

# Distribution of Sector-Level Frictions and Cross-Country Differences in Aggregate Productivity

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## Abstract

This paper examines the extent to which cross-sectional, sector-level factor price distortions explain cross-country differences in aggregate productivity. I develop a multi-sector model with frictions in the form of sector-specific taxes on factor inputs. In this model, while the magnitude of frictions does not itself affect the cross-sectional resource allocation and aggregate productivity, the distribution of frictions does. Using the model, I measure the distribution of frictions from sectoral data, and calculate the effect on aggregate productivity. I find that the distribution of sector-level frictions explains 20% to 40% of the differences in the aggregate productivity among developed countries.

JEL Codes: E23, O11, O41, O47

Keywords: distortions; frictions; resource allocation; TFP

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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 the US and France, Japan, and the UK. One source of this disparity is the difference in the level of aggregate total factor productivity (TFP). Prescott argues that aggregate TFP is the most important factor in accounting for the income differences among developed nations. If we accept this position, the next question that subsequently arises is “What accounts for level differences in aggregate TFP?” One important determinant of the level differences in aggregate TFP is cross-sectional, sector-level factor price distortions. This paper argues that these distortions account for as much as 40% of the level differences in aggregate TFP among highly developed countries.

I support my claim in the following way. First, I develop a static multi-sector general equilibrium model with sector-level frictions in the form of sector-specific taxes on factor inputs (capital and labor inputs). In this model, while the magnitude of frictions does not itself affect the cross-sectional allocation of factor inputs and aggregate productivity, the distribution of frictions does.

Next, using the model, I measure the distribution of frictions from OECD’s sectoral data for France, Italy, Japan, and the US. Then, I calculate how the distribution of sector-level frictions explains the cross-country differences in aggregate TFP between the US, France, Italy, and Japan. I find that due to the differences in the distribution of frictions between the US and other countries, the aggregate TFP for France, Italy, and Japan becomes 5.4% to 8.2% lower than that of the US. They correspond to 20% (for Japan) to 40% (for France and Italy) of differences in aggregate TFP between the US and those countries. While the magnitude of frictions on labor is larger between the US and Italy than between the US and France or Japan, the magnitude of frictions on capital is similar for all them. They also share agriculture and financial sectors as primary distortion sources. Distribution of frictions is composed of sectoral frictions and sectoral sizes, and thus, 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.

This paper follows Chari, Kehoe and McGrattan’s (2003) approach in that frictions are modeled as taxes. Owing to this, it can focus on the effect of distortions on cross-sectional resource allocation rather than the details about the cause of the distortions. On this point, there is similarity to

Restuccia and Rogerson (2007), in its theoretical analysis of how the distribution of firm-specific frictions in the form of taxes affect aggregate TFP. Another benefit of this approach exists in measurement. Through the model used in this paper, the distribution of frictions is identified from cross-sectional differences in factor input returns. The distribution of frictions measured in this way captures the overall effect of several kinds of distortions that actually distort cross-sectional resource allocation.

Several studies provide examples of distortions in cross-sectional resource allocation. Caballero, Hoshi and Kashyap (2007) 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 (2006) argue that for institutional reasons, there was a barrier to labor mobility between the agriculture and non agriculture sectors in prewar Japan. In my model, frictions in the form of taxes capture the effect of these distortions on cross-sectional resource allocation.

This study is related to a vast amount of research in growth accounting literature, which measures the effect of factor reallocation on aggregate TFP growth (see Syrquin 1986, and Basu and Fernald 2002, among others). While their studies calculate the effect on the aggregate TFP growth rate over time, this paper calculates the effect on the cross-country level differences in aggregate TFP. This study also provides the micro-foundations for the reallocation effect. Owing to this, the approach used herein can identify which sector is the cause of the distortions, and how much is really due to differences in sectoral frictions and how much is due to differences in sectoral sizes between countries.

There is growing literature that measures distortions in cross-sectional resource allocation from cross-sectional differences in factor input returns using the general equilibrium framework, and calculates their effect on aggregate TFP. My research fits into this framework. 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 de Melo (1977) to calculate the effect of removing distortions on sector-level resource allocation. Recently, Restuccia, Yang and Zhu (2004) and Vollrath (2006) use a two-sector model to measure the barriers of resource allocation between the old agriculture and modern manufacturing sectors. While their papers focus on these two

sectors and on developing countries, my paper focuses on a multi-sector environment in developed nations. Using manufacturing plant-level data from China, India and the US, Hsieh and Klenow (2007) calculate how the distribution of frictions affects aggregate TFP. Their study also deals with a multi-sector environment, and thus compliments this research.

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 framework, Section 3 analyzes the effects of frictions on aggregate TFP. Based on the results, Section 4 measures the effect of frictions on sector-level resource allocation from data, and calculates the effect of the sector-level frictions on aggregate TFP. Section 5 contains the concluding remarks.

## 2 The Model

In this section, I develop a multi-sector competitive equilibrium model with sector-level frictions. In keeping with Chari, Kehoe and McGrattan (2003), sector-level frictions are modeled in the form of sector-specific taxes on 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 the setting of the model captures several types of frictions which cause distortions on cross-sectional resource allocation.

### 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  $\tau_{Ki}$  and  $\tau_{Li}$  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:

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

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  $\alpha_i$  can vary by sector.

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

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

The FOCs are as follows:

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

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

Note that from the FOCs, we also attain the unit cost function:

$$p_i = \frac{1}{\alpha_i^{\alpha_i} (1 - \alpha_i)^{1-\alpha_i}} \frac{\{(1 + \tau_{K_i}) p_K\}^{\alpha_i} \{(1 + \tau_{L_i}) p_L\}^{1-\alpha_i}}{A_i}.$$

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., (8)–(11) hold even when some sectors do not produce.

## 2.2 Aggregator function

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

$$V = V(V_1, \dots, V_I). \quad (4)$$

I also assume that the following condition is satisfied:

$$\frac{\partial V}{\partial V_i} = p_i. \quad (5)$$

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

$$V = \sum_i p_i V_i.$$

### 2.3 Resource constraints

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

$$\sum_i K_i = K, \quad (6)$$

$$\sum_i L_i = L, \quad (7)$$

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  $\{A_i, 1 + \tau_{K_i}, 1 + \tau_{L_i}\}$ , 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 (6) and (7).

In what follows, I derive the equilibrium allocation for  $K_i$  and  $L_i$ . By substituting the FOC of capital (2) into the capital market condition (6), we get

$$\frac{1}{p_K} = \frac{K}{\sum_i \alpha_i p_i V_i / (1 + \tau_{K_i})}.$$

By substituting this equation into the FOC (2) again, we obtain

$$K_i = \frac{\alpha_i p_i V_i / (1 + \tau_{K_i})}{\sum_j \alpha_j p_j V_j / (1 + \tau_{K_j})} K.$$

This equation can be rewritten as follows:

$$K_i = \frac{\tilde{\sigma}_i \alpha_i}{\tilde{\alpha}} \tilde{\lambda}_{K_i} K, \quad (8)$$

where  $\tilde{\sigma}_i$  is the expenditure share of the sector  $p_i V_i / V$ ,  $\tilde{\alpha}$  is the weighted average of capital intensities  $\sum_i \tilde{\sigma}_i \alpha_i$ , and  $\tilde{\lambda}_{K_i}$  is the term composed of frictions.  $\tilde{\lambda}_{K_i}$  is defined as

$$\tilde{\lambda}_{K_i} \equiv \frac{\lambda_{K_i}}{\sum_j \left( \frac{\tilde{\sigma}_j \alpha_j}{\tilde{\alpha}} \right) \lambda_{K_j}}, \text{ and } \lambda_{K_i} \equiv \frac{1}{1 + \tau_{K_i}}. \quad (9)$$

I add tilde  $\tilde{\cdot}$  for the variables that depend on the functional form of  $V$ . (8) is the equilibrium allocation of  $K_i$  because if the functional form of  $V$  is specified,  $\tilde{\sigma}_i$  and  $\tilde{\alpha}$  are specified, and thus, the equilibrium allocation of  $K_i$  is completely specified.<sup>1</sup> In the same way, we obtain the equilibrium allocation of  $L_i$ :

$$L_i = \frac{\tilde{\sigma}_i (1 - \alpha_i)}{1 - \tilde{\alpha}} \tilde{\lambda}_{L_i} L, \quad (10)$$

where

$$\tilde{\lambda}_{L_i} \equiv \frac{\lambda_{L_i}}{\sum_j \left( \frac{\tilde{\sigma}_j (1 - \alpha_j)}{1 - \tilde{\alpha}} \right) \lambda_{L_j}}, \text{ and } \lambda_{L_i} \equiv \frac{1}{1 + \tau_{L_i}}. \quad (11)$$

Equations (8)–(11) uncover several findings on the effect of taxes on resource allocation of

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<sup>1</sup>For example, in the log case where  $\ln V = \sum_i \sigma_i \ln V_i$  ( $\sigma_i$  is a parameter),  $\tilde{\sigma}_i$  is equal to  $\sigma_i$  and  $\tilde{\alpha}$  is equal to  $\sum_i \sigma_i \alpha_i$ .

capital and labor. First, from (8) and (10), we find that taxes affect the allocation of resources through  $\tilde{\lambda}_{J_i}$ . Second, from (9) and (11), we find that  $\tilde{\lambda}_{J_i}$  is the ratio of the harmonic mean of the return on factor input across sectors, and the sector  $i$ 's return. 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  $\tilde{\lambda}_{K_i}$  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  $\lambda_{K_i}$  is smaller than the weighted average of  $\lambda_{K_j}$  (i.e., sector  $i$ 's capital is taxed more), then  $\tilde{\lambda}_{K_i}$  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  $\lambda_{J_i}$ s themselves, but measure  $\tilde{\lambda}_{J_i}$ s, which capture the distribution of frictions.  $\tilde{\lambda}_{J_i}$ s are measured using the following equations that are rewritten from (8) and (10):

$$\tilde{\lambda}_{K_i} = \left( \frac{\tilde{\sigma}_i \alpha_i}{\tilde{\alpha}} \right)^{-1} \frac{K_i}{K}, \text{ and } \tilde{\lambda}_{L_i} = \left( \frac{\tilde{\sigma}_i (1 - \alpha_i)}{1 - \tilde{\alpha}} \right)^{-1} \frac{L_i}{L}. \quad (12)$$

$\tilde{\lambda}_{K_i}$  is further rewritten as follows ( $\tilde{\lambda}_{L_i}$  can be rewritten in the same way):

$$\tilde{\lambda}_{K_i} = \frac{\left( \sum_j \alpha_j p_j V_j \right) / K}{\alpha_i p_i V_i / K_i}.$$

The RHS consists of the ratio of the average return on capital across sectors and the sector  $i$ 's return on capital. Thus, in this paper, distortions are measured from cross-sectional returns on factor inputs.

### 3 Analyzing the effects of frictions on Aggregate TFP

I would like to calculate the effects of frictions on aggregate TFP through sector-level resource allocation. For this purpose, in this section, I decompose aggregate TFP into components composed of sectoral TFPs, sectoral shares, and distortions on cross-sectional resource allocation. This section also provides a method to identify which sector contributes to distortions. Finally, because the component of distortions consists of the combination of sectoral frictions and sectoral sizes, I provide a method to identify the contribution of each factor.



### 3.1 Decomposition of aggregate TFP

In order to analyze the effect of frictions on sector-level resource allocation and aggregate TFP, I apply the quadratic approximation to the aggregator function  $V$  (for the quadratic approximation, see Diewert 1976). To do this, I compare the aggregator function at state  $S$ ,  $V^S$ , with that at state  $T$ ,  $V^T$  (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  $\alpha_i$  is the same across different states.

By applying the quadratic approximation, we obtain

$$\ln\left(\frac{V^S}{V^T}\right) \simeq \sum_i \frac{1}{2}(\tilde{\sigma}_i^S + \tilde{\sigma}_i^T) \ln\left(\frac{V_i^S}{V_i^T}\right).$$

It measures differences in aggregate value between state  $S$  and state  $T$ . By substituting (1), (8), and (10) into the above equation, we obtain the following decomposition:

$$\begin{aligned} \ln\left(\frac{V^S}{V^T}\right) \simeq & \sum_i \bar{\sigma}_i \left\{ \ln\left(\frac{A_i^S}{A_i^T}\right) + \ln\left(\frac{\tilde{\sigma}_i^S}{\tilde{\sigma}_i^T} \Big/ \frac{(\tilde{\alpha}^S)^{\alpha_i}(1-\tilde{\alpha}^S)^{1-\alpha_i}}{(\tilde{\alpha}^T)^{\alpha_i}(1-\tilde{\alpha}^T)^{1-\alpha_i}}\right) \right. \\ & \left. + \alpha_i \ln\left(\frac{\tilde{\lambda}_{K_i}^S}{\tilde{\lambda}_{K_i}^T}\right) + (1-\alpha_i) \ln\left(\frac{\tilde{\lambda}_{L_i}^S}{\tilde{\lambda}_{L_i}^T}\right) \right\} \\ & + \bar{\alpha} \ln\left(\frac{K^S}{K^T}\right) + (1-\bar{\alpha}) \ln\left(\frac{L^S}{L^T}\right), \end{aligned}$$

where  $\bar{\sigma}_i \equiv (\tilde{\sigma}_i^S + \tilde{\sigma}_i^T)/2$  and  $\bar{\alpha} \equiv \sum_i \bar{\sigma}_i \alpha_i$ . This equation is further rewritten as follows:

$$\begin{aligned} \ln\left(\frac{V^S}{V^T}\right) - \bar{\alpha} \ln\left(\frac{K^S}{K^T}\right) - (1-\bar{\alpha}) \ln\left(\frac{L^S}{L^T}\right) \\ \simeq & \sum_i \bar{\sigma}_i \ln\left(\frac{A_i^S}{A_i^T}\right) \\ & + \sum_i \bar{\sigma}_i \ln\left(\frac{\tilde{\sigma}_i^S}{\tilde{\sigma}_i^T} \Big/ \frac{(\tilde{\alpha}^S)^{\alpha_i}(1-\tilde{\alpha}^S)^{1-\alpha_i}}{(\tilde{\alpha}^T)^{\alpha_i}(1-\tilde{\alpha}^T)^{1-\alpha_i}}\right) \\ & + \sum_i \bar{\sigma}_i \left\{ \alpha_i \ln\left(\frac{\tilde{\lambda}_{K_i}^S}{\tilde{\lambda}_{K_i}^T}\right) + (1-\alpha_i) \ln\left(\frac{\tilde{\lambda}_{L_i}^S}{\tilde{\lambda}_{L_i}^T}\right) \right\}. \end{aligned} \quad (13)$$

The LHS of (13) conforms to a standard definition of aggregate TFP. I term the LHS as ATFP. ATFP measures the differences in aggregate TFP between  $S$  and  $T$ . In addition, I refer to the first

line of the RHS of (13) as sectoral TFP term (STFP) and the second line as sectoral share term (SS). STFP is a weighted average of sectoral TFPs and SS consists of sectoral shares and capital intensities.

The third line of the RHS of (13) consists of frictions. I refer to it as allocational efficiency term (AE). AE measures the effect of distortions on cross-sectional 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. The SS + AE is the same as the reallocation term in Syrquin (1986) and Basu and Fernald (2002) because they define the reallocation term by  $\text{ATFP} - \text{STFP}$ .

In later analysis, I further decompose AE in several different ways. For example, AE in (13) is decomposed into a state  $S$  component that consists of  $\tilde{\lambda}_{K_i}^S$  and  $\tilde{\lambda}_{L_i}^S$  and a state  $T$  component that consists of  $\tilde{\lambda}_{K_i}^T$  and  $\tilde{\lambda}_{L_i}^T$ . AE is also decomposed into a capital component that consists of  $\tilde{\lambda}_{K_i}^S$  and  $\tilde{\lambda}_{K_i}^T$  and a labor component that consists of  $\tilde{\lambda}_{L_i}^S$  and  $\tilde{\lambda}_{L_i}^T$ . The next section explains how to decompose AE into sectoral contributions.

### 3.2 Contribution of each sector to AE

Our framework enables identification of which sector contributes to allocational efficiency (AE). This section provides the method. I do not simply decompose AE in (13) into sectoral components, because then the sectoral component of a sector where  $\tilde{\lambda}_{J_i}^S/\tilde{\lambda}_{J_i}^T > 1$  becomes positive, irrespective of distortions on allocation between sector  $i$  and other sectors.

In order to identify the contribution of sector  $i$ , I calculate a fictitious AE under the following assumptions (while I drop out superscript  $S$  and  $T$  for convenience, note that these assumptions are applied to the both states). Sector  $i$ 's  $\tilde{\lambda}_{J_i}$  is the same as the actual one (i.e., the one measured from data), but  $\tilde{\lambda}_{J_m} = \tilde{\lambda}_{J_n} = \tilde{\lambda}_{J_{-i}}$  for other sectors ( $m$  and  $n$  are sectors that are not sector  $i$  and I summarize these sectors by  $-i$ ). All other assumptions are the same as the actual one. I refer to this AE as  $\text{AE}_i$ . The  $\text{AE}_i$  measures the effect of frictions that affect resource allocation between sector  $i$  and all the rest (recall (8) and (10)), and is basically the same as the AE when there are these two sectors.<sup>2</sup> In addition, as I show in appendix C, the sum of  $\text{AE}_i$  calculated as above is approximately equal to actual AE.

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<sup>2</sup>Precisely speaking, the  $\text{AE}_i$  is exactly the same as the two-sector AE, if  $(\sum_{m \neq i} \tilde{\sigma}_m \alpha_m)/(1 - \tilde{\sigma}_i)$  is the same across states.

In the empirical section,  $\tilde{\lambda}_{K-i}$  ( $= \tilde{\lambda}_{K_m}$  for sector  $m \neq i$ ) used in  $AE_i$  is measured in the following way. By rearranging

$$K - K_i = \sum_{m \neq i} K_m = \sum_{m \neq i} \frac{\tilde{\sigma}_m \alpha_m}{\tilde{\alpha}} \tilde{\lambda}_{K-i} K \quad (14)$$

(note that  $K$  and  $K_i$  here are the same as the actual ones), we obtain

$$\tilde{\lambda}_{K-i} = \left( \sum_{m \neq i} \frac{\tilde{\sigma}_m \alpha_m}{\tilde{\alpha}} \right)^{-1} \frac{K - K_i}{K}. \quad (15)$$

In the same way,  $\tilde{\lambda}_{L-i}$  is measured by

$$\tilde{\lambda}_{L-i} = \left( \sum_{m \neq i} \frac{\tilde{\sigma}_m (1 - \alpha_m)}{1 - \tilde{\alpha}} \right)^{-1} \frac{L - L_i}{L}. \quad (16)$$

### 3.3 Contribution of sectoral frictions and sectoral sizes to AE

AE depends on not only differences in sectoral frictions  $\lambda_{J_i}$ s across states but also differences in sectoral sizes  $\tilde{\sigma}_i$ s, because  $\tilde{\lambda}_{J_i}$  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 agriculture sector  $A$  and manufacturing sector  $M$  and  $\alpha_i = 0$  for these sectors. Further suppose that  $\lambda_{L_i}$  is the same between state  $S$  and state  $T$ , but  $\tilde{\sigma}_i$  is different between the states. Then, AE is calculated as

$$\begin{aligned} AE &= \bar{\sigma}_A \ln \left( \frac{\tilde{\lambda}_{LA}^S}{\tilde{\lambda}_{LA}^T} \right) + \bar{\sigma}_M \ln \left( \frac{\tilde{\lambda}_{LM}^S}{\tilde{\lambda}_{LM}^T} \right) \\ &= \ln (\tilde{\sigma}_A^T \lambda_{LA} + \tilde{\sigma}_M^T \lambda_{LM}) - \ln (\tilde{\sigma}_A^S \lambda_{LA} + \tilde{\sigma}_M^S \lambda_{LM}). \end{aligned}$$

Now further assume that  $\tilde{\sigma}_A^S > \tilde{\sigma}_A^T$  and  $\lambda_{LA} > \lambda_{LM}$ . The former assumption is reasonable when  $T$  is a more mature economy than  $S$ . The latter is also reasonable because in data,  $\lambda_{LA}$  is higher

than the average of all sectors.<sup>3</sup> AE, then becomes negative, irrespective of the same frictions  $\lambda_{Ki}$ s.

In order to identify how much is due to each factor, I calculate a fictitious  $AE_i$  using  $\tilde{\lambda}_{Ji}(\{\tilde{\sigma}_j^S, \lambda_{Jj}^T\})$ s instead of  $\tilde{\lambda}_{Ji}^S$ s, where  $\tilde{\lambda}_{Ji}(\{\tilde{\sigma}_j^S, \lambda_{Jj}^T\})$  is measured from sectoral shares of state  $S$ ,  $\{\tilde{\sigma}_j^S\}$  and taxes of state  $T$ ,  $\{\lambda_{Jj}^T\}$ . 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  $\tilde{\lambda}_{Ji}^S$ 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,  $\tilde{\lambda}_{Ki}(\{\tilde{\sigma}_j^S, \lambda_{Kj}^T\})$  is measured from

$$\tilde{\lambda}_{Ki}(\{\tilde{\sigma}_j^S, \lambda_{Kj}^T\}) = \frac{\tilde{\lambda}_{Ki}^T}{\sum_j \left( \frac{\tilde{\sigma}_j^S \alpha_j}{\tilde{\alpha}^S} \right) \tilde{\lambda}_{Kj}^T}, \quad (17)$$

because the denominator of  $\tilde{\lambda}_{Kj}^T$  (i.e.,  $\sum_m (\tilde{\sigma}_m^T \alpha_m / \tilde{\alpha}^T) \lambda_{Km}^T$ ) is canceled out and  $\lambda_{Kj}^T$ s are shown up in the RHS of the numerator and denominator of (17). In the same way,  $\tilde{\lambda}_{Li}(\{\tilde{\sigma}_j^S, \lambda_{Lj}^T\})$  is measured from

$$\tilde{\lambda}_{Li}(\{\tilde{\sigma}_j^S, \lambda_{Lj}^T\}) = \frac{\tilde{\lambda}_{Li}^T}{\sum_j \left( \frac{\tilde{\sigma}_j^S (1 - \alpha_j)}{1 - \tilde{\alpha}^S} \right) \tilde{\lambda}_{Lj}^T}. \quad (18)$$

## 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 frictions 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 the US and France, Italy, and Japan. 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  $\alpha_i$  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.

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<sup>3</sup>We can confirm it in Table 1.

## 4.1 Measurement procedure

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

$\tilde{\lambda}_{Jis}$  are measured from (12) because  $K_i$ ,  $K$ ,  $L_i$ , and  $L$  are measured from sectoral and aggregate data, and  $\tilde{\sigma}_i$  and  $\alpha_i$  are measured as discussed below. Measuring  $\tilde{\lambda}_{Jis}$  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 (15), (16), (17), and (18).

I use  $\alpha_i$  that is measured from the US data, under the assumption that good market imperfections are weak in the US, and that the  $\alpha_i$  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  $\alpha_i$  is measured from each country's data.

The reason I do not use  $\alpha_i s$  in each country is because the measured  $\alpha_i s$  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  $\alpha_i$  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,  $\alpha_i$  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,  $\alpha_i$  measured from factor input costs can have biases (for details see Appendix A.3).

The  $\tilde{\sigma}_i s$  can be measured from the sector's nominal share, under the following standard assumptions: firms which 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.<sup>4</sup> The sectors considered in this study include (1) "Agriculture, Hunting, Forestry and Fishing" (hereafter, agriculture), (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),

<sup>4</sup>For the details of the data, see also appendix B.

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  $\alpha_{iS}$ ; and sectoral shares  $\tilde{\sigma}_{iS}$ , 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.<sup>5</sup> The  $\alpha_{iS}$ s are measured as  $1 - (\text{labor income}/\text{factor costs})$  of the US using the STAN database (they are the averages of 1987, 1990, and 1993).<sup>6</sup> The  $\tilde{\sigma}_{iS}$ s are measured from the nominal value added share of each country and each period in STAN database.

In order to measure ATFP, additional data on  $L$  and  $V_i$ s are needed. Data on  $L$  is needed because “full-time equivalent jobs” which is used in France, Italy, and the US, and “hours worked” times “total employment” which is used in Japan are not comparable. For this purpose, I use “hours worked” times “total employment” for each country, where for “hours worked” I use the “average hours worked per person” provided by the OECD (this data is provided in the aggregate level but not on the sectoral level). For  $V_i$ , I use the sectoral value added, which is converted to the 1990 US dollar.

For reference, I report the measured  $\tilde{\lambda}_{K_i}$  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  $\tilde{\lambda}_{K_i}$  or  $\tilde{\lambda}_L$  becomes.

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<sup>5</sup>For the agriculture sector of Japan, I use adjusted total employment instead of “total employment.” The adjusted total employment is calculated as “number of employees” +  $0.5 \times (\text{“number of total employment”} - \text{“number of employees”})$ . For the reason that I use this, see footnote 12. If we use “total employment” instead of the adjusted total employment for Japan’s agriculture sector, the magnitude and effect of frictions become even larger.

<sup>6</sup>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,

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

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

Using (13), I calculate cross-country allocational efficiency (AE) and aggregate TFP (ATFP) between the US and France, Italy, and Japan. Note that state  $S$  in (13) 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).<sup>7</sup> 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  $-5.4\%$  for France to  $-8.2\%$  for Italy. This means that the aggregate TFPs of France, Italy, and Japan become  $5.4\%$  to  $8.2\%$  lower than that of the US, because of sector-level frictions.

To analyze the result on cross-country AE, I decompose the average cross-country AE in two different ways in Table 3. Each decomposition 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 more strict in Italy than in France, Japan or the US, and EPL reduces labor market dynamics.<sup>8</sup> 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  $-10\%$  to  $-25\%$ . This means that the aggregate TFP of France, Italy, and

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<sup>7</sup>Since cross-country sectoral share (SS) are quantitatively small (in the data, the measured values are between 0 to  $0.2\%$ ), I do not report them.

<sup>8</sup>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.

Japan is 10% to 25% lower than that of the US.<sup>9</sup> Finally, average cross-country AE/ATFP in Table 2, which is calculated by dividing AE by ATFP, ranges from around 20% for Japan to 40% for France and Italy. The result indicates that the distribution of sector-level frictions explains 20%–40% of cross-country differences in aggregate TFP between the US and France, Italy, and Japan.

#### 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 (15) and (16). In the table,  $AE_i$  is divided into a capital component and a labor component.

We find from the Table that in each country, agriculture and financial sectors explain most of the cross-country AE. First, let us focus on the agriculture sector. To understand why the agriculture sector is the cause of cross-country AE, look at the agriculture sector's  $\tilde{\lambda}_{Ji}$  in Table 1. We find that most of  $\tilde{\lambda}_{Ji}$ s in the agriculture 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 agriculture sector receives subsidies, and receives more subsidies in France, Italy, and Japan than in the US. Several statistics in OECD (2004a) show that the agriculture sector receives more direct and indirect subsidies in the EU and Japan than in the US.<sup>10</sup> My result is consistent with OECD evidence.

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

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<sup>9</sup>While in the study conducted by Prescott (2002), the level of France's aggregate productivity is higher than that of the US, the result is the contrary in my study. This is due to the differences in data sources (possibly the differences in data coverage).

I verify it as follows. From his accounting procedure, we find that the cross-country differences in aggregate productivity,  $\Delta \ln A$ , is proportional to the differences in aggregate GDP per hours worked,  $\Delta \ln(V/H)$ , where  $V$  is aggregate value added, and  $H$  is aggregate hours worked (because as he argues, remaining capital factor is not an important factor). I verify that in our dataset, aggregate  $\ln(V/H)$  of France (adjusted by purchasing power parity) is smaller than that of the US. This result is consistent with the ATFP result.

On the other hand, for the case between Japan and the US,  $ATFP/(1 - 0.3)$  is around  $-37\%$  (where 0.3 is the average of  $\tilde{\alpha}$  between the two countries), whose magnitude is slightly larger than the result in Prescott (2002) (which is  $-33\%$ ).

<sup>10</sup>For example, the ratio between average price received by producers and world market price is 1.72 for the EU, 2.46 for Japan during 1986–88, which are higher than 1.19 for the US.



several evidences which 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 differ 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 C, the sum is approximately equal to the counterfactual AE). It varies from  $-0.3\%$  for Japan to  $-1.1\%$  for France. 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 only 5% for Japan and up to 20% for France, of cross-country AE derived in the previous sections. Even if 5% to 20% are subtracted from cross-country AE, cross-country AE still explains around 20% for Japan, 30% for France, and 35% for Italy's cross-country differences in aggregate TFP.

Second, let us examine each sector. For France and Italy, the magnitude of the counterfactual  $AE_i$  is relatively large for the labor component in the agriculture sector. They correspond to the one-fifth to one-third of the labor component of  $AE_i$  in the agriculture sector in Table 4. This suggests that some of the frictions in the agriculture sector might be spurious.

#### 4.6 Capital intensity $\alpha_i$

I measure  $\alpha_i$  from the US data, under the assumption that  $\alpha_i$  is the same across developed countries. For the robustness check, I also calculate cross-country AE for the case where  $\alpha_i$  is measured from each country's data.<sup>11</sup> I report the results in Table 6.<sup>12</sup> Compared with Table 2, the magnitude

<sup>11</sup> AE expressed in (13) is modified as follows:

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

<sup>12</sup> For France and Italy, I calculate  $\alpha_i$  in the same way as for the US.

of AE becomes slightly smaller in France, but larger in Italy and Japan. And even in France, the magnitude is still large (the AE in Table 6 divided by the ATFP in Table 2 is more than 30%).

## 5 Concluding Remarks

In this paper, I proposed a simple multi-sector accounting framework to analyze the distribution of sector-level frictions on resource allocation and aggregate productivity. Using this framework, I estimated the distribution of sector-level frictions from data and calculated the extent to which they account for the aggregate productivity differences among developed countries. I found that the distribution of sector-level frictions accounted for 20% to 40% of the productivity differences between the US and France, Italy, and Japan around 1990.

I also have several caveats in my analysis. The first involves the interpretation of cross-sectional differences in returns on factor inputs. In my analysis, 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. In addition, 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.

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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 agriculture sector. Second, for agriculture sector, instead of "number of total employment," I use adjusted total employment calculated as "number of employees" +  $0.5 \times$  ("number of total employment" – "number of employees") (because if  $\alpha_i$  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 agriculture sector).

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## A Examples of Sector-Level or Firm-Level Frictions

In Section 2, I assume that the frictions that firms face appear as taxes imposed on their factor inputs, that firms are price-takers, and that a firm’s problem is static. In the following examples, following Chari, Kehoe and McGrattan (2003), I demonstrate that the allocation of the following models with distortions on cross-sectional resource allocation can be achieved in Section 2 model by appropriately choosing  $\tilde{\lambda}_{J_i}$ s, parameters in Section 2 model, which capture the distribution of

frictions. Especially, in the last example, I show that the allocation of the dynamic model with borrowing constraint at a certain period can be achieved in the static Section 2 model. Argument in the following sections is that if environment except for distortions is the same, the same allocation can be achieved in Section 2 model by choosing appropriate  $\tilde{\lambda}_{JiS}$ .<sup>13</sup>

For the discussions in Section 4.1, I also explain that for the following models,  $\alpha_i$  measured from factor input cost can have biases.

### A.1 Barrier to labor mobility

Hayashi and Prescott (2006) argue that a barrier to labor mobility from the agriculture sector to the manufacturing sector was one of the causes of stagnation in prewar Japan. I demonstrate that the allocation of this model can be achieved in Section 2 model.

First, let us consider a labor immobility model. Suppose that there are two sectors (agriculture sector  $A$  and manufacturing sector  $M$ ). 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.,  $L_A \geq \bar{L}_A$ ). I also assume that other environment of the model is the same as Section 2. Then, the typical firm's problem is

$$\max_{K_i, L_i} p_i F_i(K_i, L_i) - p_K K_i - p_{L_i} L_i, \quad i \in \{A \text{ or } M\}. \quad (19)$$

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

$$p_{LA} \neq p_{LM}. \quad (20)$$

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

Next, let us consider the model in Section 2. By appropriately choosing  $\tilde{\lambda}_{JiS}$  using (8) and (10), we can achieve the same allocation on factor inputs between the two models. If the same allocation on factor inputs is achieved,  $V_i$  and  $V$  become the same between the two models. Thus, the allocation of the labor immobility model can be achieved in Section 2 model.

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<sup>13</sup>Note that there is also criticisms on the Chari, Kehoe, and McGrattan's approach. For this, see Christiano and Davis (2007).

## A.2 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 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:

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

where  $r$  is interest rate,  $B_i$  is the volume at which the firm borrows,  $\theta$  is a collateral constraint parameter and is between zero and one,  $q_K$  is the value of capital,  $V_i(K_i, B_i)$  is the next-period value function of owning  $K_i$  and  $B_i$ , and subscripts  $-1$  and  $+1$  indicate the previous and next periods. I assume that other structure of the model in each period is the same as Section 2. Further, I assume that new capital is made from aggregate good  $V$ .

Next, let us consider Section 2 model. Suppose that aggregate capital and labor supply in Section 2 model is the same as aggregate capital and labor supply of the current period in this section's model. Then, by appropriately choosing  $\tilde{\lambda}_{J_i}$ s using (8) and (10), we can achieve the same current period allocation on factor inputs between the two models. If the same current period allocation on factor inputs is achieved, current period  $V_i$  and  $V$  also become the same between the two models. In this way, the allocation of the borrowing constraint model at a certain period can be achieved in Section 2 model.

## A.3 Biases arising in the measurement of $\alpha_i$

Here, I argue that if there are imperfections in factor market as in Appendices A.1 and A.2,  $\alpha_i$  measured from factor input cost can have biases.

To examine this, take labor immobility model in Section A.1 as an example (I assume that the functional form of firm’s production function is the same as in Section 2). 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 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.<sup>14</sup> Similar problem arises to capital side in case of the borrowing constraint model in Section A.2.

## B Data

This appendix provides information on the data.

### B.1 Sources

The sector-level data, except for capital input, are taken from the OECD STAN database (OECD 2006b). Capital input is taken from the OECD ISDB (OECD 1999a). (OECD 2005 and OECD 1999b are these manuals.) The purchasing-power-parity (PPP) data and the “average hours worked per person” data, which are used for the calculation of ATFP, are also collected from the OECD. 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.

### B.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.<sup>15</sup> I also exclude the “Community, Social and Personal Services” sector because it mainly consists of non-market activities. The definition

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<sup>14</sup>In this case,  $1 - \alpha_i$  measured from revenue share does not have biases.

<sup>15</sup>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).

### B.3 Data variables

For aggregate and sectoral nominal value added, I use “value added at current prices” from the STAN database. For factor costs which is needed to calculate  $\alpha_i$  I use “value added at factor costs” in STAN database, which is basically after-tax value added.<sup>16</sup> 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.

### B.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 prices.

In order to convert the value added used for ATFP, I first calculate real value added whose base year is 1990 and then convert it using purchasing power parity (PPP) (PPP data is taken from OECD 2006a).

Although the original capital stock data taken from the ISDB is expressed in 1990 US prices, the PPP conversion rate is different from the PPP above (as in Table 7, the original PPP used for capital stock is 15–30% higher). If the original PPP is used, the capital stock of France, Italy, and Japan becomes much smaller. It overestimates the effect of the frictions on aggregate TFP (i.e., cross-country AE/ATFP) because the differences in aggregate TFP between these countries

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<sup>16</sup>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.



and the US become smaller (and because cross-country AE is indifferent to the value of PPP). In order to avoid this bias, I reconvert capital stock using the same PPP used for value added. Since ISDB uses old national currencies while STAN uses the euro for countries in the EU, I first convert old national currencies into the euro and subsequently convert them into the US dollar. I use the irrevocable conversion rates from Schreyer and Suyker (2002) for conversion of the old European national currencies. (the same rates are used in STAN database).

## C Relation between the Sum of $AE_i$ and AE

Here, 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:

$$\sum_i AE_{Ki} = AE_K + \sum_i (\bar{\alpha} - \bar{\sigma}_i \alpha_i) \ln \left( \frac{\tilde{\lambda}_{K-i}^S}{\tilde{\lambda}_{K-i}^T} \right),$$

where  $AE_K$  is the capital component of AE ( $AE_K \equiv \sum_i \bar{\sigma}_i \alpha_i \ln \left( \tilde{\lambda}_{Ki}^S / \tilde{\lambda}_{Ki}^T \right)$ ). 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

$$\sum_i (\bar{\alpha} - \bar{\sigma}_i \alpha_i) \ln \tilde{\lambda}_{K-i}^S \simeq 0, \quad (21)$$

when  $\tilde{\sigma}_i$  is small. From (14), we obtain the following relation:

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

By substituting it into the second term of (21), we obtain

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

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,

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

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	
	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$	$\tilde{\lambda}_{Ki}$	$\tilde{\lambda}_{Li}$
Agriculture	0.60	2.51	1.68	3.43	2.30	3.16	1.02	1.66
Manufacturing	0.99	0.93	0.89	0.97	1.05	0.95	0.87	0.98
Electricity	1.33	0.88	1.31	0.91	0.93	0.62	1.25	0.61
Construction	1.94	0.93	1.91	0.86	1.10	0.88	0.63	1.11
Wholesale	0.89	1.04	0.79	0.98	0.82	1.11	0.72	1.06
Transport	1.64	0.89	1.32	0.87	1.11	0.99	1.13	0.84
Financial	0.31	0.68	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. 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	-5.4%	-6.1%	-5.0%	-5.3%
Italy	-8.2%	-8.2%	-8.0%	-8.5%
Japan	-5.7%	-6.3%	-4.8%	-5.9%
Cross-country ATFP				
France	-13.5%	-15.1%	-10.5%	-14.8%
Italy	-21.8%	-21.2%	-20.0%	-24.0%
Japan	-26.0%	-31.4%	-21.0%	-25.5%
Cross-country AE/ATFP				
France	41.2%	40.4%	47.5%	35.5%
Italy	37.9%	38.4%	40.1%	35.2%
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. Column “Average” calculates the averages of the periods.

Average	Each country	US	Capital	Labor	Sum
France	-6.4%	1.0%	-2.3%	-3.1%	-5.4%
Italy	-9.4%	1.1%	-2.1%	-6.1%	-8.2%
Japan	-6.9%	1.2%	-3.1%	-2.6%	-5.7%

Table 3: Two decompositions of average cross-country AE compared with the US. 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
Agriculture	0.1%	-3.1%	-1.0%	-4.7%	-1.1%	-1.9%
Manufacturing	0.2%	0.0%	0.2%	0.0%	0.2%	0.1%
Electricity	0.0%	0.1%	0.3%	0.0%	0.1%	0.0%
Construction	-0.2%	0.0%	-0.2%	0.0%	0.1%	0.0%
Wholesale	0.0%	0.3%	0.0%	0.1%	-0.1%	0.4%
Transport	-0.7%	0.1%	-0.1%	0.0%	0.1%	0.0%
Financial	-1.8%	-0.7%	-1.5%	-2.0%	-2.5%	-1.2%
Sum	-2.5%	-3.3%	-2.3%	-6.6%	-3.2%	-2.6%
	(-5.8%)		(-8.9%)		(-5.8%)	

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

	France		Italy		Japan	
	capital	labor	capital	labor	capital	labor
Agriculture	0.0%	-1.1%	-0.1%	-0.9%	0.0%	-0.2%
Manufacturing	0.1%	0.0%	0.2%	0.1%	0.3%	0.1%
Electricity	0.1%	0.0%	0.3%	-0.2%	-0.1%	0.0%
Construction	0.1%	-0.3%	0.0%	-0.2%	0.2%	-0.7%
Wholesale	-0.4%	0.3%	-0.1%	0.2%	-0.2%	0.3%
Transport	0.0%	0.0%	0.0%	-0.1%	0.1%	-0.3%
Financial	0.3%	-0.2%	0.3%	-0.1%	0.5%	-0.3%
Sum	0.2%	-1.3%	0.6%	-1.2%	0.7%	-1.0%
	(-1.1%)		(-0.6%)		(-0.3%)	

Table 5: Cross-country counterfactual  $AE_i$  compared with the US. It is counterfactual in that  $\tilde{\lambda}_{ji}(\{\tilde{\sigma}_j^S, \lambda_{jj}^T\})$ s in (17) and (18) are used instead of  $\tilde{\lambda}_{ji}^S$ . The values reported here are the average of 1987, 1990, and 1993 data.

	Average
Cross-country AE	
France	-4.5%
Italy	-10.6%
Japan	-8.0%

Table 6: Cross-country AE compared with the US, when  $\alpha_i$  are measured from each country's data. The AEs reported here are calculated using the equation in footnote 11. The result is the averages of 1987, 1990, and 1993.

	France	Italy	Japan
Original PPP	1.158917	0.913096	218.7
The PPP that I use	0.9943	0.6888	189.2402
Difference	15%	28%	14%

Table 7: PPP for capital stock. National currencies per US dollar. (The euro is used for France, and Italy.)