A Simple Accounting Framework for the Effect of Resource Misallocation on Aggregate Productivity

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Abstract

This paper develops a simple accounting framework that measures the effect of resource misallocation on aggregate productivity. This framework is based on a multi-sector general equilibrium model with sector-specific frictions in the form of taxes on sectoral factor inputs. This framework is flexible for demand side assumptions such as preference and aggregate production function. Moreover, this framework is consistent with that commonly used in productivity analysis. Finally, I apply this framework to measure to what extent resource misallocation affects aggregate productivity and explains the differences in aggregate productivity across developed countries. I find that the effect of resource misallocation is quantitatively large and explains more than 20% of the differences in the aggregate productivity among developed countries.

JEL Codes: E23, O11, O41, O47

Keywords: distortions; frictions; productivity; resource allocation;

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1 Introduction

There are large disparities in incomes across developed countries. Prescott (2002) reports that there is approximately a 30% to 40% difference in per capita income between highly developed countries. He argues that the most important factor of this disparity is the difference in the level of aggregate total factor productivity (TFP). From this standpoint, many theoretical models have been proposed that explain the difference in aggregate TFP. Restuccia and Rogerson (2007) point out that many of these models can be characterized as the theory of resource misallocation. This theory states that frictions due to various reasons prevent the efficient use of resources, resulting in a low aggregate TFP. Then, to what extent does resource misallocation affect aggregate TFP and explain the difference in aggregate TFP across countries?

To answer these problems, this paper proposes a simple accounting framework that measures the effect of resource misallocation on aggregate TFP from data. This framework is based on a multi-sector general equilibrium model with sector-specific frictions in the form of taxes on sectoral factor inputs (capital and labor). As in Chari, Kehoe and McGrattan (2002) and Restuccia and Rogerson (2007), the sector-specific frictions in the form of taxes of each firm or sector reflect various kinds of frictions the firm or sector faces. As in Chari et al. (2002), this framework can measure these sector-specific frictions using the model from data (they are measured from the differences in factor input returns between sectors) and assess the effect of these frictions on aggregate TFP. A characteristic of their tax (or wedge) approach is that it can deal with various kinds of frictions that distort resource allocation all together.

Compared with other papers cited below that measure the effect of resource misallocation on aggregate TFP, there are two characteristics in this paper's framework. First, this paper's framework is flexible for demand side assumptions such as the form of preference or aggregate production function. Second, this paper's framework is consistent with that commonly used in productivity analysis.

I apply this framework to OECD's sectoral data for France, Italy, Japan, and the US. I measure how the effect of sector-level resource misallocation affects the differences in aggregate TFP between France, Italy, or Japan, and the US. I find that due to the sector-level resource misallocation, the aggregate TFP for France, Italy, and Japan becomes 5.2% to 8.4% lower than that of the US.

These values are quantitatively significant; they correspond to 20% (for Japan) to 50% (for Italy) of differences in aggregate TFP between those countries and the US (I do not report for France since the aggregate TFP of France is higher than that of the US). While the effect of frictions on labor is larger between Italy and the US than between France or Japan and the US, the effect of frictions on capital is similar for all them. Agricultural and financial sectors are primary sources of the differences in resource misallocation between those countries and the US. The effect of resource misallocation is composed of that of sectoral frictions and that of sectoral sizes. I also identify which factor (i.e., differences in sectoral frictions or sizes between countries) is crucial to the result. I find that differences in sectoral frictions are important.

There are several papers that measure resource misallocation from cross-sectional differences in factor input returns using general equilibrium framework and calculate resource misallocation effect on aggregate TFP. This paper fits into this literature. To the best of my knowledge, the earliest work in this field is de Melo (1977). A computable multi-sector general equilibrium model is applied to the Colombian economy by Melo (1977) to calculate the effect of removing distortions on sector-level resource allocation. Recently, Restuccia, Yang and Zhu (2008) and Vollrath (2008) use a two-sector model to measure the magnitude of barriers to resource allocation between the old agricultural and non-agricultural sectors. Using a standard model of monopolistic competition with heterogeneous firms and manufacturing plant-level data from China, India and the US, Hsieh and Klenow (2007) estimate how resource misallocation affects aggregate TFP.[1] As mentioned above, compared with these papers, this papers framework is flexible in the assumption of preference of aggregate production function, and compatible with the framework commonly used in productivity analysis.[2] Finally, using this paper's framework (to be precise, the framework of the previous version of this paper, Aoki, 2006), Miyagawa, Fukao, Hamagata and Takizawa (2008) measure the effect of sector-level resource misallocation on the Japanese aggregate TFP from the Japanese Industrial Productivity (JIP) Database.

Literature on productivity analysis has measured the effect of change in sectoral reallocation on aggregate TFP growth (see Syrquin, 1986, and Basu and Fernald, 2002, among others). I show that this paper's decomposition is a generalization of theirs; while their studies measure the effect

[1]Their study and this paper's were conducted around the same time.

[2]These papers explicitly or implicitly first impose a particular form of preference or aggrigate production function, then analyze the effect of resource misallocation on aggregate TFP. On the other hand, this paper's framework either does not need to assume them or can flexibly choose preferences or aggregate production function freely.

of resource misallocation on the aggregate TFP growth rate over time, this paper's framework can also measure its effect on the level of aggregate TFP and the cross-country difference in aggregate TFP. This paper also provides the micro-foundations for the reallocation effect. Owing to this, the approach used herein can identify which sector is the cause of resource misallocation, and how much of resource misallocation is really due to sectoral frictions or sectoral sizes.

Several studies provide examples of distortions in resource allocation. Caballero, Hoshi and Kashyap (2008) argue that during the Japanese stagnation of the 1990s, the forbearance lending of banks shifted resources from healthy firms to zombie firms and zombie dominated sectors. Kiyotaki and Moore (1997) argue that the differences in the degree of borrowing constraint between firms can shift resources from high productivity firms to low productivity firms. Hayashi and Prescott (2008) argue that for institutional reasons, there was a barrier to labor mobility between the agricultural and non-agricultural sectors in prewar Japan. Frictions in the form of taxes in my model capture the effect of these distortions on resource allocation.

The remainder of the paper is organized into four sections. Section 2 sets up and analyzes a static multi-sector general equilibrium model with frictions in the form of sector-specific taxes on factor inputs. Using the model, Section 3 develops a method to measure the effects of resource misallocation on aggregate TFP. Using the developed framework, Section 4 measures the effect of sector-level resource misallocation on aggregate TFP from data. Section 5 contains the concluding remarks.

2 The Model

In this section, I develop a multi-sector competitive equilibrium model with sector-specific frictions. In keeping with Chari et al. (2002), sector-specific frictions are modeled in the form of taxes on sectoral factor inputs, the firms are price-takers, pay linear taxes on capital and labor, and each firm's problem is static. I argue in Appendix A that several types of frictions in each sector are isomorphic to taxes on this sector's factor inputs.[3]

[3] Isomorphic implies that the same allocation is achieved.

2.1 I Industrial sectors

There are I industrial sectors in the economy. Firms in each sector produce goods (homogeneous within a sector but heterogeneous between sectors) by using two factor inputs: capital K and labor L. I also denote factor input in general by $J \in \{K, L\}$. Firms are price-takers in both the good and factor markets, and pay linear taxes on capital and labor inputs, which vary by sectors. Thus, firms in sector i produce goods given the goods price of the sector, p_i and capital and labor costs, $(1 + \tau_{Ki})p_K$ and $(1 + \tau_{Li})p_L$ where τ_{Ki} and τ_{Li} are capital and labor taxes of the sector, and p_K and p_L are the common factor prices of capital and labor across sectors. Due to each sector producing different goods, the goods price p_i can vary across sectors in equilibrium (even if there are no taxes). On the other hand, because capital and labor are homogeneous across sectors, if $\tau_{Ki} = 0$ and $\tau_{Li} = 0$, the factor costs incurred by firms become the same. Because firms are price takers and assuming a firm's production function to be a constant-returns-to-scale, a firm corresponds to a sector, and I thus identify a sector with a firm below.

The firms have Cobb-Douglas production technology exhibiting constant returns to scale. Therefore, a firm i's production function can be written as follows:

$$V_i = F_i(K_i, L_i) \equiv A_i K_i^{\alpha_i} L_i^{1-\alpha_i}, \tag{1}$$

where V_i is output, K_i is capital input, L_i is labor input and A_i is productivity of the firm. I assume that the capital intensity α_i can vary by sector.

In this setting, the firm's problem is written as

$$\max_{K_i, L_i} \; p_i F_i(K_i, L_i) - (1 + \tau_{Ki})p_K K_i - (1 + \tau_{Li})p_L L_i.$$

The FOCs are as follows:

$$\frac{\alpha_i p_i V_i}{K_i} = (1 + \tau_{Ki})p_K, \tag{2}$$

$$\frac{(1-\alpha_i) p_i V_i}{L_i} = (1 + \tau_{Li})p_L. \tag{3}$$

If firm's profit is negative for any positive K_i and L_i, the firm chooses not to produce, and the above FOCs do not hold. Although, hereafter I assume that the above FOCs hold for all sectors, the results used in the following sections, i.e., (9)–(12) hold even when some sectors do not produce.

2.2 Aggregator function

I assume the constant returns to scale (CRS) aggregator function:

$$V = V(V_1, \ldots, V_I). \tag{4}$$

I also assume that the following condition is satisfied:

$$\frac{\partial V}{\partial V_i} = p_i. \tag{5}$$

This condition is satisfied if V is an aggregate good and firms that produce V are competitive, or if V is the household's utility and the household chooses V_i to maximize V. Under these conditions, the following equation holds:

$$V = \sum_i p_i V_i. \tag{6}$$

2.3 Resource constraints

Finally, I assume that aggregate capital and labor supply are exogenous. Thus, the following resource constraints apply:

$$\sum_i K_i = K, \tag{7}$$

$$\sum_i L_i = L, \tag{8}$$

where K and L are aggregate capital and labor supply.

2.4 Equilibrium

A competitive equilibrium of this economy is defined in the following way.

Definition. Given productivities and taxes of I goods sectors $\{A_i, 1+\tau_{Ki}, 1+\tau_{Li}\}$, and aggregate capital and labor K and L, *a competitive equilibrium* is a set of output, capital, labor, and prices of I goods sectors $\{V_i, K_i, L_i, p_i\}$, aggregate value V, and common factor prices p_K and p_L that satisfy the following conditions:

1. FOCs of firms in I goods sectors (2) and (3),
2. CRS assumption and marginal condition (4) and (5),
3. Resource constraints (7) and (8).

In what follows, I derive the expressions for K_i and L_i. Using (2) and (7), K_i can be rewritten as follows:

$$\begin{aligned}
K_i &= \frac{\frac{(1+\tau_{Ki})p_K K_i}{(1+\tau_{Ki})p_K}}{\sum_j \frac{(1+\tau_{Kj})p_K K_j}{(1+\tau_{Kj})p_K}} K \\
&= \frac{p_i Y_i \alpha_i \frac{1}{(1+\tau_{Ki})p_K}}{\sum_j p_j Y_j \alpha_j \frac{1}{(1+\tau_{Kj})p_K}} K \\
&= \frac{\tilde{\sigma}_i \alpha_i \frac{1}{1+\tau_{Ki}}}{\sum_j \tilde{\sigma}_j \alpha_j \frac{1}{1+\tau_{Kj}}} K,
\end{aligned}$$

where $\tilde{\sigma}_i$ is the expenditure share of the sector $p_i V_i / V$. This equation is rearranged as follows:

$$K_i = \frac{\tilde{\sigma}_i \alpha_i}{\tilde{\alpha}} \tilde{\lambda}_{Ki} K, \tag{9}$$

where $\tilde{\alpha}$ is the weighted average of capital intensities $\sum_i \tilde{\sigma}_i \alpha_i$, and $\tilde{\lambda}_{Ki}$ is the term composed of frictions.[4] $\tilde{\lambda}_{Ki}$ is defined as

$$\tilde{\lambda}_{Ki} \equiv \frac{\lambda_{Ki}}{\sum_j \left(\frac{\tilde{\sigma}_j \alpha_j}{\tilde{\alpha}}\right) \lambda_{Kj}}, \text{ and } \lambda_{Ki} \equiv \frac{1}{1+\tau_{Ki}}. \tag{10}$$

I add tilde ˜ for the variables that depend on the functional form of V. In the same way, we obtain the equilibrium allocation of L_i:

$$L_i = \frac{\tilde{\sigma}_i (1-\alpha_i)}{1-\tilde{\alpha}} \tilde{\lambda}_{L_i} L, \tag{11}$$

[4] Hsieh and Klenow (2007) also derive a similar expression.

where

$$\tilde{\lambda}_{Li} \equiv \frac{\lambda_{Li}}{\sum_j \left(\frac{\tilde{\sigma}_j(1-\alpha_j)}{1-\tilde{\alpha}}\right)\lambda_{Lj}}, \text{ and } \lambda_{Li} \equiv \frac{1}{1+\tau_{Li}}. \tag{12}$$

Equations (9)–(12) uncover several findings on the effect of taxes on resource allocation of capital and labor. First, from (9) and (11), we find that taxes affect the allocation of resources through $\tilde{\lambda}_{Ji}$. Second, from (10) and (12), we find that $\tilde{\lambda}_{Ji}$ is the ratio of the reciprocal of sector i's return on factor input and the mean of the reciprocals of the returns across sectors, Due to this property, the absolute magnitude of the taxes does not affect the resource allocation between sectors. For instance, if tax on capital is identical across sectors, then $\tilde{\lambda}_{Ki}$ becomes unity and is equal to the value with no frictions. On the other hand, the distribution of taxes across sectors affects resource allocation. For example, if λ_{Ki} is smaller than the weighted average of λ_{Kj} (i.e., sector i's capital is taxed more), then $\tilde{\lambda}_{Ki}$ becomes less than unity and less capital is allocated to sector i than to the level with no frictions.

In the empirical section, I do not measure frictions λ_{Ji}s themselves, but measure $\tilde{\lambda}_{Ji}$s, which capture the distribution of frictions. $\tilde{\lambda}_{Ji}$s are measured using the following equations that are rewritten from (9) and (11):

$$\tilde{\lambda}_{Ki} = \left(\frac{\tilde{\sigma}_i\alpha_i}{\tilde{\alpha}}\right)^{-1}\frac{K_i}{K}, \text{and } \tilde{\lambda}_{Li} = \left(\frac{\tilde{\sigma}_i(1-\alpha_i)}{1-\tilde{\alpha}}\right)^{-1}\frac{L_i}{L}. \tag{13}$$

3 Analyzing the effects of Resource Misallocation on Aggregate TFP

In order to calculate the effects of resource misallocation on aggregate TFP, in this section, I decompose aggregate TFP into components composed of sectoral TFPs and distortions on resource allocation. This section also provides a method to identify which sector contributes to distortions. Since the component of distortions consists of the combination of sectoral frictions and sectoral sizes, I also provide a method to identify the contribution of each factor.

3.1 Decomposition of aggregate TFP

In order to analyze the effect of resource misallocation on aggregate TFP, I compare the aggregator function at state S, V^S, with that at state T, V^T and apply the mean value theorem (hereafter, the variables with superscript S denote those at state S such as V^S). State S, for example, corresponds to Japan, while state T corresponds to the US. I assume that the capital intensity of each sector α_i is the same across different states.

By applying the mean value theorem and using (5) and (6), we obtain

$$\begin{aligned}\ln\left(\frac{V^S}{V^T}\right) &= \sum_i \frac{\partial \ln V}{\partial \ln V_i} \ln\left(\frac{V_i^S}{V_i^T}\right) \\ &\simeq \sum_i \bar{\sigma}_i \ln\left(\frac{V_i^S}{V_i^T}\right),\end{aligned}$$

where $\bar{\sigma}_i \equiv (\tilde{\sigma}_i^S + \tilde{\sigma}_i^T)/2$. The RHS is the Tornqvist index of the value added difference. By substituting (1), (9), and (11) into the above equation, we obtain the following decomposition:

$$\begin{aligned}\sum_i \bar{\sigma}_i \ln\left(\frac{V_i^S}{V_i^T}\right) \quad &\simeq \quad \sum_i \bar{\sigma}_i \left\{\ln\left(\frac{A_i^S}{A_i^T}\right) + \alpha_i \ln\left(\frac{\tilde{\lambda}_{Ki}^S}{\tilde{\lambda}_{Ki}^T}\right) + (1-\alpha_i)\ln\left(\frac{\tilde{\lambda}_{Li}^S}{\tilde{\lambda}_{Li}^T}\right)\right\} \\ &\quad + \bar{\alpha}\ln\left(\frac{K^S}{K^T}\right) + (1-\bar{\alpha})\ln\left(\frac{L^S}{L^T}\right), \end{aligned} \tag{14}$$

where $\bar{\alpha} \equiv \sum_i \bar{\sigma}_i \alpha_i$. (Appendix B shows that other terms are approximately zero.)

I define the aggregate TFP of state S relative to state T and refer to it as ATFP as follows:

$$\text{ATFP} \equiv \sum_i \bar{\sigma}_i \ln\left(\frac{V_i^S}{V_i^T}\right) - \bar{\alpha}\ln\left(\frac{K^S}{K^T}\right) - (1-\bar{\alpha})\ln\left(\frac{L^S}{L^T}\right).$$

This is the standard definition of aggregate TFP.[5] By rewriting (14), using the definition of aggregate TFP, I obtain

$$\text{ATFP} \simeq \sum_i \bar{\sigma}_i \ln\left(\frac{A_i^S}{A_i^T}\right) + \sum_i \bar{\sigma}_i \left\{\alpha_i \ln\left(\frac{\tilde{\lambda}_{Ki}^S}{\tilde{\lambda}_{Ki}^T}\right) + (1-\alpha_i)\ln\left(\frac{\tilde{\lambda}_{Li}^S}{\tilde{\lambda}_{Li}^T}\right)\right\}. \tag{15}$$

I refer to the first term of the RHS in (15) as sectoral TFP term (STFP). STFP is a weighted average of sectoral TFPs and is also Domar (1961) weighted aggregate TFP. The second term of the

[5] See Christensen, Jorgenson and Lau (1973) and Caves, Christensen and Diewert (1982).

RHS in (15) consists of frictions. I refer to it as allocational efficiency term (AE). AE measures the effect of distortions on resource allocation on aggregate TFP. Note that if sector-specific frictions reduce aggregate TFP at state S rather than at state T, then AE has to be negative. When S corresponds to period t and T corresponds to period $t-1$, AE is equal to the reallocation term in Syrquin (1986) and Basu and Fernald (2002) because they define the reallocation term as the residual of the time differences of ATFP and STFP). In this sense, this paper's decomposition is a generalization of theirs.

One advantage of this paper's decomposition compared with previous works is that one can also calculate the loss of aggregate TFP caused by distortions on resource allocation. Miyagawa et al. (2008) and Aoki (2008), applying the framework of this paper, calculate the aggregate TFP loss caused by distortions on sector-level resource allocation, when state S corresponds to actual state and state T corresponds to no distortion state, $\tilde{\sigma}_i$ and A_i of state T are the same as those of state S, and $\tilde{\lambda}_{Ji}^T = 1$.

In later analysis, I further decompose AE in several different ways. For example, AE in (15) can be decomposed into a state S component that consists of $\tilde{\lambda}_{Ki}^S$ and $\tilde{\lambda}_{Li}^S$ and a state T component that consists of $\tilde{\lambda}_{Ki}^T$ and $\tilde{\lambda}_{Li}^T$. AE can also be decomposed into a capital component that consists of $\tilde{\lambda}_{Ki}^S$ and $\tilde{\lambda}_{Ki}^T$ and a labor component that consists of $\tilde{\lambda}_{Li}^S$ and $\tilde{\lambda}_{Li}^T$. The next section explains how to decompose AE into sectoral contributions.

3.2 Contribution of each sector to AE

An advantage of our framework is that it can identify which sector's frictions are the cause of the loss of aggregate TFP. This section provides the method. In order to identify the contribution of sector i, I calculate a fictitious AE under the following assumptions (while I drop out superscripts S and T for convenience, note that these assumptions are applied to the both states). I fix factor inputs of a particular sector (I refer to it as sector i) to its actual observed values and then reallocated *efficiently* the *remaining* factor inputs across the remaining sectors of the economy. Then, the only source of distortion would be in sector i. For simplicity, I also assume that sectoral shares $\tilde{\sigma}_i$s are fixed. I refer to the AE calculated under this assumption as AE_i.

AE_i is mathematically derived as follows. First, from (9) and (11), sector i's $\tilde{\lambda}_{Ji}$ is the same as the actual one. Second, since factor prices are the same across the remaining sectors, $\tilde{\lambda}_{Jm} = \tilde{\lambda}_{Jn} =$

$\tilde{\lambda}_{J-i}$ for the remaining sectors (m and n are sectors that are not sector i and I summarize these sectors by $-i$). Other settings are the same as AE. This AE$_i$ is equal to the AE when there are only two sectors: sector i and all the rest (for details, see Appendix D). I also show in Appendix D that the sum of AE$_i$ calculated as above is approximately equal to actual AE.

In the empirical section, $\tilde{\lambda}_{K-i}$ used in AE$_i$ is measured in the following way. By rearranging

$$K_{-i} \equiv K - K_i = \sum_{m \neq i} K_m = \sum_{m \neq i} \frac{\tilde{\sigma}_m \alpha_m}{\tilde{\alpha}} \tilde{\lambda}_{K-i} K \tag{16}$$

(note that K, K_i, and thus K_{-1} here are the same as the actual ones), we obtain

$$\tilde{\lambda}_{K-i} = \left(\frac{\tilde{\sigma}_{-i} \alpha_{-i}}{\tilde{\alpha}} \right)^{-1} \frac{K_{-i}}{K}, \tag{17}$$

where $\tilde{\sigma}_{-i} \equiv 1 - \tilde{\sigma}_i$ and $\alpha_{-i} \equiv \sum_{m \neq i} \tilde{\sigma}_m / (1 - \tilde{\sigma}_i) \alpha_m$ (i.e., α_{-i} is a weighted average of a_m $(m \neq i)$). In the same way, $\tilde{\lambda}_{L-i}$ is measured by

$$\tilde{\lambda}_{L-i} = \left(\frac{\tilde{\sigma}_{-i}(1 - \alpha_{-i})}{1 - \tilde{\alpha}} \right)^{-1} \frac{L_{-i}}{L}, \tag{18}$$

where $L_{-i} \equiv L - L_i$.

3.3 Contribution of sectoral frictions and sectoral sizes to AE

AE depends on not only differences in sectoral frictions λ_{Ji}s across states but also differences in sectoral sizes $\tilde{\sigma}_i$s, because $\tilde{\lambda}_{Ji}$ depends on the both factors. This section illustrates why the distinction between both factors is important and provides a method to identify how much is due to each factor.

To understand how important differences in $\tilde{\sigma}_i$s across states are on AE, suppose a two-sector example, in which there are agricultural sector A and non-agricultural sector N and $\alpha_i = 0$ for these sectors. Further suppose that λ_{Li} is the same between state S and state T, but $\tilde{\sigma}_i$ is different between the states. Then, AE is calculated as

$$
\begin{aligned}
\text{AE} &= \bar{\sigma}_A \ln\left(\frac{\tilde{\lambda}^S_{LA}}{\tilde{\lambda}^T_{LA}}\right) + \bar{\sigma}_N \ln\left(\frac{\tilde{\lambda}^S_{LN}}{\tilde{\lambda}^T_{LN}}\right) \\
&= \ln\left(\tilde{\sigma}^T_A \lambda_{LA} + \tilde{\sigma}^T_N \lambda_{LN}\right) - \ln\left(\tilde{\sigma}^S_A \lambda_{LA} + \tilde{\sigma}^S_N \lambda_{LN}\right).
\end{aligned}
$$

Now further assume that $\tilde{\sigma}^S_A > \tilde{\sigma}^T_A$ and $\lambda_{LA} > \lambda_{LN}$. The former assumption is reasonable when T is a more mature economy than S. The latter is also reasonable because in data, λ_{LA} is higher than the average of all sectors.[6] AE then becomes negative, irrespective of the same frictions λ_{Ki}s.[7]

In order to identify how much is due to sectoral sizes, I calculate a fictitious AE$_i$ using $\tilde{\lambda}_{Ji}(\{\tilde{\sigma}^S_j, \lambda^T_{Jj}\})$s instead of $\tilde{\lambda}^S_{Ji}$s, where $\tilde{\lambda}_{Ji}(\{\tilde{\sigma}^S_j, \lambda^T_{Jj}\})$ is calculated from sectoral shares of state S, $\{\tilde{\sigma}^S_j\}$ and sectoral frictions of state T, $\{\lambda^T_{Jj}\}$ as follows (the state T part remains the same as the original AE):

$$
\tilde{\lambda}_{Ki}(\{\tilde{\sigma}^S_j, \lambda^T_{Kj}\}) \equiv \frac{\lambda^T_{Ki}}{\sum_j \left(\frac{\tilde{\sigma}^S_j \alpha_j}{\tilde{\alpha}^S}\right) \lambda^T_{Kj}}, \quad \tilde{\lambda}_{Li}(\{\tilde{\sigma}^S_j, \lambda^T_{Lj}\}) \equiv \frac{\lambda^T_{Li}}{\sum_j \left(\frac{\tilde{\sigma}^S_j (1-\alpha_j)}{1-\tilde{\alpha}^S}\right) \lambda^T_{Lj}}.
$$

I refer to this fictitious AE$_i$ as counterfactual AE$_i$. If the magnitude of AE$_i$ is large because of differences in $\tilde{\sigma}_i$ between countries, the counterfactual AE$_i$ would be close to the AE$_i$ calculated by $\tilde{\lambda}^S_{Ji}$s. If the results are due to differences in $\tilde{\lambda}_{Ji}$s between countries, the counterfactual AE$_i$ would be small in magnitude.

In the empirical section, $\tilde{\lambda}_{Ki}(\{\tilde{\sigma}^S_j, \lambda^T_{Kj}\})$ is measured from

$$
\tilde{\lambda}_{Ki}(\{\tilde{\sigma}^S_j, \lambda^T_{Kj}\}) = \frac{\tilde{\lambda}^T_{Ki}}{\sum_j \left(\frac{\tilde{\sigma}^S_j \alpha_j}{\tilde{\alpha}^S}\right) \tilde{\lambda}^T_{Kj}}, \tag{19}
$$

because the denominator of $\tilde{\lambda}^T_{Kj}$ (i.e., $\sum_m (\tilde{\sigma}^T_m \alpha_m / \tilde{\alpha}^T) \lambda^T_{Km}$) is canceled out and λ^T_{Kj}s are shown up in the RHS of the numerator and denominator of (19). In the same way, $\tilde{\lambda}_{Li}(\{\tilde{\sigma}^S_j, \lambda^T_{Lj}\})$ is measured from

$$
\tilde{\lambda}_{Li}(\{\tilde{\sigma}^S_j, \lambda^T_{Lj}\}) = \frac{\tilde{\lambda}^T_{Li}}{\sum_j \left(\frac{\tilde{\sigma}^S_j (1-\alpha_j)}{1-\tilde{\alpha}^S}\right) \tilde{\lambda}^T_{Lj}}. \tag{20}
$$

[6] We can confirm it in Table 1.

[7] Aoki (2008) reports that this effect was quantitatively large in prewar and postwar Japan.

4 Empirical Results

In this section, using the framework developed in the previous sections and the sectoral data of developed countries, I calculate the contribution of sector-level resource misallocation to cross-country differences in aggregate TFP. After measuring the distribution of sector-level frictions from data, I calculate allocational efficiency (AE) and the share of AE in aggregate productivity (ATFP) between France, Italy, Japan, and the US. I also identify which sector is the cause of the distortions and whether the results come from differences in sectoral sizes across countries or not. Since I impose an assumption that α_i is the same across countries, I also check its robustness. Hereafter I refer to AE, ATFP, etc. between these countries as cross-country AE, ATFP, etc.

4.1 Measurement procedure

We can measure allocational efficiency by measuring $\tilde{\lambda}_{Ji}$s, $\tilde{\lambda}_{J-i}$s, $\tilde{\lambda}_{Ji}(\{\tilde{\sigma}_j^S, \lambda_{Jj}^T\})$s, α_is, and $\tilde{\sigma}_i$s.

$\tilde{\lambda}_{Ji}$s are measured from (13) because K_i, K, L_i, and L are measured from sectoral and aggregate data, and $\tilde{\sigma}_i$ and α_i are measured as discussed below. Measuring $\tilde{\lambda}_{Ji}$s in this way would capture several kinds of distortions that affect cross-sectional, sector-level resource allocation such as those in Appendix A. In the same way, $\tilde{\lambda}_{J-i}$s and $\tilde{\lambda}_{Ji}(\{\tilde{\sigma}_j^S, \lambda_{Jj}^T\})$s are measured from (17), (18), (19), and (20).

I use α_i that is measured from the US data, under the assumption that good market imperfections are weak in the US, and that the α_i of a given sector is the same across developed countries for the reasons explained below. For the robustness check, in Section 4.6, I also measure cross-country AE where α_i is measured from each country's data.

The reason I do not use α_is in each country is because the measured α_is can be biased if there are market imperfections. Since taxes in our model do not correspond to measured tax data, we cannot measure an unbiased α_i by simply using FOCs in (2) and (3). Thus, we have to deal with the same difficulties in measuring capital intensity as discussed in the previous studies. First, it is known that if there are imperfections in the goods market, α_i measured from revenue share can have biases, while that measured from factor input costs does not have biases (for details, see Basu and Fernald, 2002). On the other hand, if there are imperfections in factor markets, α_i measured from factor input costs can have biases (for details see Appendix A.4).

The $\tilde{\sigma}_i$s can be measured from the sector's nominal share, under the following standard assumptions: firms that produce V are competitive, or V is household's utility and the household chooses V_i to maximize V.

4.2 Data

I use annual OECD's sectoral database (ISDB and STAN databases) for France, Italy, Japan, and the US for 1987, 1990, and 1993.[8] The sectors considered in this study include (1) "Agriculture, Hunting, Forestry and Fishing" (hereafter, agricultural), (2) "Mining and Quarrying" and "Total Manufacturing" (manufacturing), (3) "Electricity, Gas and Water Supply" (electricity), (4) "Wholesale and Retail Trade" (wholesale), (5) "Transport and Storage and Communication" (transport), and (6) "Financial Intermediation" (financial). For the cross-country comparison, I am careful to maintain consistency of sector classification between countries, because in general, the more subdivided the definition of sector classification is, the bigger the effect of frictions on aggregate TFP.

We need data on sectoral capital inputs K_is; aggregate capital input K; sectoral labor inputs L_is; aggregate labor input L; sectoral capital intensities α_is; and sectoral shares $\tilde{\sigma}_i$s, in order to measure AE. For K_i and K, I use gross capital stock data in ISDB. For L_i and L, I use "full-time equivalent jobs" for France, Italy, and the US and "hours worked" times "number of total employment" for Japan in STAN database.[9] The α_is are measured as $1 -$ (labor income/factor costs) of the US using the STAN database (they are the averages of 1987, 1990, and 1993).[10] The $\tilde{\sigma}_i$s are measured from the nominal value added share of each country and each period in STAN database.

In order to measure ATFP, internationally comparable data on L, K, and V_is are needed. Sum of L_is above is not comparable across countries because "full-time equivalent jobs" which is used

[8] For the details of the data, see also Appendix C.

[9] For the agricultural sector of Japan, I use adjusted total employment instead of "total employment." The adjusted total employment is calculated as "number of employees" + 0.5 × ("number of total employment" − "number of employees"). For the reason that I use this, see footnote 15. If we use "total employment" instead of the adjusted total employment for Japan's agricultural sector, the magnitude and effect of frictions become even larger.

[10] Labor income is calculated from "compensation of employees" times "total employment (full-time equivalent jobs)" divided by "employees (full-time equivalent jobs)."

I use factor costs, which is basically after-tax value added, because when tax is imposed on the goods a firm produces, firm's FOC becomes,

$$\alpha_i = 1 - \frac{p_L L_i}{(1-\tau_i)V_i}.$$

in France, Italy, and the US, and "hours worked" times "total employment" which is used in Japan are not comparable. Therefore, for L in ATFP, I use hours worked times "total employment" for each country, where the hours worked is the "average hours worked per person" provided by the OECD (this data is provided in the aggregate level but not on the sector level). For K and V_i, I convert them to the 1990 US dollar.

For reference, I report the measured $\tilde{\lambda}_{Ki}$ and $\tilde{\lambda}_L$ in Table 1 (the values are the averages of 1987, 1990, and 1993 for each country and each sector). The higher the sectoral returns on capital or labor compared with other sectors of the same country are, the lower the measured $\tilde{\lambda}_{Ki}$ or $\tilde{\lambda}_{Li}$ becomes.

4.3 Cross-country AE and its contribution to cross-country ATFP

Using (15), I calculate cross-country allocational efficiency (AE) and aggregate TFP (ATFP) between the US and France, Italy, and Japan. Note that state S in (15) corresponds to France, Italy, or Japan, while state T corresponds to the US. Table 2 reports these results. The first column in Table 2 reports the averages of cross-country allocational efficiency (AE), aggregate TFP (ATFP), and AE divided by ATFP (AE/ATFP). For reference, I also report these values for each year in other columns. Herein follows my explanation for them.

The average cross-country AE ranges from -5.2% for France to -8.4% for Italy. This means that the aggregate TFPs of France, Italy, and Japan relative to the US become 5.2% to 8.4% lower because of sector-level resource misallocation.

To analyze the result on cross-country AE, I decompose the average cross-country AE in two different ways in Table 3. Decomposition in each case has a sum of components (i.e., each country component plus US component or capital component plus labor component) equal to the average AE. First, the table reports the decomposition of the average AE into each country component and US component. In all cases, the US component is small and near to 1%. That means that distortion by sector-level frictions is small in the US (it lowers US aggregate TFP by 1%), while distortion is large in other countries.

Table 3 also reports the capital and labor components of the average cross-country AE. We find that the magnitude of capital component is similar across countries, and that the magnitude of labor component between the US and Italy is larger than that between the US and other countries.

The latter finding might suggest specialties in Italy's labor market. According to several reports by the OECD, employment protection legislation (EPL) is stricter in Italy than in France, Japan or the US, and EPL reduces labor market dynamics.[11] Thus, EPL can work as frictions on labor mobility across sectors. It is possible that EPL can be the source of my result.

In order to calculate how cross-country AE explains cross-country differences in aggregate TFP, I also calculate ATFP between the US and other countries. The average cross-country ATFPs in Table 2 range from 1.5% for France, −18.3% for Italy, and −26% for Japan. This means that the aggregate TFP of France is 1.5% higher and the aggregate TFP of Italy and Japan is around 20% lower than that of the US.[12] Finally, In order to capture the magnitude of AE, I calculate average cross-country AE/ATFP in Table 2 except for France (I do not report it for France, because the ATFP of France is positive while its AE is negative). AE/ATFP is around 22% for Japan and 46% for Italy. Thus, the distribution of sector-level frictions is a quantitatively significant factor of cross-country differences in aggregate TFP between these developed countries.

4.4 Contribution of each sector to AE

In this section, I analyze which sector contributes to cross-country AE by using the result in Section 3.2. Table 4 reports cross-country AE_i calculated using $\tilde{\lambda}_{J-i}$ in (17) and (18). In the table, AE_i is divided into a capital component and a labor component.

We find from the table that in each country, agricultural and financial sectors explain most of the cross-country AE. First, let us focus on the agricultural sector. To understand why the agricultural sector is the cause of cross-country AE, look at the agricultural sector's $\tilde{\lambda}_{Ji}$ in Table 1. We find that most of $\tilde{\lambda}_{Ji}$s in the agricultural sector of France, Italy, and Japan are more than unity and higher than those of the US. When $\tilde{\lambda}_{Ji}$ is more than unity, returns on factor input are lower than the averages. This result is consistent with the interpretation that the agricultural sector receives subsidies, and receives more subsidies in France, Italy, and Japan than in the US. Several statistics in OECD (2004a) show that the agricultural sector receives more direct and indirect subsidies in the EU and Japan than in the US.[13] My result is consistent with OECD evidence.

[11] Chapter 2 in OECD (1999c) reports that several different studies show that Italy is one of the most strict EPL country over the postwar periods. In addition, Chapter 2 in OECD (2004b) reports that strict EPL makes it more difficult for jobseekers to enter employment.

[12] The result that the aggregate TFP of France is higher than that of the US is consistent with the result in Prescott (2002) and Fukao, Miyagawa and Takizawa (2007) (the latter is labor productivity comparison).

[13] For example, the ratio between average price received by producers and world market price is 1.72 for the EU,

Second, let us focus on the financial sector. Most of the financial sector's $\tilde{\lambda}_{Ji}$s of France, Italy, and Japan in Table 1 are less than unity and lower than those of the US. The result is consistent with the interpretation that the financial sectors in France, Italy, and Japan are more protected from competition or have more monopoly power than in the US. Rajan and Zingales (2003) collect several evidences that show that incumbents in financial market are more protected in France, Italy, and Japan than in the US, at least until the early 1990s. My result on the financial sector is consistent with their findings.

4.5 Contribution of sectoral frictions and sectoral sizes to AE

As argued in Section 3.3, results on cross-country AE depend not only on differences in sectoral frictions across countries but also on differences in sectoral sizes. The interpretation of the results in the previous sections differs depending on which is really the cause of the cross-country AE. Here, in order to check this problem, I calculate the counterfactual AE_i discussed in Section 3.3.

Table 5 reports the counterfactual AE_i. First, let us look at the sum of capital and labor components of the counterfactual AE_i for each country (as shown in Appendix D, the sum is approximately equal to the counterfactual AE). It varies from −0.2% to −0.4%. It means that even if the sectoral frictions of France, Italy, and Japan are the same as those of the US, cross-country AE becomes negative. However, the magnitude is small. The counterfactual AE is at most around 5% of cross-country AE derived in the previous sections. Second, for each country, the labor component of is negative while the capital component is positive. This suggests that some of labor frictions might be spurious.

4.6 Capital intensity α_i

I measure α_i from the US data, under the assumption that α_i is the same across developed countries. For the robustness check, I also calculate cross-country AE for the case where α_i is measured from each country's data.[14] I report the results in Table 6.[15] Compared with Table 2, the magnitude

2.46 for Japan during 1986–88, which are higher than 1.19 for the US.

[14] AE expressed in (15) is modified as follows:

$$\text{AE} = \sum_i \bar{\sigma}_i \left\{ \alpha_i^S \ln \tilde{\lambda}_{Ki}^S - \alpha_i^T \ln \tilde{\lambda}_{Ki}^T \right\} + \sum_i \bar{\sigma}_i \left\{ (1-\alpha_i^S) \ln \tilde{\lambda}_{Li}^S - (1-\alpha_i^T) \ln \tilde{\lambda}_{Li}^T . \right\}$$

[15] For France and Italy, I calculate α_i in the same way as for the US.

of AE becomes slightly smaller in France, but rather larger in Italy and Japan.

5 Concluding Remarks

In this paper, I proposed a simple multi-sector accounting framework to measure the effect of resource misallocation on aggregate productivity. The characteristics of this framework are that it is micro-founded, is flexible for demand side assumptions and is consistent with the framework commonly used in productivity analysis. Using this framework, I measured to what extent resource misallocation affects aggregate TFP and explains the difference in aggregate TFP across developed countries. I found that the effect of sector-level resource misallocation was quantitatively significant and accounted for more than 20% among developed countries.

There are several shortcomings in this paper's analysis. The first involves the interpretation of cross-sectional differences in returns on factor inputs. In this paper, cross-sectional differences in returns are interpreted as distortions. However, other interpretations such as differences in efficiency wage and quality of factor inputs (e.g., differences in educational attainment) across sectors, and the existence of investment adjustment costs are also possible. For the former two instances, some of these effects might cancel out in cross-country analysis if the degree of these effects is similar across countries. The effect in the last case might be inferred from change in the effect of measured frictions over a period of time. However, further improvements are needed on these problems.

Second, this paper does not take into account material inputs. If frictions on the allocation of materials exist, they can also affect aggregate productivity. Exploration of this issue is also left for future research. Analysis using high quality database is also important. Miyagawa et al. (2008), which use the JIP Database, are advancement in this respect.

For Japan, the procedure is basically the same too, except for the following things. First, "labor income" is calculated from "compensation of employees" times "number of total employment" divided by "number of employees" for all sectors except for the agricultural sector. Second, for agricultural sector, instead of "number of total employment," I use adjusted total employment calculated as "number of employees" + 0.5 × ("number of total employment" − "number of employees") (because if α_i is calculated as in other sectors, $1 - \alpha_i$ exceeds unity, and because there are many part-time farmers who are self-employed and unpaid family workers in Japan's agricultural sector).

Finally, α_is are also the averages of 1987, 1990, and 1993.

References

Aoki, Shuhei (2006) "A Simple Accounting Framework for Distortion on Sectoral Resource Allocation". Paper presented at the 2006 Fall Meeting of Japan Economic Association.

——— (2008) "Was the Barrier to Labor Mobility an Important Factor for the Prewar Japanese Stagnation?", MPRA Paper 8178, University Library of Munich, Germany.

Basu, Susanto and John G. Fernald (2002) "Aggregate productivity and aggregate technology", *European Economic Review*, Vol. 46, No. 6, pp. 963–991, June.

Caballero, Ricardo J., Takeo Hoshi, and Anil K. Kashyap (2008) "Zombie Lending and Depressed Restructuring in Japan", *forthcoming in American Economic Review.*

Caves, Douglas W, Laurits R Christensen, and W Erwin Diewert (1982) "Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers", *Economic Journal*, Vol. 92, No. 365, pp. 73–86, March.

Chari, V. V., Patrick J. Kehoe, and Ellen R. McGrattan (2002) "Accounting for the Great Depression", *American Economic Review*, Vol. 92, No. 2, pp. 22–27, May.

Christensen, Laurits R, Dale W Jorgenson, and Lawrence J Lau (1973) "Transcendental Logarithmic Production Frontiers", *The Review of Economics and Statistics*, Vol. 55, No. 1, pp. 28–45, February.

Domar, Evsey D. (1961) "On the Measurement of Technological Change", *The Economic Journal*, Vol. 71, No. 284, pp. 709–729, December.

Fukao, Kyoji, Tsutomu Miyagawa, and Miho Takizawa (2007) "Productivity Growth and Resource Reallocation in Japan", Hi-Stat Discussion Paper Series d07-224, Institute of Economic Research, Hitotsubashi University.

Hayashi, Fumio and Edward C. Prescott (2008) "The Depressing Effect of Agricultural Institutions on the Prewar Japanese Economy", *forthcoming in Journal of Political Economy.*

Hsieh, Chang-Tai and Peter J. Klenow (2007) "Misallocation and Manufacturing TFP in China and India", NBER Working Papers 13290, National Bureau of Economic Research, Inc.

Kiyotaki, Nobuhiro and John Moore (1997) "Credit Cycles", *Journal of Political Economy*, Vol. 105, No. 2, pp. 211–48, April.

de Melo, Jaime A P (1977) "Distortions in the Factor Market: Some General Equilibrium Estimates", *The Review of Economics and Statistics*, Vol. 59, No. 4, pp. 398–405, November.

Miyagawa, Tsutomu, Kyoji Fukao, Sumio Hamagata, and Miho Takizawa (2008) "Efficiency of Sector-Level Resource Allocation (in Japanese)", in Kyoji Fukao and Tsutomu Miyagawa eds. *Productivity and Japan's Economic Growth: Industry-Level and Firm-Level Studies Based on the JIP Database*: University of Tokyo Press.

OECD (1999a) "International Sectoral Data Base (ISDB) 1998", available from http://www.oecd.org/document/63/0,2340,en_2649_201185_2674495_1_1_1_1,00.html.

——— (1999b) *ISDB 98 User's guide*. Available from http://www.oecd.org/dataoecd/38/54/2674511.pdf.

——— (1999c) "OECD Employment Outlook".

——— (2004a) "OECD Agricultural Policies 2004". Available from http://www.oecd.org/dataoecd/63/54/32034202.pdf.

——— (2004b) "OECD Employment Outlook".

——— (2005) *OECD STAN database for Industrial Analysis*. Documentation. Available from http://www.oecd.org/dataoecd/53/21/34464010.doc.

——— (2006a) "Corporate Data Environment", available from http://www1.oecd.org/scripts/cde.

——— (2006b) "SourceOECD National Accounts Database", Annual National Accounts – volume I – Exchange Rate, PPPs, and Population Vol 2006 release 02.

——— (2006c) "Structural Analysis (STAN) database", available from http://www.oecd.org/sti/stan.

Prescott, Edward C. (2002) "Richard T. Ely Lecture: Prosperity and Depression", *American Economic Review*, Vol. 92, No. 2, pp. 1–15, May.

Rajan, Raghuram G. and Luigi Zingales (2003) *Saving Capitalism from the Capitalists*: Princeton University Press.

Restuccia, Diego and Richard Rogerson (2007) "Policy Distortions and Aggregate Productivity with Heterogeneous Plants", Working Papers tecipa-283, University of Toronto, Department of Economics.

Restuccia, Diego, Dennis Tao Yang, and Xiaodong Zhu (2008) "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis", *forthcoming in Journal of Monetary Economics*.

Schreyer, Paul and Wim Suyker (2002) "Creation of the euro area: Implications for economic statistics",Technical report, OECD. Statistics Brief. Available from http://www.oecd.org/dataoecd/19/3/1844573.pdf.

Syrquin, Moshe (1986) "Productivity Growth and Factor Reallocation", in Hollis Burnley Chenery and Moshe Syrquin eds. *Industrialization and Growth: A Comparative Study*: New York: Oxford University Press, pp. 229–262. .

Vollrath, Dietrich (2008) "How Important are Dual Economy Effects for Aggregate Productivity?", *forthcoming in Journal of Development Economics*.

Appendix

A Examples of Sector-Level or Firm-Level Frictions

In the Section 2 model, the frictions that firms face appear as taxes imposed on their factor inputs, firms are price-takers, and a firm's problem is static. In the following examples, following Chari et al. (2002), I argue that several types of frictions in each sector is isomorphic to taxes on this sector's factor inputs in that the same allocation is achieved. Especially, in the last example, frictions in a dynamic model is isomorphic to taxes in the static Section 2 model in terms of current period allocation.

As mentioned in Section 4.1, Appendix A.4 explains that α_i measured from factor input cost can have biases for the following models.

A.1 Barrier to labor mobility

Hayashi and Prescott (2008) argue that a barrier to labor mobility from the agricultural sector to the non-agricultural sector was one of the causes of stagnation in prewar Japan. I demonstrate that the allocation of this model can be achieved in the Section 2 model.

First, let us consider a labor immobility model. Suppose that there are two sectors (agricultural sector A and non-agricultural sector N). Firms in each sector are competitive. However, there is a constraint on labor mobility between the sectors, in the form that labor input in sector A L_A has to be at least $\bar{L}_A$ (i.e., $L_A \geq \bar{L}_A$). Other settings of the model are the same as Section 2. Then, the typical firm's problem is

$$\max_{K_i, L_i} p_i F_i(K_i, L_i) - p_K K_i - p_{Li} L_i,\ i \in \{A \text{ or } N\}. \tag{21}$$

Factor price on labor can be different between the sectors, because of the constraint on labor mobility:

$$p_{LA} \neq p_{LN}. \tag{22}$$

Therefore, the allocation can be different from no friction case.

I set $(1 + \tau_{LA}) = p_{LA}$ and $(1 + \tau_{LN}) = p_{LN}$ in the Section 2 model. Then, the effect of the barrier to labor mobility is isomorphic to the taxes in the Section 2 model. For the proof, suppose that $\tilde{\sigma}_i$ in the Section 2 is the same as that in the above model. Then, from (9) and (11) the same K_i and L_i is achieved. Thus, the same V_i is achieved. In both models,

$$\tilde{\sigma}_i = \frac{\partial V}{\partial V_i} V_i / V.$$

Since the RHS is the function of $\{V_i\}$ the supposition that $\tilde{\sigma}_i$ is the same is right.

A.2 Imperfect competition

I demonstrate that frictions caused by imperfect competition such as monopoly, oligopoly, or monopolistic competition can also be expressed as taxes on factor inputs.

Let us consider the following firm's problem: the firm is a price-taker in the factor market but a price-setter in the output market. Other settings of the model are the same as Section 2.

Accordingly, the firm's cost minimization problem is

$$\min_{K_i, L_i} \; p_K K_i + p_L L_i, \tag{23}$$

$$\text{s.t.} V_i = F_i(K_i, L_i). \tag{24}$$

The FOCs of the problem are

$$p_i \frac{\partial F_i(K_i, L_i)}{\partial K_i} = \frac{p_i}{\gamma_i} p_K, \tag{25}$$

$$p_i \frac{\partial F_i(K_i, L_i)}{\partial L_i} = \frac{p_i}{\gamma_i} p_L, \tag{26}$$

where γ_i is the Lagrange multiplier and p_i is the price of the good that the firm produces. Since γ_i is equal to marginal cost, p_i/γ_i is the markup and is equal to unity when the firm is a price-taker in output market.

I set $(1 + \tau_{Ki})$ and $(1 + \tau_{Li})$ are equal to p_i/γ_i in the Section 2 model. Then, the effect of imperfection is isomorphic to the taxes in the Section 2 model. The proof can be shown in the same way as in Section A.1.

A.3 Borrowing constraint

Kiyotaki and Moore (1997) show that differences in the degree of borrowing constraint between firms can affect resource allocation and aggregate productivity. I demonstrate that the allocation of this model at a certain period can be achieved in the Section 2 model.

First, let us consider a borrowing constraint model. Suppose that a typical firm is competitive and that the firm faces a borrowing constraint; the firm's problem is written as follows:

$$\begin{aligned}
\max_{K_i, L_i, B_i} \quad & \pi_i + \frac{1}{1+r} J_i(K_i, B_i), \\
\text{s.t.} \quad & \pi_i = p_i F_i(K_i, L_i) - p_L L_i - q_K (K_i - (1-\delta) K_{i,-1}) \\
& \qquad + \frac{B_i}{1+r} - B_{i,-1}, \\
& B_i \leq \theta q_{K,+1} K_i, \\
\text{given} \quad & K_{i,-1}, \; B_{i,-1},
\end{aligned}$$

where r is interest rate, B_i is the volume at which the firm borrows, θ is a collateral constraint parameter and is between zero and one, q_K is the value of capital, $J_i(K_i, B_i)$ is the next-period value function of owning K_i and B_i, and subscripts -1 and $+1$ indicate the previous and next periods. Other settings of the model are the same as Section 2. Aggregate capital and labor of the current period are exogenously provided. Then, the FOCs are as follows:

$$p_i \frac{\partial F_i(K_i, L_i)}{\partial K_i} = q_K - \frac{1}{1+r} \frac{\partial J_i(K_i, B_i)}{\partial K_i} - \frac{1}{1+r} \theta q_{K,+1} \left(1 + \frac{\partial J_i(K_i, B_i)}{\partial B_i}\right), \tag{27}$$
$$p_i \frac{\partial F_i(K_i, L_i)}{\partial L_i} = p_L.$$

I set $(1 + \tau_{Ki})$ is equal to the RHS of (27) and $(1 + \tau_{Li}) = 1$ in the Section 2 model. Then, the effect of borrowing constraint is isomorphic to the taxes in the Section 2 model. The proof can be shown in the same way as in Section A.1.

A.4 Biases arising in the measurement of α_i

Here, I argue that if there are imperfections in factor market as in Appendices A.1 and A.3, α_i measured from factor input cost can have biases.

To examine this, take labor immobility model in Section A.1 as an example. In this model, because firms are price takers for factor markets, $1 - \alpha_i$ is equal to the cost share of labor input. Because of the barrier to labor mobility, the labor input cost becomes different between sectors, even if the quality of labor input is homogeneous. However, the labor input cost is usually measured under the assumption that the cost of labor input with the same quality level is the same between sectors. Thus, measured $1 - \alpha_i$ can have biases, if the labor input cost measured in this way is used.[16] Similar problem arises to capital side in case of the borrowing constraint model in Section A.3.

B Derivation of (14)

In order to derive (14), we need to show that terms $\bar{\alpha} \sum_i \frac{\bar{\sigma}_i \alpha_i}{\bar{\alpha}} \Delta \ln \left(\frac{\tilde{\sigma}_i \alpha_i}{\tilde{\alpha}}\right)$ and $(1-\bar{\alpha}) \sum_i \frac{\bar{\sigma}_i (1-\alpha_i)}{1-\bar{\alpha}} \Delta \ln \left(\frac{\tilde{\sigma}_i (1-\alpha_i)}{1-\tilde{\alpha}}\right)$ are approximately zero (Δ denotes the difference between states S and T). These terms are ap-

[16] In this case, $1 - \alpha_i$ measured from revenue share does not have biases.

proximately zero, because when $\sum_i \gamma_i = 1$, the following relation holds:

$$\begin{aligned}\sum_i \gamma_i \Delta \ln \gamma_i &\simeq \sum_i \gamma_i \frac{\Delta \gamma_i}{\gamma_i} \\ &= 1 - 1 \\ &= 0.\end{aligned}$$

Moreover, in our dataset, these terms are quantitatively small (0% to 0.2%).

C Data

This appendix provides information on the data.

C.1 Sources

The sector-level data, except for capital input, are taken from the OECD STAN database (OECD, 2006c). Capital input is taken from the OECD ISDB (OECD, 1999a). (OECD, 2005 and OECD, 1999b are these manuals.) The purchasing-power-parity (PPP) data are taken from OECD (2006b). The "average hours worked per person" data, which are used for the calculation of ATFP, are taken from the Labour Market Statistics of OECD Corporate Data Environment (OECD, 2006a). All data are annual (data periods are 1987, 1990, and 1993). The countries I use for the analysis are France, Italy, Japan, and the US.

C.2 Sector classification

The sectors I include in my analysis are (1) "Agriculture, Hunting, Forestry and Fishing," (2) "Mining and Quarrying" + "Total Manufacturing," (3) "Electricity, Gas and Water Supply," (4) "Wholesale and Retail Trade; Repairs," (5) "Transport and Storage and Communication," and (6) "Financial Intermediation." I exclude "Real Estate, Renting and Business Activities," because it contains a large number of owner-occupied dwellings.[17] I also exclude the "Community, Social and Personal Services" sector because it mainly consists of non-market activities. The definition

[17] The values of the variables would be biased because the labor input for the owner-occupied dwellings are not measured. In addition, the share of owner-occupied dwellings is different across countries (for example, Japan is said to have a high share, and the US a low share).

of sector classification according to STAN and ISDB is essentially the same for the sectors that are chosen for this study (while STAN is based on ISIC rev.3, ISDB is based on ISIC rev.2).

I exclude the "Hotels and Restaurants" sector, which is usually included in the "Wholesale and Retail Trade; Repairs" sector, because this data is not available for Japan (for Japan, "Hotels and Restaurants" is included in "Community, Social and Personal Services" sector and cannot be separated).

C.3 Data variables

For aggregate and sectoral nominal value added, I use "current price value added at producer's prices" from the STAN database. For factor costs which is needed to calculate α_i, I use "value added at factor costs" in STAN database, which is basically after-tax value added.[18] For aggregate and sectoral capital input, I use "gross capital stock including OECD estimates" from the ISDB. Since the sources of aggregate and sectoral labor input is written in Section 4.2, I do not repeat here.

In order to calculate cross-country ATFP, variables need to be comparable between countries. In the next section, I discuss how to convert data using PPP.

C.4 Conversion to the 1990 US dollar

In order to calculate cross-country ATFP, I convert the value added and capital stock to the 1990 US dollar.

In order to convert the value added used for ATFP, I first calculate real value added whose base year is 1990 from nominal value added explained above and then convert it using purchasing power parity (PPP) at 1990.[19]

Although the original capital stock data taken from the ISDB is expressed in 1990 US dollar, the PPP conversion rate is different from the PPP above (as in Table 7, the PPP used for capital stock data in ISDB is 15–30% higher). If the ISDB PPP is used, the capital stock of France, Italy, and Japan becomes much smaller. It overestimates the effect of the frictions on aggregate TFP

[18] While we use factor costs data of each country in Section 4.6's analysis, the "value added at factor costs" is not available in Japan at 1987. For this, I substitute $(1 - \tau_i')$ times sector i's "value added at current prices" for the factor costs, where $(1 - \tau_i')$ is defined by sector i's ratio of "value added at factor costs" and "value added at current prices" in Japan at 1990.

[19] I convert value added using PPP at 1990 to be consistent with capital stock data whose base year is 1990.

(i.e., cross-country AE/ATFP) because the differences in aggregate TFP between these countries and the US become smaller (and because cross-country AE is indifferent to the value of PPP). In order to avoid this bias, I convert capital stock using the same PPP used for value added as follows. I first reconvert capital stock at 1990 US dollar into that at the 1990 prices of each country. Then, I convert old national currencies into the euro using the irrevocable conversion rates taken from Schreyer and Suyker (2002)(the same rates are used in STAN database). I subsequently convert them into the US dollar using the PPP used for value added.

D Relation between AE_i and AE

This appendix shows that AE_i is equal to the AE that consists of sector i and all the rest, and that if $\tilde{\sigma}_i$ is small for each sector, the sum of AE_i is approximately equal to AE.

First, I show that AE_i is the same as the AE that consists of sector i and all the rest. The capital component of AE_i, AE_{Ki}, can be written as follows:

$$\mathrm{AE}_{Ki} = \bar{\sigma}_i \alpha_i \ln\left(\frac{\tilde{\lambda}^S_{Ki}}{\tilde{\lambda}^T_{Ki}}\right) + \bar{\sigma}_{-i}\bar{\alpha}_{-i} \ln\left(\frac{\tilde{\lambda}^S_{K-i}}{\tilde{\lambda}^T_{K-i}}\right),$$

where $\bar{\sigma}_{-i} \equiv 1 - \bar{\sigma}_i$ and $\bar{\alpha}_{-i} \equiv \sum_{m\neq i} \bar{\sigma}_m/(1-\bar{\sigma}_i)\alpha_m$ (i.e., $\bar{\alpha}_{-i}$ is a weighted average of a_m $(m \neq i)$). Moreover, (17) shows that $\tilde{\lambda}_{K-i}$ corresponds to $\tilde{\lambda}_{Kj}$ of all the rest. The labor component of AE_i can be written in the same way.

Next, I show that if $\tilde{\sigma}_i$ is small for each sector, the sum of AE_i is approximately equal to AE. The sum of the capital component of AE_i, AE_{Ki} is written as follows:

$$\sum_i \mathrm{AE}_{Ki} = \mathrm{AE}_K + \sum_i (\bar{\alpha} - \bar{\sigma}_i \alpha_i) \ln\left(\frac{\tilde{\lambda}^S_{K-i}}{\tilde{\lambda}^T_{K-i}}\right),$$

where AE_K is the capital component of AE ($\mathrm{AE}_K \equiv \sum_i \bar{\sigma}_i \alpha_i \ln\left(\tilde{\lambda}^S_{Ki}/\tilde{\lambda}^T_{Ki}\right)$). We show that the second term of RHS of the above equation approximately becomes zero. Since we can show for the labor component in the same way, we can show the opening statement of the appendix.

To show the second term of RHS of the above equation approximately becomes zero, I further focus on state S component (the same result applies to state T component). Thus, I show

$$\sum_i (\bar{\alpha} - \bar{\sigma}_i \alpha_i) \ln \tilde{\lambda}_{K-i}^S \simeq 0, \tag{28}$$

when $\tilde{\sigma}_i$ is small. From (16), we obtain the following relation:

$$\tilde{\lambda}_{K-i}^S = 1 + \frac{1 - \tilde{\lambda}_{Ki}^S}{\frac{\tilde{\alpha}^S}{\tilde{\sigma}_i^S \alpha_i} - 1}$$

By substituting it into (28) and rearranging, we obtain

$$\begin{aligned}
(28) &= \sum_i \left(\frac{\bar{\alpha} - \tilde{\sigma}_i^S \alpha_i}{\tilde{\alpha}^S - \tilde{\sigma}_i^S \alpha_i} \right) \left(\frac{\tilde{\alpha}^S}{\tilde{\sigma}_i^S \alpha_i} - 1 \right) \tilde{\sigma}_i^S \alpha_i \ln \left(1 + \frac{1 - \tilde{\lambda}_{Ki}^S}{\frac{\tilde{\alpha}^S}{\tilde{\sigma}_i^S \alpha_i} - 1} \right) \\
&= \sum_i \left(1 + \frac{\bar{\alpha} - \tilde{\alpha}^S}{\tilde{\alpha}^S} \frac{1}{1 - \frac{\tilde{\sigma}_i^S \alpha_i}{\tilde{\alpha}_S}} \right) \tilde{\sigma}_i^S \alpha_i \ln \left(1 + \frac{1 - \tilde{\lambda}_{Ki}^S}{\frac{\tilde{\alpha}^S}{\tilde{\sigma}_i^S \alpha_i} - 1} \right)^{\frac{\tilde{\alpha}^S}{\tilde{\sigma}_i^S \alpha_i} - 1}.
\end{aligned}$$

For a sufficiently small $\tilde{\sigma}_i^S$,

$$\left(1 + \frac{\bar{\alpha} - \tilde{\alpha}^S}{\tilde{\alpha}^S} \frac{1}{1 - \frac{\tilde{\sigma}_i^S \alpha_i}{\tilde{\alpha}_S}} \right) \simeq \left(1 + \frac{\bar{\alpha} - \tilde{\alpha}^S}{\tilde{\alpha}^S} \right), \text{ and } \left(1 + \frac{1 - \tilde{\lambda}_{Ki}^S}{\frac{\tilde{\alpha}^S}{\tilde{\sigma}_i^S \alpha_i} - 1} \right)^{\frac{\tilde{\alpha}^S}{\tilde{\sigma}_i^S \alpha_i} - 1} \simeq \exp\left(1 - \tilde{\lambda}_{Ki}^S\right).$$

Thus, if $\tilde{\sigma}_i^S$ is small in all sectors,

$$\begin{aligned}
(28) &\simeq \left(1 + \frac{\bar{\alpha} - \tilde{\alpha}^S}{\tilde{\alpha}^S} \right) \sum_i \tilde{\sigma}_i^S \alpha_i \left(1 - \tilde{\lambda}_{Ki}^S \right) \\
&= 0.
\end{aligned}$$

The last equation becomes zero, because $\sum_i \tilde{\sigma}_i^S \alpha_i = \tilde{\alpha}^S$ and $\sum_i \tilde{\sigma}_i^S \alpha_i \tilde{\lambda}_{Ki}^S = \tilde{\alpha}^S$ from the definitions.

	France		Italy		Japan		US	
	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$
Agricultural	0.76	3.19	1.81	3.65	2.30	3.16	1.02	1.66
Manufacturing	0.85	0.81	0.83	0.89	1.05	0.95	0.87	0.98
Electricity	1.26	0.84	1.18	0.81	0.93	0.62	1.25	0.61
Construction	1.85	0.89	1.94	0.86	1.10	0.88	0.63	1.11
Wholesale	1.01	1.19	0.83	1.03	0.82	1.11	0.72	1.06
Transport	1.96	1.07	1.66	1.08	1.11	0.99	1.13	0.84
Financial	0.34	0.73	0.36	0.46	0.24	0.62	1.39	0.92

Table 1: Measured $\tilde{\lambda}_{Ki}$ and $\tilde{\lambda}_{Li}$ for each country. Note: The values reported here are the averages of 1987, 1990, and 1993 data for each country and each sector.

	Average	1987	1990	1993
Cross-country AE				
France	−5.2%	−5.8%	−4.6%	−5.0%
Italy	−8.4%	−8.2%	−8.1%	−8.7%
Japan	−5.7%	−6.3%	−4.8%	−5.9%
Cross-country ATFP				
France	1.5%	0.1%	4.6%	−0.2%
Italy	−18.3%	−17.7%	−16.4%	−20.9%
Japan	−26.0%	−31.4%	−21.0%	−25.5%
Cross-country AE/ATFP				
France	–	–	–	–
Italy	45.9%	46.5%	49.4%	41.8%
Japan	22.1%	20.0%	23.0%	23.3%

Table 2: Cross-country allocational efficiency (AE), aggregate TFP (ATFP) and AE divided by ATFP (AE/ATFP) compared with the US at 1987, 1990, 1993. Notes: Column "Average" calculates the averages of the periods. I do not report AE/ATFP for France, because the ATFP of France is positive while its AE is negative.

Average	Each country	US	Capital	Labor	Sum
France	−6.4%	1.2%	−2.1%	−3.1%	−5.2%
Italy	−9.5%	1.2%	−2.3%	−6.0%	−8.4%
Japan	−6.9%	1.2%	−3.1%	−2.6%	−5.7%

Table 3: Two decompositions of average cross-country AE compared with the US. Notes: The result is the averages of 1987, 1990, and 1993. In the first case, the average AE is decomposed into each country and US components, and in the second case, the average AE is decomposed into capital and labor components. In both cases, the sum of the components is equal to the sum in the last column, which is the same as the average AE in Table 2.

	France		Italy		Japan	
	capital	labor	capital	labor	capital	labor
Agricultural	0.1%	−3.5%	−1.1%	−4.8%	−1.1%	−1.9%
Manufacturing	0.4%	0.0%	0.2%	0.1%	0.2%	0.1%
Electricity	0.0%	0.1%	0.2%	0.0%	0.1%	0.0%
Construction	−0.2%	0.0%	−0.2%	0.0%	0.1%	0.0%
Wholesale	0.0%	0.7%	0.0%	0.2%	−0.1%	0.4%
Transport	−0.8%	0.0%	−0.2%	0.0%	0.1%	0.0%
Financial	−1.6%	−0.6%	−1.5%	−2.0%	−2.5%	−1.2%
Sum	−2.1%	−3.2%	−2.4%	−6.5%	−3.2%	−2.6%
	(−5.3%)		(−8.9%)		(−5.8%)	

Table 4: Cross-country AE_i compared with the US. Notes: AE_i calculates the sector i's contribution to cross-country AE. As shown in Appendix D, the sum is approximately equal to the capital and labor components in Table 3. The values reported here are the averages of 1987, 1990, and 1993 data.

	France		Italy		Japan	
	capital	labor	capital	labor	capital	labor
Agricultural	0.0%	−0.7%	−0.1%	−0.8%	0.0%	−0.2%
Manufacturing	0.4%	0.2%	0.4%	0.2%	0.3%	0.1%
Electricity	0.0%	0.0%	0.2%	−0.1%	−0.1%	0.0%
Construction	0.1%	−0.4%	0.0%	−0.2%	0.2%	−0.7%
Wholesale	−0.5%	0.5%	−0.2%	0.3%	−0.2%	0.3%
Transport	0.1%	−0.2%	0.1%	−0.3%	0.1%	−0.3%
Financial	0.5%	−0.2%	0.3%	−0.1%	0.5%	−0.3%
Sum	0.6%	−0.8%	0.7%	−1.1%	0.7%	−1.0%
	(−0.2%)		(−0.4%)		(−0.3%)	

Table 5: Cross-country counterfactual AE_i compared with the US. Notes: It is counterfactual in that $\tilde{\lambda}_{Ji}(\{\tilde{\sigma}_j^S, \lambda_{Jj}^T\})$s in (19) and (20) are used instead of $\tilde{\lambda}_{J_i}^S$. The values reported here are the averages of 1987, 1990, and 1993 data.

	Average
Cross-country AE	
France	−4.5%
Italy	−10.7%
Japan	−8.0%

Table 6: Cross-country AE compared with the US, when α_i are measured from each country's data. Notes: The AEs reported here are calculated using the equation in footnote 14. The result is the averages of 1987, 1990, and 1993.

	France	Italy	Japan
ISDB PPP used for capital	1.158917	0.913096	218.7
PPP used for value added	0.9943	0.6888	189.2402
Difference	15%	28%	14%

Table 7: Comparison of PPPs. Notes: "ISDB PPP used for capital" denotes PPP used for capital stock data in ISDB. "PPP used for value added" denotes PPP used for the conversion of value added (and capital stock) in this paper. These values are national currencies per US dollar at 1990. (The euro is used for France, and Italy.)