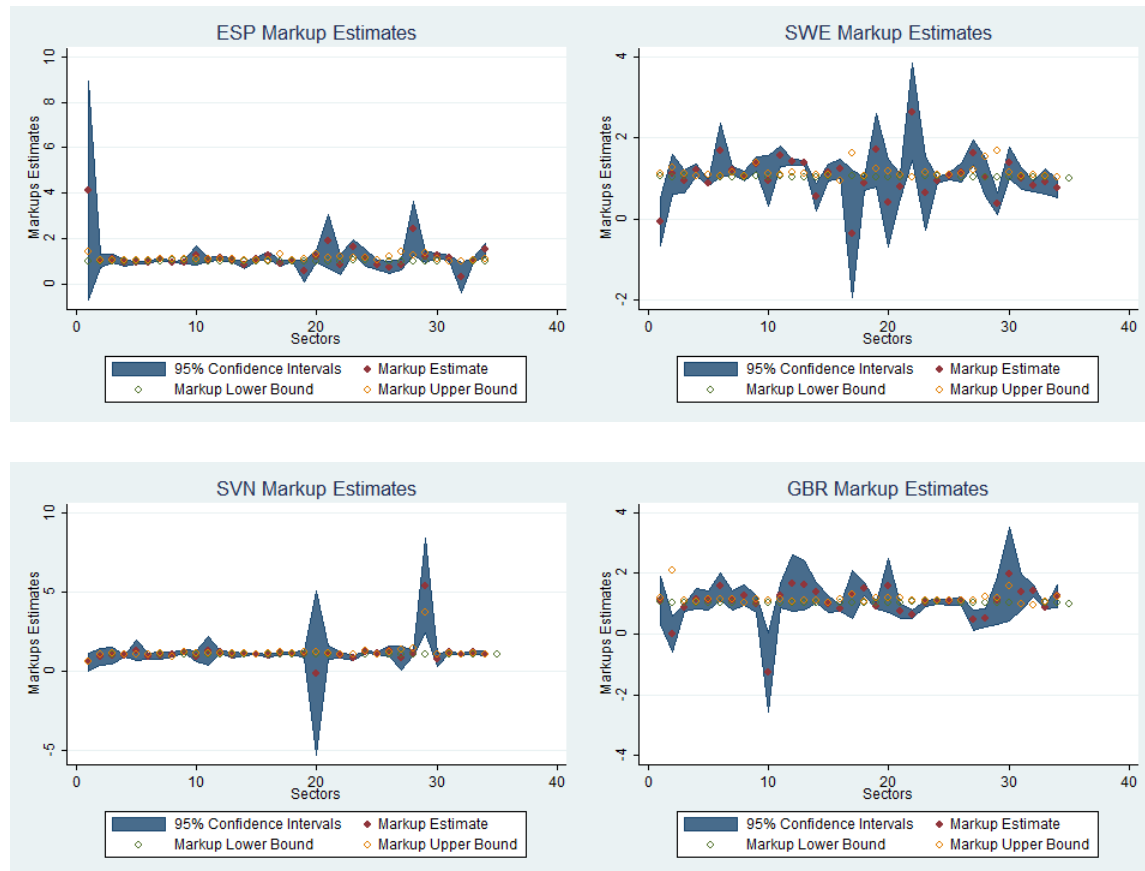


Figure 12: Plots of Markups as compared to their bounds by sector for each country

Figure 13: All Sector Productivities and GDP per Capita



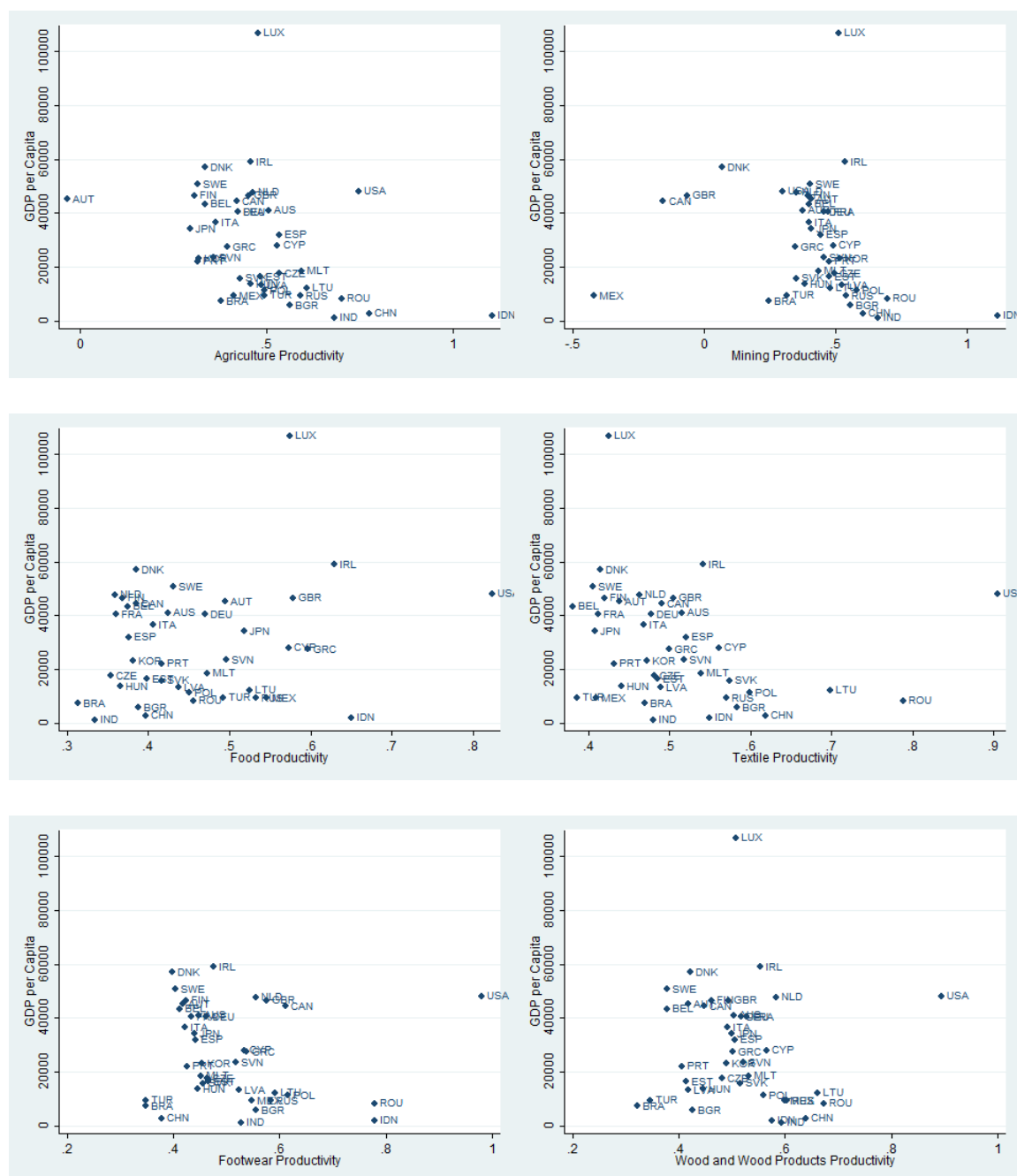


Figure 14: Plots of sector productivity as compared to GDP per capita for each country

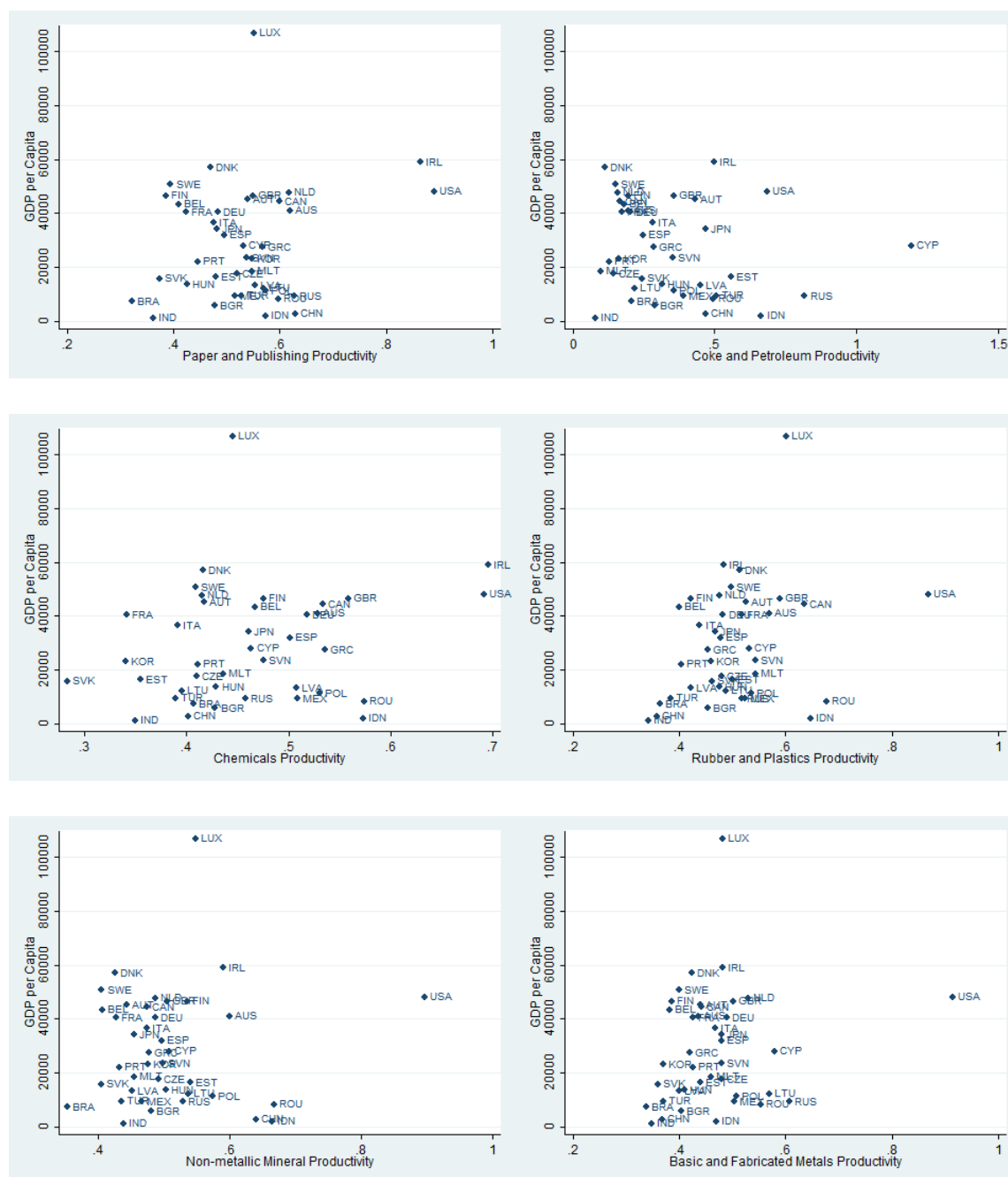


Figure 15: Plots of sector productivity as compared to GDP per capita for each country

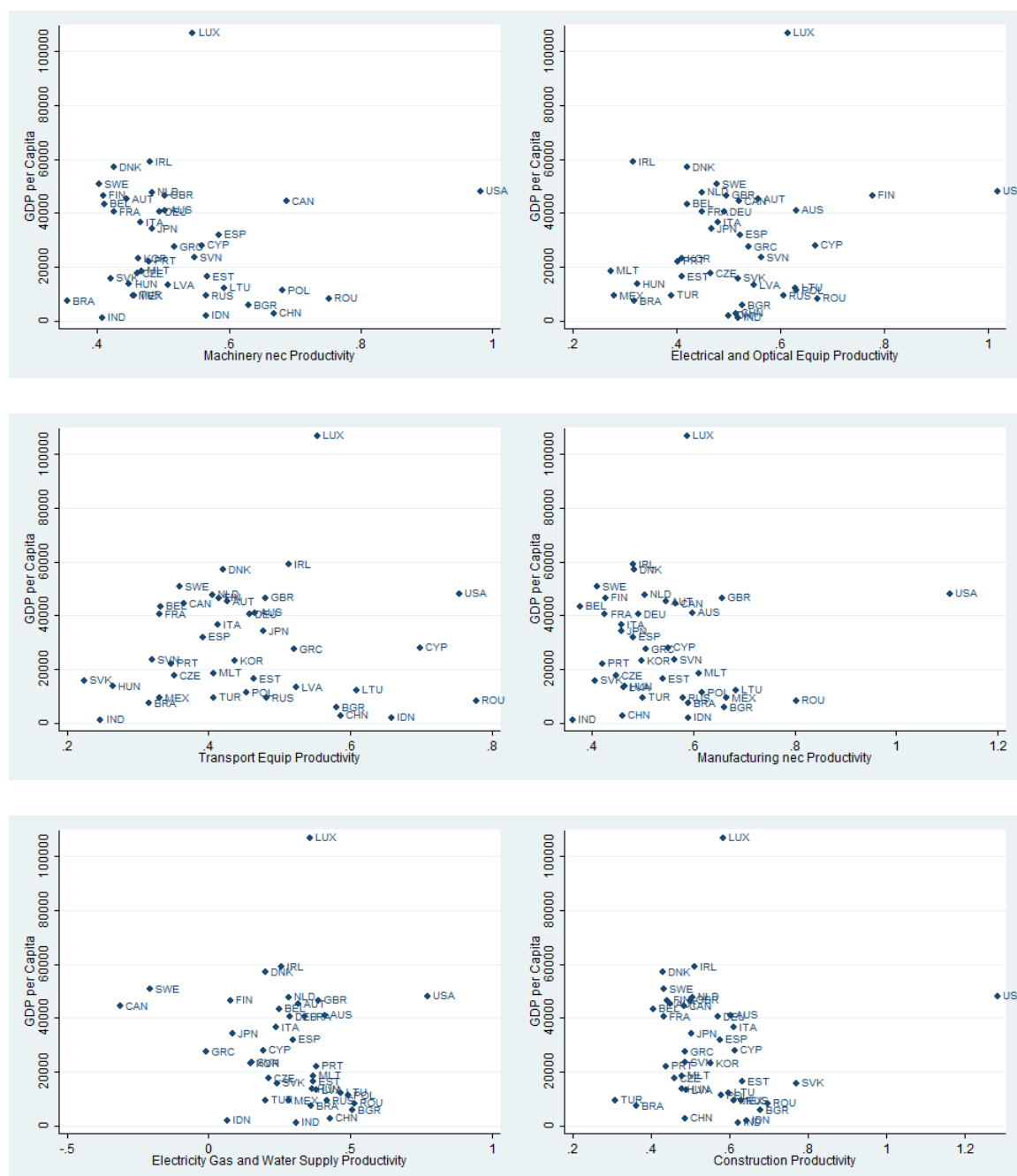


Figure 16: Plots of sector productivity as compared to GDP per capita for each country

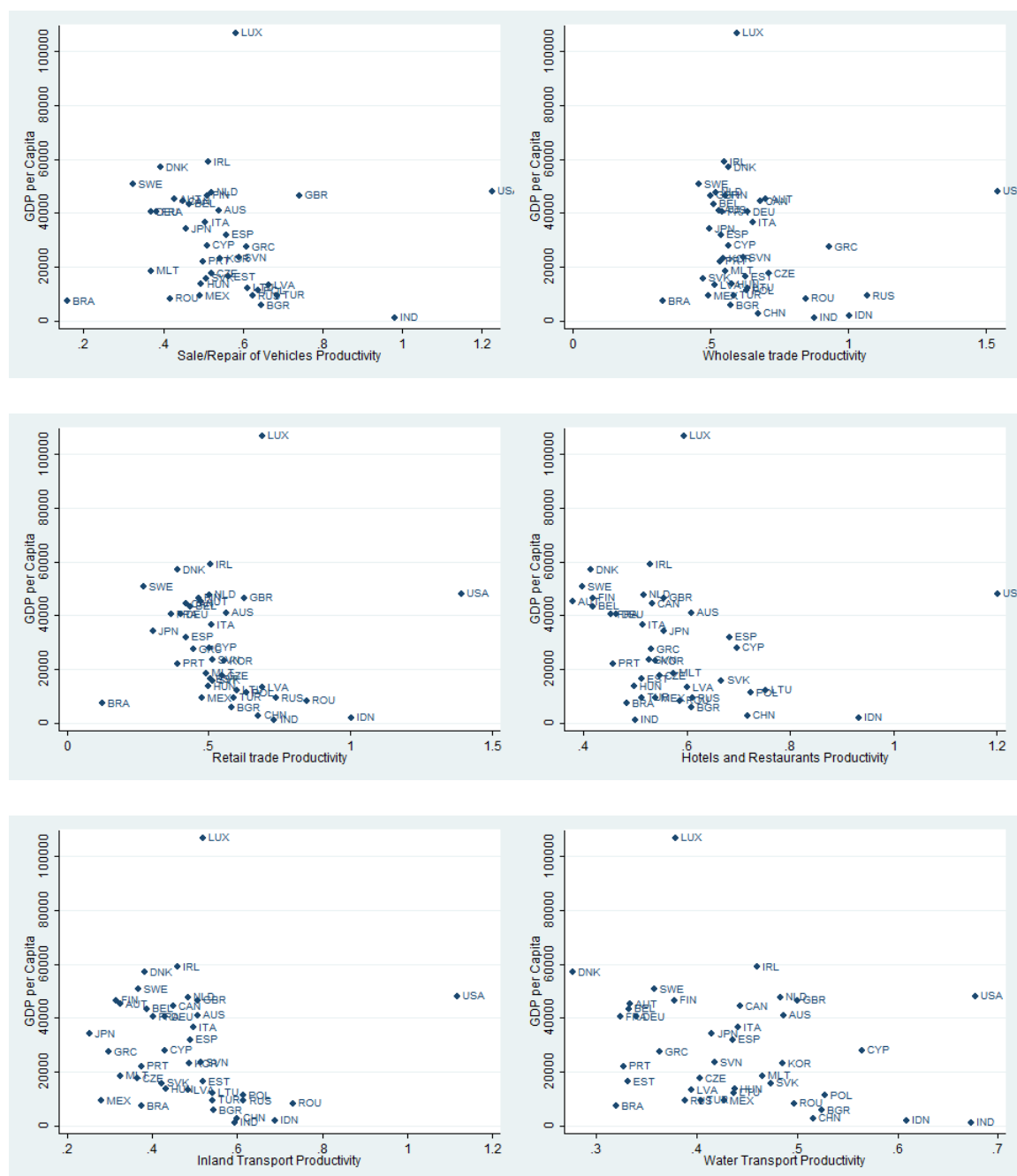


Figure 17: Plots of sector productivity as compared to GDP per capita for each country

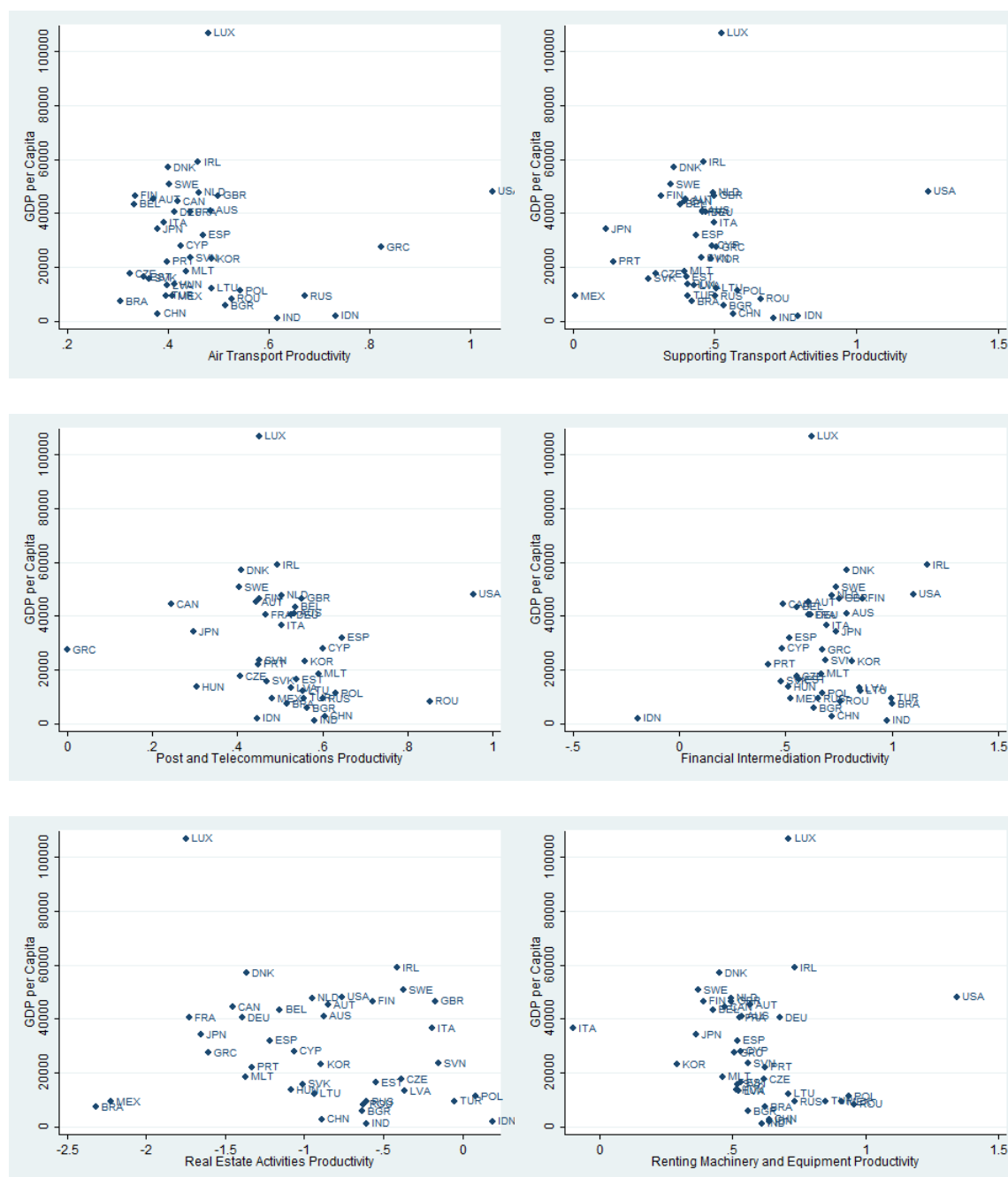


Figure 18: Plots of sector productivity as compared to GDP per capita for each country

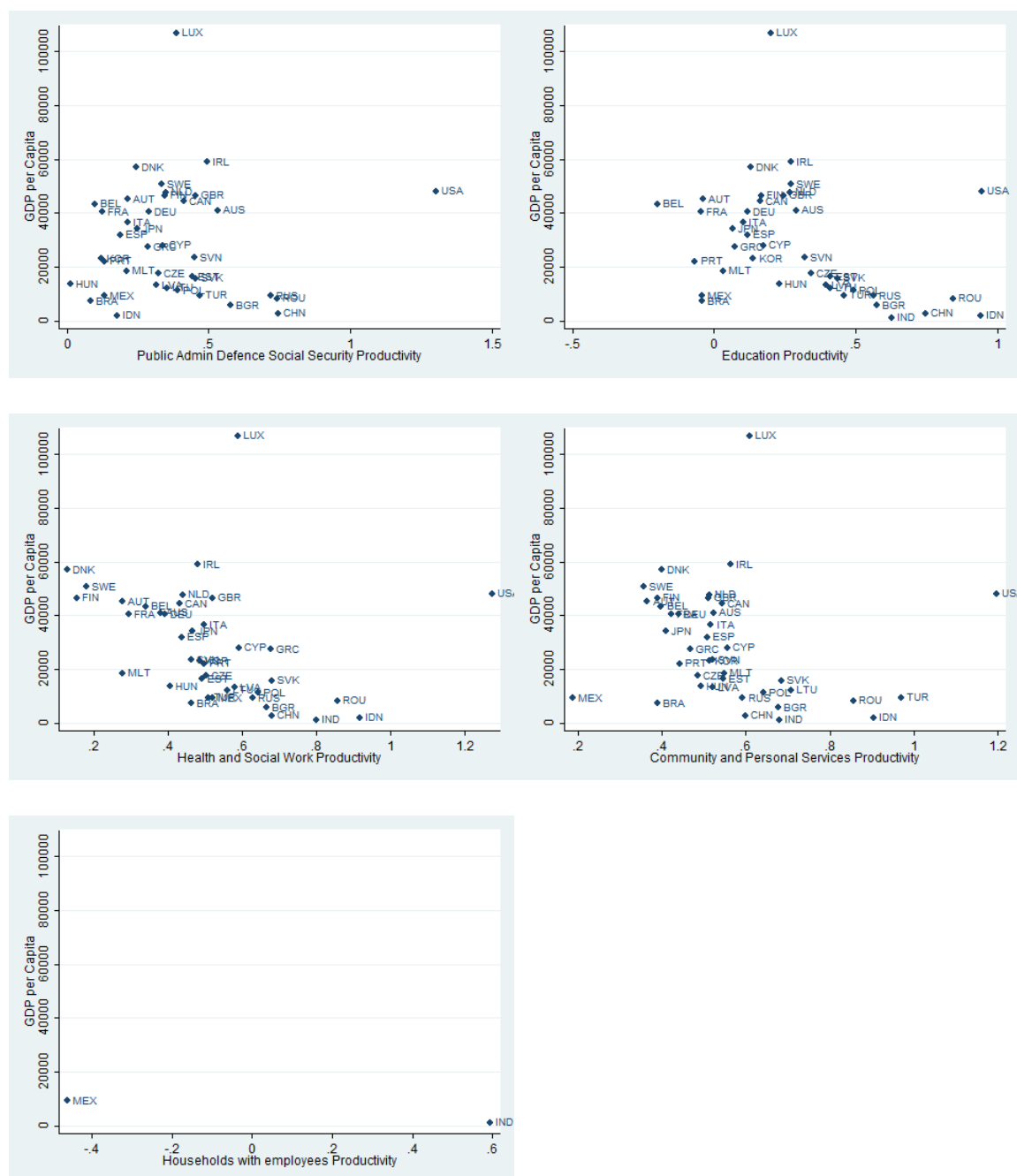


Figure 19: Plots of sector productivity as compared to GDP per capita for each country

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