Essays on Misallocation and Economic Development

by

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ABSTRACT

This dissertation consists two chapters related with misallocation and economic development.

The first chapter studies the organization of production, as summarized by the number of managers per plant, the number of workers per manager and the mean size of plants in terms of employment. First, I document that in the manufacturing sector, richer countries tend to have (i) more managers per plant, (ii) less workers per manager and (iii) larger plants on average. I then extend a knowledge-based hierarchies model of the organization of production where the communication technology depends on the managerial level in the hierarchy and the abilities of subordinates. I estimate model parameters so that the model jointly produces plant size distribution and number of managers per plant in the United States manufacturing sector. I find that when the largest, more complex, plants face distortions that are twice as large as distortions faced by smaller plants, output declines by 33.4% and the number of managers per plant falls by 30%. Moreover, I find that a 10% increase in communication cost parameters can account for a 35% decrease in the aggregate output without having a significant effect on the number of managers per plant.

The second chapter examines the relationship between bribery, plant size and economic development. Using the Enterprise Survey, I document that small plants spend higher fraction of their output on bribery than big plants do. Then I develop a one sector growth model in which size-dependent distortions, bribery opportunities and different plant sizes coexist. I find that size-dependent distortions become less distortionary in the presence of bribery opportunities and the effect of such distortions on the plant size become reversed since bigger plants are able to avoid from distortions by paying larger bribes. My results indicate that changes in the distortion level do not affect output and size significantly because managers are able to circumvent the distortions by adjusting their bribery expenditures. However, the removal of distortions can have a substantial effect on both the output and the mean size. Output in Turkey can increase by 12.3%, while the mean size can increase by almost double.

Desteklerini hiç esirgemeyen, her şeyi borclu olduğum canım anneme, babama ve kardeşime...

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TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Chapter 1

PRODUCTION COMPLEXITY, TALENT MISALLOCATION AND DEVELOPMENT

1.1 Introduction

A large body of extant literature concurs that productivity is the main driver of per capita income differences across countries. [1] This paper focuses on the determinants of organization of production at the plant level as one of the determinants of productivity differences across countries.

I document variation in the organization of production across countries by the number of managers per plant. I refer to variation in the number of managers per plant as variation in *production complexity.* I collect data on the number of managers, workers and plants in the manufacturing sector across a set of developed countries. I document three facts related to production complexity. First, richer countries tend to have more managers in a plant on average. Second, there are fewer workers per manager in richer countries. Finally, mean plant size, calculated as the average number of employed per plant, is larger in richer countries. To summarize, there are more people working in plants, and there are more managers in plants among the manufacturing sector in richer countries. However, managers in richer countries manage fewer people on average.

I extend the knowledge-based hierarchies model of Garicano and Rossi-Hansberg (2006) in order to quantitatively study the determinants of plant size and production complexity. In the model, a representative household sorts heterogeneous household

[1] See Klenow and Rodriguez-Clare (1997), Prescott (1998), Hall and Jones (1999), Caselli (2005) and Hsieh and Klenow (2010) for review, among others.

members into different occupations across different organizations. Each household member has one unit of time. Production takes place in organizations and requires solving tasks (problems) and labor. There is a continuum of tasks, which are ranked according to their level of difficulty. Harder problems require more knowledge compared to simpler ones. Household members with a higher level of knowledge (ability) can solve harder problems. There are different occupations in the organizations. While the production workers' responsibilities are solving tasks and production, managers do not involve in production. Instead, they instruct production workers if the production workers encounter a problem that they don't know how to solve. Since the production workers need to describe the problem to the managers and the managers need to convey the solution to them, communication between the managers and the production workers takes time. This communication cost limits the span-of-control of the managers since the household members have a limited amount of time.

An innovation in the model is that communication costs between managers and subordinates differ according to the manager's level in the hierarchy and the knowledge of subordinates. This allow us to connect successfully the model to data. The communication cost depends on the managerial layer because the technology that a top manager at a plant uses to communicate with her middle managers is different than the technology that the middle managers uses when communicating with production workers. For example, it is possible that communication among the top manager and the middle managers is done via e-mails or regular meetings, whereas the middle managers are directly engaging with production workers in the field. Additionally, communication technology available in a plant is dependent upon the complexity of organizations. More complex organizations adopt better communication technologies than simpler ones. For example, middle managers of complex multi-layer organizations use more modern techniques to communicate with production workers than managers of 2−layer plants that consist of one manager and (possibly) many production workers.

Subordinates first identify the problem they can not solve and describe the problem to the managers and they then learn how to solve it if managers know the answer. Subordinates with higher knowledge are better not only at describing such problems to managers but also at understanding the solution that managers convey to them. Therefore, managers spend less time in communication with more knowledgeable subordinates.

For quantitative purposes, I focus on a special case of the model where 1−layer, 2−layer and 3−layer plants coexist. The 3−layer plants consist of one top manager at the third layer, multiple middle managers at the second layer and production workers at the first layer. On the other hand, the 2−layer plants have one manager at the second layer and production workers at the first layer. Moreover, there are self-employed plants with only 1−layer which does not have any paid employees. Hence, the representative household sorts household members into these six different occupations according to their level of knowledge.

Household members with higher knowledge become managers of the plants, while the rest work as subordinates in the equilibrium. The most knowledgeable managers run 3−layer (complex) plants and the managers of the 2−layer plants have less knowledge than the top managers of the 3−layer plants. In addition, the self-employed household members have least knowledge among plant owners. The middle managers are subordinates and managers at the same time. While they are subordinates of the top managers, they are also managers of the production workers in the 3−layer plants.

There is a key complementarity between the abilities of the individuals in the model. Managers with high levels of knowledge are assigned to run larger plants in equilibrium. They can increase their production by hiring more subordinates. Since more knowledgeable subordinates can solve more problems and ask less questions, managers can increase the number of employees by hiring more knowledgeable subordinates. This complementarity between the knowledge of managers and subordinates results in a positive sorting of subordinates to managers. In other words, in equilibrium, the more knowledgeable managers work with more knowledgeable subordinates and vice versa.

The heterogeneous communication costs increase the complementarity between the knowledge of managers and that of subordinates. Since the more able managers work with more able subordinates, and communication with more able subordinates requires less time, the more able managers are able to run larger plants when communication costs are heterogeneous. For example, since the most able top managers work with the most able middle managers and the most able production workers of the 3−layer plants, time spent in communication between managers and subordinates is less than that of the other plants with less able managers. This enables the most able top managers to run even larger plants.

I discipline model parameters in order to jointly generate (i) the plant size distribution and (ii) the number of managers per plant in the U.S. To my knowledge, this paper is the first study which quantitatively carries Garicano and Rossi-Hansberg (2006) model to the data with multiple layers of management. The model successfully generates the number of managers per plant, the properties of plants size distribution and the fraction of self-employed (non-employer) plants in the data. My results show that 3−layer (complex) plants use better communication technologies both at the top management and the middle management levels, than 2−layer plants. However, the time spent in communication is highest for middle managers since their subordinates are the least able production workers in the economy.

I then conduct three sets of counter-factual analyses. First, I study the effects of size-dependent policies in the development literature. The second exercise is motivated by the extant literature that shows adoption of information and communication technologies (ICT) differs between the U.S. and European firms. Finally, I ask how big size-dependent distortions and communication costs should be to generate GDP per capita and mean size differences between the U.S., and France and Italy.

The size-dependent policies place more distortions on the bigger plants and favor the smaller plants. Accordingly, I introduce different distortion levels as output taxes to the different types of plants. In particular, I consider the set of distortions in which the simpler plants (self-employed and $2-$layer plants) are distorted less than the $3-$layer plants. I find sizable effects on output and the plant size, that are arguably more substantial than similar studies. The size-dependent distortions distort both the composition of plants and the allocation of talent in this paper. When the size-dependent distortions are presented in the model, fraction of simpler plants increases, and the employment and output are reallocated toward simpler plants away from big plants. In addition, the size-dependent distortions distort talent allocation not only between occupations but also within occupations. The most able middle managers start to run their self-employed plants and the most able production workers of the $3-$layer plants work for $2-$layer plants. Therefore, the highest able top managers work with lower able middle managers and production workers in a distorted economy. Moreover, less able managers in simpler organizations demand more abled subordinates, since the wage profile of all subordinates decreases. When the self-employed and the $2-$layer plants are distorted at a 10% in the form of output tax and the $3-$layer plants are subject to a 20% distortion, the number of managers per plant declines by 30%, and the aggregate output decreases by 33.4%. Moreover, as the size dependency of the distortions increases, the output and the number of managers per plant decrease even further. I find that the size-dependent distortions that tax production of 3−layer plants at 20% and 2−layers at 10% decrease the output by 68% and the number of manager per plant by 43%.

In the second quantitative exercise, I increase the communication cost parameters for all managers at the same percentage. This is mainly motivated by differences in the adoption rate of ICT across countries that can potentially affect communication costs. The increase the communication costs renders the organization of production in complex organizations more difficult. Therefore talent and output are reallocated from 3−layer organizations toward 2−layer and 1−layer organizations. The higher communication costs have a similar effect on the aggregate output and the number of managers per plant with the idiosyncratic distortions correlated with the size of the plants. While a 10% increase in the communication cost parameters for all types of plants decreases aggregate output by 35% without much larger effects on the number of managers per plant, a 20% increase has a much more bigger effect on both aggregate output and the number of managers per plant. In this case, output decreases by 65%, the latter decreases by nearly 28%.

Finally, I attempt to generate output per capita and plant size differences in France and Italy compared to the U.S. using the size-dependent policies and the higher communication costs. Both the higher cost of communication and the size-dependent distortion are able to generate a positive correlation between output per capita and mean size. My results show that combination of the size-dependent distortions and the higher communication costs can jointly go a long way toward accounting output per capita and size differences across countries. I then test the model implications of the relationship between the number of mangers per plant and GDP per capita. While the model is able to generate the sign of the correlation, the number of managers per plant that model predicts is higher than the number observed across countries in the data.

The rest of the paper is presented as follows. I discuss the related literature in the next section. In Section 1.3, I present the data sources and the motivating facts. In Section 1.4, I explain the model. In Section 1.5, I parametrize the model and describe the calibration strategy. Section 1.6 presents the quantitative experiments with higher communication costs and size-dependent distortions. In Section 1.7, I discuss the implications of the model in terms of observed relative income, mean size and managers per plant differences in the data. Section 1.8 concludes.

1.2 Background

This paper contributes to several strands of the literature. First, it contributes to the organization of knowledge (knowledge-based hierarchies) literature which is proposed and developed by Garicano (2000), Garicano and Rossi-Hansberg (2006) and Caliendo and Rossi-Hansberg (2012). My contribution to this literature is incorporating heterogeneous communication cost into the model. That is, the communication cost between the subordinates and the managers differs depending on the type of subordinates and level of managers in the hierarchy and the type of organization. [2]

Recent empirical studies that use micro level matched employer-employee data support the organization of knowledge model's predictions. Caliendo *et al.* (2015) uses matched French dataset and identifies different layers among employees. Their results shows that firms with high value added have higher probability to add a layer into their organizations and firms increase their span of control and pays less wages when they add a layer. In addition, Caliendo *et al.* (2017) uses Portuguese matched employer-employee data set that confirms the findings of Caliendo *et al.*

[2]See Antràs and Rossi-Hansberg (2009), Garicano and Rossi-Hansberg (2015) and Garicano and Van Zandt (2013) for the review of organization of knowledge and hierarchies in detail.

(2015) and shows that firms with higher number of layers have higher productivity as well. Moreover, Tåg *et al.* (2016) confirms previous empirical findings by using Swedish matched employer-employee dataset.

There are also empirical studies on the organizational differences across countries. Bloom *et al.* (2012b) studies the importance of delegation in the firm dynamics and organization. Bloom *et al.* (2014) distinguishes two types of informational and communication technologies and studies effect of them on the organizations across European and the U.S. firms. My contribution to the empirics of literature, however, does not come from using micro level matched employer-employee dataset. Instead, I construct a dataset set of managerial occupations across countries and show that richer countries have more managers in their plant on average. Hence, their production organizations are more complex compared to the poorer ones.

Recently, the knowledge-based hierarchies models call many quantitative macro research's attention. López and Torres-Coronado (2018) studies the effect of size-dependent distortions on the talent misallocation and Kapicka and Slavík (2018) shows the effect of the progressive taxation on inequality using $2-$layer version of the Garicano and Rossi-Hansberg (2006) model. Roys and Seshadri (2014) studies the importance of human capital accumulation on productivity using knowledge-based hierarchies model. Geerolf (2016) shows that knowledge-based hierarchies model can generate Pareto distribution of firm size. Gumpert (2018) studies wage differences between multinational and domestic firms, and Mariscal (2018) shows the effect of information technologies on the organization of the firms and the labor share in the U.S. using Caliendo and Rossi-Hansberg (2012) model. My contribution to the quantitative side of organization of knowledge models is to fit the $3-$layer version of the Garicano and Rossi-Hansberg (2006) model to the data and to measure the importance of the size-dependent distortions and the communication cost differences across countries in a general equilibrium setup.

This paper also contributes to the recent literature that studies the importance of management practices across countries. Bloom and Van Reenen (2007) conducts surveys across the world and shows that richer countries have better management practices on average. [3] Guner *et al.* (2018) documents that managers in richer countries have steeper life-time earnings profile and shows that the size-dependent distortions are important factor on generating the life-time earning profile differences across countries.

In addition, my paper is closely related to the delegation literature. Bloom *et al.* (2012b) documents that managers do not delegate in countries where trust is low among people. Akcigit *et al.* (2016) builds an endogenous growth model to measure the effects of lack of delegation on productivity. Grobvosek (2017) shows that weak law enforcement related with low productivity by developing a multi layer Lucas (1978) span-of-control model where the weak law enforcement lets middle managers to divert some of the revenues. I contribute to the delegation literature by considering the role of information and communication technologies and the size-dependent distortions on the managerial delegation and organization of production in a knowledge-based hierarchies model where the hierarchies emerge endogenously.

This paper also contributes to the growing misallocation literature in the economic development. Hsieh and Klenow (2009) and Restuccia and Rogerson (2008), focus on factor misallocation where factors of productions are not quantitatively allocated to the their best use. [4] In this line of literature, various papers studies why there are many small and unproductive production units in poorer countries. Guner

[3] See Bloom and Van Reenen (2010) for a survey of management practices across firms and countries

[4] See Hopenhayn (2014) and Restuccia and Rogerson (2017a) for reviews of misallocation literature.

et al. (2008) identifies the size-depended distortions as one of the source of small and unproductive plants in poorer countries. Garcia-Santana and Ramos (2015) show that countries with higher distortions have smaller production units. Poschke (2018) develops an occupational choice model with skill-based technology and analyzes technological changes that favors better managers as one of the reasons of small plant size in poorer countries. Bento and Restuccia (2017a) shows that the idiosyncratic distortions that are correlated with the productivity can account for the plant size distribution differences across countries. I contribute to this literature by showing that the effects of size-dependent distortions on the aggregate output and plant size distribution is amplified when the organization of the production is taken into consideration. Moreover, I propose the adoption of information and communication technology as one of the sources of the plant size distribution dispersion across countries and misallocation.

Finally, I contribute to the recent literature on talent misallocation by Hsieh *et al.* (2013), Celik (2018), Adamopoulos *et al.* (2017) and Ranasinghe (2017). Porzio (2017) studies cross-country differences in talent allocation to different production teams. I show that higher communication costs associated with lower usage of ICT and the size dependent distortions allocate talented agents to the smaller production units which reduces the aggregate output.

1.3 Data and Motivating Facts

In this section, first, I describe data sources that I use to construct my dataset. Then I discuss the empirical regularities that motivates the paper: the average plant size and the number of managers per plant increases with the GDP per capita whereas countries with relatively low GDP per capita have less workers per manager.

1.3.1 Data Sources

In this paper, I focus only on manufacturing sector. I use Eurostat and OECDStat for the 15 European countries and 6 other developed countries' statistical offices in order to collect the number of plants data between the period 1999 and 2011. [5] I define a plant as the smallest unit that operation (production) is engaged. Therefore the number of plants refers to the number of establishments in non-European countries and it refers to the number of enterprises in European countries.

I use World Input-Output Database (WIOD) Socio Economic Accounts (SEA) 2014 release for the number of employment and employee data for the period between 1995 and 2011 (See Timmer *et al.* (2015) for detailed information). Moreover, Timmer *et al.* (2018) reports the business function (management, production, R&D and marketing) employment shares for the same period. Therefore, I multiplied the employment shares of management and other workers in order to find the number of managers and non-managers (production, R&D and marketing workers) in the manufacturing sector. Finally, GDP per capita numbers in 2011 dollars come from Penn World Tables 9.0 by Feenstra *et al.* (2015).

1.3.2 Motivating Facts

The mean plant size is defined as the number of employment divided by the number of plants. Figure 1.1 shows that countries with higher GDP per capita tend to have bigger plants on average. The mean size is highest in the U.S. where there are 46.6 persons per plant on average between 1999 and 2011 whereas Greece has 6.3 persons per plant on average between 1997 and 2011. The trend line with slope 2.7 is obtained by regressing the logarithm of mean size on the logarithm of GDP per

[5] See Appendix A.1 for the complete list of countries and the data sources for the number of plants data.

capita weighted with the total employment. This positive relationship is significant at 1% level albeit the small sample size. In Appendix A.2, I showed that it is also robust with the mean size defined by number of employees and with the different time periods used. This positive relationship is also shown by Bento and Restuccia (2017a) and Poschke (2018). However, the income elasticity of the mean size that I find is higher than the previous studies since my sample consists only high income countries and I don't count plants with zero paid employee (non-employer plants) in non-European countries.

I define the managers per plant as the ratio of total number of managers to the total number of plants. Figure 1.2 displays the main motiving fact of this paper. The production complexity, managers per plant, increases with the GDP per capita. Correlation between managers per plant and GDP per capita is 0.89 and the elasticity of the managers per plant with respect to GDP per capita is statistically significant at 1% level and it is 4.8. The U.S has 5.3 managers per plant, the highest in the sample, on average between 1999 and 2011 but Korea and Greece have only 0.2 and 0.4 manager per plant, respectively. Significant positive relationship is robust to the choice of year and the data sources used (see Appendix A.2 for robustness.).

There are nine countries who have less than one manager per plant on average between 1999 and 2011. These countries, also, have less than one manager per plant according to the ILO database (See Figure A.2.1 and Appendix A.2 for detailed discussion of managers per plant using ILO database.). There are two possible reasons for these countries to have less than one manager per plant. First, not only small plants but also self-employment is more prevalent in these countries as Figure 1.3 shows. Since occupations' employment shares are obtained by survey method, these self-employed individuals may not consider themselves as managers. Second, if one manager or owner runs more than one plant prevalently in the economy, managers per plant on average may be less than one for those countries.

The elasticity of the managers per plant with respect to the GDP per capita is higher than the income elasticity of mean size. Hence, managers in countries with higher GDP per capita manages less workers per manager on average as Figure 1.4 shows.

To sum up, richer countries have bigger plants,there are more persons in plants on average, and they have more managers per plant than poorer countries. Managers in poorer countries manages more person compared to the managers in richer countries.

1.4 Model

The model is built on Garicano and Rossi-Hansberg (2006) knowledge-based hierarchies. The innovation in this paper is that communication costs differ across managerial layers and they depend on the knowledge of subordinates. In this section, I focus on a version of the model where maximum $3-$layer plants exist. A general version with $L-$layers is presented in the Appendix A.3.

1.4.1 Environment

There is a single household with measure one of household members. Each household member has *one* unit of time, supplied inelastically, and some knowledge (ability), z. The knowledge is distributed over a known distribution with cdf $G(z)$ and pdf $g(z)$ on $[\underline{z},\ \bar{z}]$. There is also continuum of tasks (problems), z', and their difficulty is distributed over a known distribution with cdf $F(z')$ and pdf $f(z')$ on the range $[\underline{z}',\ \bar{z}']$. The difficulty of a task, z', also denotes the knowledge required to solve this particular task. Tasks are ranked according to their difficulty so that a household member with knowledge z can solve all the problems until z, $[\underline{z}',\ z]$. In other words, a household member with knowledge z can solve $F(z)$ fraction of problems. Moreover, easier tasks are more frequent than the harder ones, $f' < 0$.

Production involves solving tasks and it requires time. A household member with knowledge z can produce $AF(z)$ with her 1 unit of time where A is the technology parameter common to all household members and $F(z)$ is the fraction of tasks she can solve. Production takes place in organizations and complexity of an organization is determined by how many layers organization has. The simplest type of organizations is 1-layer plants where a household member with knowledge z produces $AF(z)$ output alone. I denote 1-layer plants as self-employed. More complex organizations have many layers. $3-$layer plants have one top manager on the layer 3, middle managers on the layer 2 and production workers on the layer 1 whereas $2-$layer plants have one manager on the layer 2 and production workers on the layer 1.

Production workers draw problems from the distribution of tasks and solve them (produce) whereas managers do not involve into production, instead they teach production workers how to solve difficult problems. Production workers in multi-layer organizations draw problems from the distribution F. If they know the answer, they produce. However, If the problem that they draw requires more knowledge than their knowledge, the production workers ask it to the manager(s) one layer above of them. If managers know the answer, they teach it to the workers and workers produce. Since the production workers need to describe the problem to the managers and the managers need teach them (if they know the answer), communication between managers and production workers takes time of managers. If the managers do not know the answer as well, they ask it to the manager(s) one layer above them. Again managers who are asked incur a communication cost. This process continues until the unsolved questions are asked to the top manager. Thus, the output of an organization is determined by the number of production workers and the knowledge of top manager.

The communication cost depends on the knowledge of subordinates and the level of managerial layer. Since the subordinates with more knowledge is better at explaining the questions that they cannot solve as well as understanding the solutions, communication takes less time to the managers compared to the communication with less knowledge subordinates. Moreover, the communication technology that different managerial layers adopted is different from each other. For example, cost of communication for the same task will be different when middle managers are communicating with production workers than when top managers are communicating with middle managers.

This economy consists three type of plants: $3-$layer, $2-$layer and $1-$layer plants. In addition, there are six different occupations: top managers of the $3-$layer plants, managers of the $2-$layer plants, managers of the $1-$layer plants (self-employed), middle managers of the $3-$layer plants, workers of the $2-$layer plants and workers of the $3-$layer plants.

Self-employed managers (managers of $1-$layer plants) do not have any paid workers. Hence their production is determined by what fraction of problems they can solve and the common technology parameter A. For example, a self-employed household member with knowledge $\tilde{z}_{SE}$ solves $F(\tilde{z}_{SE})$ fraction of the problems so her total production (income) is $R_{SE}(\tilde{z}_{SE}) = AF(\tilde{z}_{SE})$.

A manager of a $2-$layer plant with ability $\tilde{z}_2$ chooses how many ($\tilde{n}_p$) and what type $\tilde{z}_p$ of production workers to hire in order to maximize her profit, $R_2(\tilde{z})$. Production workers can solve $F(\tilde{z}_p)$ fraction of the problems that they draw from the distribution F. Since there are $\tilde{n}_p$ number of production workers, $[1 - F(\tilde{z}_p)]\,\tilde{n}_p$ problems will be asked to the manager. However, the manager can solve only $F(\tilde{z})$ fraction of n_p problems and manager teaches production workers how to solve those questions. Figure 1.5 depicts how production is organized in $2-$layer plants. Thus total production in this 2−layer plant is $AF(\tilde{z})n_p$ and the managers income is total production minus total cost which is wages paid to the workers:

$$R_2(\tilde{z}_2) = \max_{\{\tilde{n}_p, \tilde{z}_p\}} AF(\tilde{z}_2)\tilde{n}_p - w_1(\tilde{z}_p)\tilde{n}_p \tag{1.1}$$

s.t

$$h_2(\tilde{z}_p)\left[1 - F(\tilde{z}_p)\right]\tilde{n}_p = 1$$

where $w_1(.)$ is the wage function that managers of 2−layer plants pay to the production workers at 2−layer plants and $h_2(z_p)$ is the communication cost that the manager incurs when answering $[1 - F(z)]\, n_p$ questions. Thus the left hand side of the time constraint of 2−layer managers is the total time spend on answering production workers questions by the manager and the right hand side is the total available time of the managers which is one since there is only one manager in 2−layer plants. The number of production workers demanded can be written as a function of the knowledge of production workers and the communication cost as following:

$$\tilde{n}_p = \frac{1}{h_2(\tilde{z}_p)\left[1 - F(\tilde{z}_p)\right]} \tag{1.2}$$

The knowledge of the production workers, $\tilde{z}_p$, determines the labor demand, $\tilde{n}_p$, through two channels as can be seen in equation (1.2). First, if the production workers have more knowledge, they solve more of the problems by themselves and so they ask less questions to the manager. Since less questions are asked to the manager, the manager can manage more production workers. Second, the production workers are not only better at explaining the problems that they can not solve to the manager, they are better at also understanding the solution if the manager knows the answer compared to the production workers with less knowledge. Therefore, communication is less costly to the manager if production workers have more knowledge so that managers can manage more production workers with more knowledge.

In 3−layer plants, the top managers are at the layer 3, middle managers are at the layer 2 and the production workers are at layer 1. The problem of a top manager of a 3−layer plant with ability $\tilde{z}_3$ is maximizing her profit, $R_T(\tilde{z}_3)$, by choosing the number of middle managers and production workers (n_m and n_p respectively) and their types (z_m and z_p respectively). Figure 1.6 shows how production is organized in the 3−layer plants. Each production worker draws problems from the distribution F and solve $F(z_p)$ fraction of them. Since they cannot solve $[1 - F(z_p)]$ fraction of the problems, they are going to ask them to the middle managers. The middle managers can solve only $F(z_m)$ fraction of the problems so they teach the production workers how to solve $F(z_m) - F(z_p)$ fraction of the problems. The middle managers ask the problems that they can not solve to the top manager. The top manager is asked $[1 - F(z_m)]$ fraction of n_p problems because the middle managers cannot solve $[1 - F(z_m)]$ fraction of the problems drawn. Once the top manager teaches to the middle managers and the middle managers teaches to the production workers how to solve remaining $F(\tilde{z}_3) - F(z_m)$ fraction of the problems, the total production happens in this plant. Therefore, the profit of the top manager is the total production, $AF(\tilde{z}_3)n_p$, minus the total cost which is wages paid to the production workers and the middle managers:

$$R_T(\tilde{z}_3) = \max_{\{n_m, n_p, z_m, z_p\}} AF(\tilde{z}_3)n_p - n_p w_2(z_p) - n_m w_3(z_m) \tag{1.3}$$

$$\text{s.t}$$

$$h_m(z_p)\,[1 - F(z_p)]\,n_p = n_m$$

$$h_T(z_m)\,[1 - F(z_m)]\,n_p = 1$$

$w_2()$ and $w_3()$ are the wage functions that the top manager pays to the production workers and middle managers at the 3−layer plants respectively. $h_m(z_p)$ and $h_T(z_m)$ are the communication costs middle managers and the top managers incur when answering their subordinates' questions respectively. First constraint is the time constraints of the middle managers. The right hand side shows the total available time at the layer 2: there are n_m middle managers and each of them has 1 unit of time. The left hand side of the time constraint of middle managers shows total time spend on answering production workers questions. Second constraint is the time constraint of the top manager: the top manager has one unit of time that is the right-hand side and the left-hand side shows the total time spent to answer the middle managers questions.

The number of production workers demanded, n_p, can be written as a function of the knowledge of middle managers, z_m using the time constraint of the top manager in problem (1.3):

$$n_p = \frac{1}{h_T(z_m)\,[1 - F(z_m)]} \tag{1.4}$$

Equation (1.4) states that the top managers whose middle managers have more knowledge demand also more production workers. In other words, the 3−layer plants with more knowledgeable middle managers have more production workers because the more knowledgeable middle managers can answers more of the questions that production workers ask.

The demand for middle managers in 3−layer plants is determined by not only the knowledge of production workers but also the knowledge of the middle managers themselves. The number of middle managers demanded, n_m, can be found by dividing the time constraint of the middle managers to the time constraint of the top manager in problem (1.3):

$$n_m = \frac{h_m(z_p)\,[1 - F(z_p)]}{h_T(z_m)\,[1 - F(z_m)]} \tag{1.5}$$

The numerator of the equation (1.5) shows that the production workers with more knowledge ask less questions and it is easier to communicate with them compared to the production workers with relatively less knowledge. Therefore, the top manager, the plant owner, demands less middle managers if they have more knowledge production workers. On the other hand, the denumerator of the equation (1.5) shows that the top managers' demand for the number of middle managers increases with the knowledge of middle managers. That is to say, the top manager can manage more middle managers if the middle managers know more since they will ask less questions and communication with them takes less time compared to the communication with relatively less knowledge managers.

1.4.2 Equilibrium

In this section, I first describe the equilibrium allocation of household members into the six different occupations. Then I discuss the equilibrium matching of subordinates to the managers. Finally, I will provide a formal definition of the equilibrium in $3-$model.

Equilibrium allocation of household member into occupations is shown in Figure 1.7. There are five different thresholds, z_i's, that describes the set of knowledge for six different occupations. Lowest able household members ($[\underline{z}, z_1]$) work for $3-$layer plants as production workers and next group of household members ($[z_1, z_2]$) work for $2-$layer plants as production workers. The middle managers ($[z_2, z_3]$) have more knowledge than production workers but less knowledge than the plant owners: self-employed agents, managers of 2 and $3-$layers plants. Therefore, self-employed household members ($[z_3, z_4]$) are the lowest able agents among plant owners whereas they have higher knowledge than the paid employees (the production workers and the middle managers). Top managers (managers of the 3−layer plants, $[z_5, \bar{z}]$) are the household members with highest knowledge and the managers of the 2−layer plants ($[z_4, z_5]$) have less knowledge than the top managers and more knowledge than the self-employed agents. [6]

The managers with higher level of knowledge demand more labor compared to the managers with lower knowledge but they have limited amount of time. They can increase their span of control by hiring more skilled subordinates since more skilled subordinates are able to solve more questions and thus they ask less questions to the managers. This complementary between ability of managers and subordinates generates positive sorting of subordinates to the managers: high knowledge subordinates work with high knowledge managers and low skilled subordinates work for low knowledge managers.

Figure 1.8 describes hypothetical equilibrium assignments of subordinates to the managers: the lowest able managers work with the lowest able subordinates and the highest able managers work with the highest able managers. Let $m_i()$ denote the mathing function that assigns subordinates to the managers. $m_1()$ matches workers in 3−layer plants to the middle managers such that the lowest able workers among the workers in 3−layer plants work for the lowest able middle managers and the highest able workers among the workers in 3−layer plants work for the highest able middle managers. The assignment of workers in 2−layer plants to the managers of the 2−layer plants is described by the m_2 matching function. The lowest able workers among the workers in 2−layer plants match with the lowest able managers of 2−layer plants and the highest able workers in 2−layer plants work for the highest able managers of the 2−plants. Finally, $m_3()$ matches the middle managers to the

[6] See Garicano and Rossi-Hansberg (2006) for the proof of hierarchical and pyramidal assignment.

top managers. Again, the lowest able middle managers works for the lowest able top managers and the highest able middle managers works for the highest able household members who are the highest able top managers.

Although the Figure 1.8 depicts one-to-one matching of the knowledge of subordinates to the knowledge of managers, a mass of production workers in 3−layer plants are matched with a mass of middle managers. In addition a mass of production workers in 2−layer plants and mass of middle managers are matched with a manager of 2−layer and a top manager of 3−layer plants respectively in equilibrium. In other words, each type of managers work with single type but many of subordinates. For example, a manager of a 2−layer plants chooses single type of production workers, z_p, but she chooses n_p number of them. Moreover, the middle managers are both subordinates and managers: they are managers of the workers in 3−layer plants and they are subordinates of the top managers at the same time. Since self-employed household members do not have any paid employee, they are not matched with any subordinates.

Equilibrium allocation of household members to occupations and matching matching functions must satisfy the labor market clearing conditions. Let $n(z)$ be the number of subordinates demanded by the manager with ability z. Then labor market clearing condition for the workers in 3−layer plants is for every $z \in [\underline{z}, z_1]$

$$\int_{\underline{z}}^{z} g(z')dz' = \int_{z_2}^{m_1(z)} \frac{n(z')}{n(m_3(z'))} g(z')dz' \tag{1.6}$$

left-hand side is the supply of production workers at 3−layer plants for every z and the right-hand side is the production workers demanded by the top manager: top manager demands $n(m_3())$ of middle managers and middle managers manages $n()$ number of production workers.

The labor market clearing condition of production workers in 2−layer plants is for every $z \in [z_1, z_2]$:

$$\int_{z_1}^{z} g(z')dz' = \int_{z_4}^{m_2(z)} n(z')g(z')dz' \tag{1.7}$$

This condition shows that supply of production workers in 2−layer plants is equal to demand for them by corresponding managers for each type of workers in 2−layer plants.

The supply of middle managers for each type has to be equal to demand of the corresponding top managers. Therefore, the labor market clearing condition for the middle managers is for every $z \in [z_2, z_3]$

$$\int_{z_2}^{z} g(z')dz' = \int_{z_5}^{m_3(z)} n(z')g(z')dz' \tag{1.8}$$

where the left-hand side of the labor market clearing condition for the middle managers is the supply of middle managers for each type of middle managers and the right-hand side of the labor market clearing condition is the demand for each type of middle managers by the corresponding top managers.

The equilibrium consist of thresholds, $\{z_1, z_2, z_3, z_4, z_5\}$, matching functions, $\{m_1, m_2, m_3\}$, and wage functions $\{w_1, w_2, w_3\}$ such that

- The household allocates household members to the six different occupations in order to maximize her total income, Y_H:

$$Y_H = w_1(z) + w_2(z) + w_3(z) + R_{SE}(z) + R_2(z) + R_T(z) \tag{1.9}$$

- Wage functions, w_i's, satisfy the indifference conditions:

$$w_1(z_1) = w_2(z_1), \quad w_1(z_2) = w_3(z_2), \quad w_3(z_3) = R_{SE}(z_3),$$
$$R_{SE}(z_4) = R_2(z_4), \quad R_2(z_5) = R_T(z_5) \tag{1.10}$$

- Matching functions, m_i's, satisfy the labor market clearing conditions 1.6, 1.7 and 1.8 such that the highest knowledge subordinates are matched with the highest knowledge managers and the lowest knowledge subordinates are matched with lowest knowledge managers.

First indifference condition states that the household members with knowledge z_1 are indifferent between being workers in a $3-$layer plant or in a $2-$layer plant. Household members with knowledge z_2 are indifferent between being workers in a $2-$layer plant and being middle managers in a $3-$layer plant which is described by the second indifference condition. The third indifference condition says that household members with knowledge z_3 are indifferent between being middle managers and being a self-employed and producing alone. Forth indifference condition states that marginal household members with knowledge z_4 are indifferent between being self-employed and running $2-$layer plants. Finally, the last indifference condition shows that household members with knowledge z_5 is indifferent between running $2-$layer plants and being top managers by hiring middle managers. [7]

1.4.3 Characterization of the Equilibrium

In this section, I, first, explain how to solve the wage profile of production workers in $2-$layer organizations and their assignment to the managers of the $2-$layer plants. Then, I provide the characterization of the wage function of the production workers and the middle managers in the $3-$layer plants as well as their assignments to their managers. In other words, I will show how the production workers are matched with the middle managers and how the middle managers are matched with the top manager in the $3-$ layer organizations.

The problem of a $2-$layer plant's manager with knowledge $\tilde{z}_2$ can be written by

[7] See Appendix A.5 for the solution algorithm for finding an equilibrium with $3-$layers.

substituting the number of production workers demanded, equation (1.2), into the problem (1.1):

$$R_2(\tilde{z}_2) = \max_{\{\tilde{z}_p\}} \left[AF(\tilde{z}_2) - w_1(\tilde{z}_p)\right] \frac{1}{h_2(\tilde{z}_p)\left[1 - F(\tilde{z}_p)\right]} \tag{1.11}$$

The managers' problem is now reduced to choosing only the knowledge of workers. The first order condition with respect to $\tilde{z}_p$ characterizes the wage function of the production workers in 2−layers plants as following:

$$w_1'(\tilde{z}_p) = \left[AF(\tilde{z}_2) - w_1(\tilde{z}_p)\right] \frac{h_2(\tilde{z}_p)f(\tilde{z}_p) - h_2'(\tilde{z}_p)\left[1 - F(\tilde{z}_p)\right]}{h_2(\tilde{z}_p)\left[1 - F(\tilde{z}_p)\right]} \tag{1.12}$$

Assignment of production workers to the 2−layer managers is characterized by using the market clearing condition of production workers in 2−layer plants. Using the Leibniz rule and the equation (1.2), the derivative of equation (1.7) with respect to z characterizes matching function, m_2:

$$m_2'(z) = h_2(z)\left[1 - F(z)\right] \frac{g(z)}{g(m_2(z))} \tag{1.13}$$

where z is an element of the ability set that defines production workers in 2−layer plants, $[z_1, z_2]$.

The problem of a top manager of 3−layer plant with knowledge $\tilde{z}_3$ can be written as the top manager chooses only the knowledge of the production workers and the knowledge of middle managers by substituting equations (1.4) and (1.5) into the problem (1.3):

$$R_T(\tilde{z}_3) = \max_{\{z_m, z_p\}} \left[AF(\tilde{z}_3) - w_2(z_p) - w_3(z_m)h_m(z_p)\left[1 - F(z_p)\right]\right] \frac{1}{h_T(z_m)\left[1 - F(z_m)\right]} \tag{1.14}$$

The first order conditions with respect to z_p and z_m provides a system of differential equations for the wage functions as follows:

$$\begin{aligned} w_2'(z_p) =& w_3(z_m)\left(h_m(z_p)f(z_p) - h_m'(z_p)\left[1-F(z_p)\right]\right) \\ w_3'(z_m) =& \left[\frac{AF(\tilde{z}_3) - w_2(z_p)}{h_m(z_p)\left[1-F(z_p)\right]} - w_3(z_m)\right]\frac{h_T(z_m)f(z_m) - h_T'(z_m)\left[1-F(z_m)\right]}{h_T(z)\left[1-F(z_m)\right]} \end{aligned} \tag{1.15}$$

Assignment of the production workers to the middle managers in 3−layer plants satisfies the market clearing condition for the production workers in 3−layer plants. Hence, the derivative of the equation (1.6) with respect to z can be derived by using the Leibniz rule and the equations (1.4) as follows:

$$m_1'(z) = h_m(z_p)\left[1-F(z)\right]\frac{g(z)}{g(m_1(z))} \tag{1.16}$$

where z is an element of the set that contains production workers in 3−layer plants, S_{3W}.

Moreover, the middle managers are matched with the top managers of 3−plant. The derivative of the market clearing condition for the middle managers, equation (1.8), with respect to z defines the differential equation of the matching function, $m_3()$, that assigns the middle managers to the top manager:

$$m_3'(z) = \frac{h_T(z)\left[1-F(z)\right]}{h_m(m_1^{-1}(z))\left[1-F(m_1^{-1}(z))\right]}\frac{g(z)}{g(m_3(z))} \tag{1.17}$$

where z is an element of the set that contains the middle managers in the 3−layer plants, $[z_2, z_3]$, m_1^{-1} is the inverse of matching function that maps the production workers to the middle managers such that $m_1^{-1}(z)$ in equation (1.17) defines the ability of production workers that are matched to the middle managers with ability z.

An equilibrium is characterized by the 5 threshold ability levels , 3 matching function and the 3 wage functions that satisfies the equilibrium definitions. The threshold ability levels defines the sets of 6 different occupations: the set of production workers in 3−layer plants, $[\underline{z}, z_1]$, the set of production workers in 2−layer plants, $[z_1, z_2]$, the set of middle managers, $[z_2, z_3]$, the set of self-employed, $[z_3, z_4]$, the set of managers of 2−layer plants, $[z_4, z_5]$ and finally the set of top managers of 3−layer plants, $[z_5, \bar{z}]$.

1.4.4 Discussion

Since time of the managers is limited and running a multi-layer plant requires time to communicate with the subordinates, the span-of-control of the managers is limited by the ability of their subordinates. If the plant owners want to increase their span-of-control, they need to hire subordinates with more knowledge. This complementary between managers and subordinates' skills results in the positive sorting. In other words, the higher able managers works with the higher able subordinates and lower able managers work with the lower able subordinates.

The contribution of this paper to the models of knowledge-hierarchies comes from the heterogeneity of the communication cost between managers and the subordinates. I let communication cost depend on both the knowledge of subordinates and the management layer. Managers faces different communication cost when they tell answers of the problems to the subordinates with different knowledge level. The subordinates with higher knowledge are also better at understanding the solution compared to the subordinates with lower knowledge. Hence, communication cost incurred by the manager who tells the answer to the subordinates decreases with the knowledge level of the subordinates.

Moreover, different management levels use different type of communication. For example, managers of the 2−layer organizations uses different type of methods and technologies to communicate with the production workers than the managers of any 3−layer plant use to communicate with the subordinates. In addition, the managers at different layers have different type of communication methods in the multi-layer organizations. The communication between the top manager and the middle managers is different than the communication between the middle managers and the production workers.

The heterogeneous communication cost enables the managers to increase their span-of-control and production. The top managers with relatively higher level of knowledge runs the more complex plants and have have relatively better middle managers and production workers because of the complementarity between the managers' knowledge and the subordinates' knowledge. Since it is easier to communicate with the higher able middle managers and the production workers, the top managers can increase their span-of-control even more compared to the case where all plants have same communication cost.

1.5 Parameter Values

The common technology parameter for all plants, A, is set to 1 for normalization. I assume truncated-Pareto distribution for both the distribution of tasks, $F(.)$, and the distribution of knowledge, $G(.)$. [8] Both distributions are defined over the same range $[1, \bar{z}]$, where the lowest value is assumed to be 1 for simplicity. However, I allow the distribution of the tasks and the knowledge to take different shape parameters, $\eta_i \quad i \in \{F, G\}$. More specifically, I use the following truncated-Pareto distribution

[8] In Appendix A.4 I show the calibration results where the distribution of knowledge and the tasks follow uniform-uniform and gamma-exponential pairs for the purposes of robustness. Calibration of the model with many other pairs is available upon request.

function:

$$G(z) = \frac{1 - z^{-\eta_G}}{1 - \bar{z}^{-\eta_G}} \qquad \text{and} \qquad F(z) = \frac{1 - z^{-\eta_F}}{1 - \bar{z}^{-\eta_F}} \tag{1.18}$$

The communication cost of managers is a decreasing function of subordinates' knowledge, and it differs with each managerial layer and type of organization. Accordingly, I assume that the communication cost functions take the following functional forms:

$$h_i(z) = \frac{\phi_i}{1 + z}, \quad i \in \{2, m, T\} \tag{1.19}$$

These functional form and distribution assumptions give six parameters, $\{\eta_F, \eta_G, \bar{z}, \phi_2, \phi_m, \phi_T\}$. I calibrate these six parameters to generate the mean size and the managers per plant as well as the plant size distribution of the U.S. manufacturing sector in 2016.

Six moment conditions are the mean size, the managers per plant, the fraction of plants with 1-19 employees, the fraction of plants with 20-99 employees, the employment share of plants with 100+ employees and the fraction of the self-employed plants.

I use the County Business Patterns (CBP) data in order to calculate data counterparts of the model for the number of employees and the number of plants. The number of establishments does not include non-employer establishments which are establishments with zero paid employees. Moreover, the CBP provides the number of employees instead of employment unlike Timmer *et al.* (2015). Therefore, I first calculate the mean size of the establishments in the manufacturing sector by dividing the total number of employees by the total number of plants provided by the CBP. I find that the mean size of the establishments with at least one paid employee is

39.76 in 2016. Bento and Restuccia (2017a) show that the ratio of the mean size of establishments including non-employer plants to the mean size of establishments excluding non-employer establishments is 0.51 using the Nonemployer Statistics (NES) dataset. Therefore, I use 20.3 (multiplying 39.76 by 0.51) as the mean size of plants in manufacturing sector.

When I calculate the model counter part of the mean size, I take the self-employed plants with zero paid employees into consideration following the same logic as I do for the data. In the model, the mean size is calculated using the following formula:

$$\text{Mean Size} = \frac{\begin{array}{c}\text{workers in 3}-\text{layer and 2}-\text{layer plants +}\\ \text{middle managers + self-employed}\end{array}}{\underbrace{\begin{array}{c}\text{self-employed + managers of 2}-\text{layer plants+}\\ \text{top managers of 3}-\text{layer plants}\end{array}}_{\text{\# of plants}}} \tag{1.20}$$

Notice that the denominator of the equation (1.20) denotes the total number of plants since each manager owns a plant.

I calculate the managers per plant in 2016 using the CBP and ILOSTAT database since Timmer *et al.* (2015) and Timmer *et al.* (2018) provide data until 2011. I multiply the number of employees provided by the CBP with the share of management occupations provided by the ILOSTAT to determine the number of managers in the manufacturing sector in 2016. According to my calculations, there are 7.3 managers per plant in the manufacturing sector in the U.S..

Since the CBP provides the number of employees and the number of plants with at least one paid employee, I calculate the managers per plant and the plant size distribution without taking self-employed household members into consideration in the model. Therefore, I use following formula to calculate the managers per plant in the model:

$$\begin{array}{c}\text{Managers} \\ \text{per plant}\end{array} = \frac{\begin{array}{r}\text{middle managers + managers of 2}-\text{layer plants} \\ +\text{ top managers of 3}-\text{layer plants}\end{array}}{\text{managers of 2}-\text{layer plants + top managers of 3}-\text{layer plants}} \tag{1.21}$$

The plant size distribution in the U.S. manufacturing sector is calculated using the CBP dataset in 2016. Since the CBP provides the number of employees and the number of plants with at least one paid employee, I use the NES datasets to calculate the share of self-employed (non-employer) plants. According to the NES 2016 dataset combined with the CBP dataset, the percentage of non-employer establishments is 54.5% of total establishments.

The calibrated model parameters are shown in Table 1.1. Additionally, the performance of the calibration is presented in Table 1.2.

1.5.1 Discussion

The calibrated communication parameters, ϕ_i's, show that communication technology in complex organizations (3−layer plants) is more efficient than communication technology in simpler organizations ($\phi_T > \phi_m > \phi_2$). However, the average communication cost that middle managers incur is higher than the average communication cost that 2−layer managers are subject to, and the top managers of the 3−layer plants spend less time on communicating with middle managers on average. The middle managers spend 0.44 units of time per question on average when answering production workers' questions whereas 2−layer managers spend 0.35 units of their time on average communicating with their production workers. But the top managers of 3−layer plants spend only 0.19 units of time on average answering middle managers' questions.

The average size of the plant with at least one paid employee (plants with 2−

layers and 3−layers) is 46, which is higher than the average size of plants reported by the CBP since the fraction of self-employed in the benchmark model is higher than the NES dataset reports. Moreover, all 3−layer plants have more than 100 employees. There are 327 employees in 3−layer plants on average, whereas the mean size of the 2−layer plants is 17.4.

The aggregate output in this economy is defined as follows:

$$\text{Agg. Output} = \int_{\underline{z}}^{z_{3w}^{2w}} \frac{AF(m_3(m_1(z)))}{h_T(m_1(z))\left[1 - F(m_1(z))\right]} g(m_3(m_1(z)))dz$$
$$+ \int_{z_{3w}^{2w}}^{z_{2w}^{mm}} \frac{AF(m_2(z))}{h_2(z)\left[1 - F(z)\right]} g(m_2(z))dz + \int_{z_{mm}^{se}}^{z_{se}^{2m}} AF(z)g(z)dz \tag{1.22}$$

where the first term on the right hand side is the total production in the 3−layer plants, the second integral defines the total production in 2−layer plants and the last integral is the total production of self-employed household members.

While 3−layer plants comprise only 4% of all plants, employment and the output are highly concentrated at complex organizations (3−layer plants). Even after taking self-employed agents into consideration, 3−layer plants account for 64% of total employment and 78% of total output produced in the economy. However, 2−layer plants comprise 40% of all plants, and they account for 34% of employment and 18% of total output. On the other hand, although self-employed household members comprise 56% of plants, they produce only 4% of aggregate output.

Table 1.3 compares the average earnings of household members in different occupations. The average earnings of production workers at 3−layer plants are normalized to 1 in order to make the comparison easier. The most able household members run the biggest plants (3−layer plants) and accordingly their earnings are the highest in the economy. The top managers earn 12.87 times more than the production workers that work for them on average. Moreover, the most able top managers earn 89.5 times more than the least able production workers.

The dispersion in the earnings is more apparent at the top and the bottom of the distribution. The ratio of the most able top managers' earnings to that of the least able top managers $\left(\frac{R_T(\bar{z})}{R_T(z_{2m}^{tm})}\right)$ is 13.9. additionally, the ratio of the wage of most able production workers at 3−layer plants to the wage of the least able household member $\left(\frac{w_2(z_{3m}^{2m})}{w_2(\underline{z})}\right)$ is 1.68. However, the wage of the highest earning middle managers $(w_3(z_{mm}^{se}))$, for example, is only 4% higher than the wage of the lowest earning middle managers $(w_3(z_{2m}^{mm}))$.

1.6 Quantitative Findings

In this section, I first introduce a simple form of size-dependent distortions to the model [9] , I then explain how the model responds to changes in communication cost.

1.6.1 Effects of Size-Dependent Distortions

Size-dependent policies are prevalent across countries. Guner *et al.* (2008) discuss the effects of such policies that favor the small plants and/or punish the bigger plants in France Italy, Japan and Korea. Moreover, Garicano *et al.* (2016) and Gourio and Roys (2014) examine how output and earnings can be affected from the size-dependent distortions that are present in France. Moreover, there are also other studies focus on distortions that are correlated with the productivity without specifying the exact underlying distortions such as Restuccia and Rogerson (2008).

In order to measure the effects of the size-dependent distortions in my model, I

[9] Changes in the common technology parameter, A, do not have any effect on either the allocation of household members into an occupation or on the assignments of subordinates to managers. However, they do affect the total output and the earnings of households, as expected. See Appendix A.6 for more details.

conduct an experiment where different types of organizations face potentially different distortion rates in the form of output taxes. I denote τ_{SE}, τ_{2L} and τ_{3L} as the distortion rates for self-employed household members, the managers of $2-$layer plants and the managers of $3-$layer plants respectively. For example, while self-employed household members can keep $(1-\tau_{SE})$ fraction of their output, the managers of $2-$layer plants can keep $(1-\tau_{2L})$ fraction and the $3-$layer plants keep $(1-\tau_{3L})$ fraction of their output. All of the tax revenues collected are transferred to the household in a lump-sum manner.

More complex organizations are larger than the simpler organizations. In the benchmark economy, the average size of $3-$layer plants is 327 whereas the average size of $2-$layer plants is 17.5. Therefore the distortion rates that are higher for $3-$layer and $2-$layer plants can be interpreted as an example of size-dependent distortions. There is more than one possible case in which we can study size dependent distortions in this type of setup. I define any set of distortions as size-dependent distortions if it satisfies any of the following conditions:

$$\begin{aligned} &1)\ \ \tau_{SE} < \tau_{2L} < \tau_{3L} \\ &2)\ \ \tau_{SE} \leq \tau_{2L} < \tau_{3L} \\ &3)\ \ \tau_{SE} < \tau_{2L} \leq \tau_{3L} \end{aligned} \tag{1.23}$$

Table 1.6 presents the effects of different distortions on the aggregate measures of the economy.The first column is the benchmark economy and the second column shows when all types of plants are distorted at the same 10% rate. In other words, all plants, regardless of their type and size, face the same distortion rate, 10%, so that there are no size-dependent distortions. When all plants are distorted at the same rate, neither the equilibrium allocation of the household members to the occupations nor the matching of subordinates to the managers changes. The intuition for this result is similar to the results in changes in the common technology parameter discussed in the Appendix A.6: the indifference conditions for the household members that are at the margin of being in different occupations are not affected by the uniform distortion rates across occupations. Hence, the allocation of household members to occupations is not affected. Moreover, the matching of subordinates to managers remains same since the output tax does not affect either the time constraint of managers or the distribution of knowledge.

Results The third column of Table 1.6 shows the results when the 3−layer plants are distorted more than the self-employed and the 2−layer plants. In particular, the self-employed household members and the managers of 2−layer plants face the same 10% distortion rate whereas the 3−layer plants are distorted at a 20%.

The mean size decreases to 16 people in a plant on average for two reasons. First, the fraction of plants increases in the economy since the more able middle managers become self-employed household members as the wages decrease. Second, the more able top managers of 3−layer plants decrease their scale by having fewer employees. The mean size of the 3−layer plants decreases from 327 to 279.

Since there is no difference between being self-employed and being a manager of 2−layer plants in terms of distortions, the self-employed household members on the margin run 2−layer plants thanks to the decrease in wages. In other words, the most able self-employed household members in the benchmark economy become the least able managers of 2−layer plants in the distorted economy. This is the reason for the falling fraction of self-employed plants when the distortion rates for self-employed and 2−layer plants are same.

Output falls by 34% because the size of the complex plants decreases. The output accounted by the 3−layer plants decreases 13 percentage points, while the share of

2−layer and self-employed plants increases. The managers per plant and the fraction of middle managers among all managerial occupations decreases as well, because the 3−layer plants decrease their labor demand and the number of plants in the economy increases.

The last column of Table 1.6 shows the result when the size dependency of distortions increases. In other words, the 3−layer and 2−layer plants are subject to a 20% and 10% distortion rate, respectively whereas the self-employed household members do not pay any taxes.

In this exercise, the self-employed plants are not distorted, unlike the previous case where they are subject to the same distortion rate as 2−layer plants. Therefore, the managers of 2−layer plants who are at the margin of being self-employed become self-employed household members because of the high tax rate. The fraction of self-employed plants increases to 75%, and the fraction of middle managers decreases to 45% with the distortions.

The mean size of the 2−layer and 3−layer plants decreases to 11.2 and 93.7, respectively. Overall, the mean size of the economy decreases to 6.7 for the same two reasons as the previous case: more plants and less workers in the complex organizations.

The size-dependent distortions reallocate the production toward simpler plants. The share of self-employed plants in total production increases from 4% to 45%. The aggregate output decreases by 67.7%, and the employment share of plants with at least 100 employees and the output account by 3−layer plants falls 39 and 50 percentage points, respectively.

Table 1.7 shows the effect of the size-dependent distortions on the average earnings of the household members in each occupation. The average earnings of the production workers in the benchmark are normalized to one similar to the previous exercise.

When all of the plants are distorted at the same 10% rate, the average earnings of all of the occupations decrease by the same rate. In other words, everybody earns 10% less than the benchmark case. However, as the distortions become size-dependent, the average earnings of occupation decreases disproportionately. With the size-dependent distortions, the top managers of $3-$layer plants experience the biggest drop in average earnings. This is because they are subject to the highest tax rates and they decrease their output more than the other managers due to the reallocation of talent to the simpler organizations.

The quantitative effects of the size-dependent distortions on output and mean size are larger than the effects of such distortions in previous studies. The amplification of the quantitative effects results from two sources. First, size-dependent distortions affect the composition of the plants in each layer. In other words, the fraction of each type of organization changes according to distortions that each type of plants are subject to. Second, size-dependent distortions also affects the matching of subordinates to the managers. Although there is still positive sorting of subordinates to the managers, the type of subordinates hired changes with the size-dependent distortions since the occupational assignments change and the wages of all subordinates falls with the size-dependent distortions. Next section discusses two reasons of amplification mechanism of size-dependent distortions in detail.

Understanding the Effects of Size-Dependent Distortions Next, I explain the mechanism by which size-dependent distortions affect the equilibrium of the benchmark economy. In particular, I describe the results when the last form of size-dependent distortions in equation (1.23) is present in the economy. An example of this type of size-dependent distortion would be $\tau_{SE} = 0 < \tau_{2L} = \tau_{3L} = 0.1$ which distorts $2-$layer and $3-$layer plants at the same rate whereas the self-employed plants are not distorted.

The equilibrium effects of the size-dependent distortions are similar in the literature mentioned above. In an economy where bigger plants are more distorted, these plants seek to decrease their scale more than smaller plants. This effect will be translated as a decrease in wages since the only way to reduce the production scale is hiring less labor. A decrease in the wage rate reallocates employment within and between organizations. The effect of size-dependent distortions on earnings and occupation choice is depicted in Figure 1.9.

The most able middle managers become self-employed household members as their wage rate decreases. Moreover, the least able managers of the $2-$layer plants switch to self-employment because of the higher distortions. The occupational change among managers creates equilibrium effects that result in reallocation of household members into occupations and the reassignment of subordinates to the managers.

Consider the managers of $3-$layer plants: the most able middle managers become self-employed household members so the most able top managers now work with the less able middle managers. Since less able middle managers ask more questions than the previous middle managers, the most able top managers hire fewer middle managers. At the same time, the least able production workers in the $2-$layers plants work for the $3-$layer plants as production workers.

The managers of the $2-$layer plants who are at the margin of running a $3-$layer plant hire middle managers and start to be managers of $3-$layer plants. These managers are able to switch their occupations to be the managers of $3-$layer plants thanks to decreases in the wage rates. That is, hiring middle managers becomes cheaper relative to the benchmark case.

To summarize, size-dependent distortions increase the fraction of simpler organizations whereas they decrease the production scale of complex, $2-$ layer and $3-$layer organizations by distorting the occupational choice and reallocating less able subordinates to the complex organizations. The mechanism explained in this section is a result of a specific type of distortions. Any one of the size-dependent distortions in equation (1.23) has a similar effect on the allocation of household members to the managerial occupations. However, for example, the size-dependent distortions, where each type of organization is distorted at different rates, may result in a different allocation of production workers into managers depending on the size-dependency of the distortions and the distribution of knowledge. In other words, if the size-dependency of the distortions increases, the most able production workers of the $3-$layer plants may become a production workers of the $2-$layer plants. This makes the most able managers of $3-$layer plants work not only with less able middle managers but also with less able production workers. Therefore, reallocation of household members into occupations and the assignment of subordinates to managers follows the same mechanism, with the effects of higher communication costs as explained in the previous section in detail.

1.6.2 Larger Communication Costs

Van Ark *et al.* (2008) and Timmer and Van Ark (2005) show that productivity slowdowns in European countries after 1995 can be largely attributed to the slow adoption of ICT. Moreover, Bloom *et al.* (2012a) show that the U.S. firms are more successful in using ICT than their European counterparts. Bloom *et al.* (2014) distinguish information technology from communication technology and show that while the information technology increases decentralization, communication technology has the opposite effect on decentralization.

Motivated by this research, I design an experiment in which the communication cost parameters for all managers increase at the same time and rate. In other words, communication between subordinates and managers is manipulated to take more time compared to the benchmark economy by increasing all $\phi_i \;\; i \in \{m, 2, T\}$ at the same rate. Table 1.4 shows the results when the communication cost increases by 10% and 20% compared to the benchmark economy.

Effects of the Higher Communication Cost A proportional increase in the cost parameter has a potentially sizable effect on mean size, managers per plant and aggregate output as Table 1.4 shows. A 20% increase in the communication cost parameters for all managers, ϕ_i's, decreases mean size by half and output by more than half. However, managers per plant is less sensitive to changes in communication cost: a 20% increase in the ϕ_i's decreases managers per plant to 5.4 from 7.5.

The average communication cost that middle managers and managers of 2−layer plants increases by 24% and 21%, respectively when the communication cost parameters increase by 20%. However, the top managers of 3−layer plants spend 42% more time communicating with the middle managers. The reason that middle managers and managers of 2−layer plants experience a lower increase in the average communication time than the top managers is the reallocation effect as discussed in next section. All of the middle managers and the 2−layer managers who have not changed their occupations due to the increase in communication cost are matched with more knowledgeable subordinates. However the most able top managers are matched with the less able middle managers.

There are two reasons for the decrease in the mean size. First, since the organization of production in complex plants becomes more costly, the managers decrease their demand for subordinates. The increase in communication costs decreases the size of 3−layer organizations more than the size of 2−layer plants. The mean size of 3−layer plants decreases from 327 to 124 if communication cost parameters increase by 20%. However, the mean size of the 2−layer plants decreases from 18 to 11 with the 20% increase in ϕ_i's. Second, there are more plants in the economy with higher communication costs. The number of plants (self-employed household members, managers of 2−layer and 3−layer plants) increases 101% with the 20% increase in communication cost parameters.

The employment share of plants with more than 100 employees decreases from 65% to 42% when communication cost parameters increase by 20%. Employment is reallocated from complex 3−layer organizations to the simpler plants. The share of middle managers among all of the managers (including self-employed household members) decreases from 73% to 62% and managers per plant decreases from 7.5 to 5.4 as the communication cost parameters increase by 20%.

The output is reallocated from complex 3−layer organizations toward simpler 2−layer and self-employed plants like reallocation in employment. When the communication cost parameters increase by 20%, the output accounted by 3−layer plants decreases from 78% to 49% whereas the self-employed plants increase their share in total production to a quarter from 4%.

The effect of an increase in communication cost parameters on the average earning profiles is shown in Table 1.5. In this table, the average earnings of production workers in 3−layer plants in the benchmark economy is normalized to 1 so that all of the average earnings can be interpreted according to the average earnings of the production workers in the benchmark economy. For example, the average earnings of the top managers of 3−layer plants is 12.87 times higher than the average earnings of production workers in 3−layer plants. However, if the communication cost parameters increase by 10%, the average earning of the production workers in 3−layer plants decreases by 4%, and the average earnings of the top managers in 3−layer plants becomes 9.82 times higher than the average earnings of production workers in 3−layer plants in the benchmark economy.

The average earnings of all of the household members decrease with higher communication costs. The earnings inequality among household members measured by the ratio of the average earnings of the top managers to the average earnings of the production workers in 3−layer plants decreases as communication costs increase. While the ratio of top earners to the bottom earners is 12.87 in the benchmark economy, it decreases to 10.2 and 8.4 when the communication cost parameters increases by 10% and 20% respectively.

Understanding the Effects of Higher Communication Cost The direct effect of an increase in the communication cost parameter to the number of production workers demanded in the 2−layer and 3−layer plants is negative. This can be seen in equations (1.2) and (1.4). However, there is no direct effect of a proportional increase on the communication cost parameter to the number of middle managers demanded in 3−layer plants. Consider the equation (1.5) after substituting the communication cost functions given by the equation (1.19):

$$n_m = \frac{\phi_m(1+z_m)\,[1-F(z_p)]}{\phi_T(1+z_p)\,[1-F(z_m)]} \tag{1.24}$$

a proportional increase in ϕ_m and ϕ_T increases both the denumerator and the numerator by the same fraction, so that the overall direct effect of a proportional increase in the communication cost will be zero. However, there are equilibrium effects not only on the demand for the number of production workers but also on the demand for the number of middle managers.

Organizing production into teams requires more time when communication cost parameter ϕ_i increases. Given that the amount of managerial time is limited, the plant owners (the managers of 2−layer plants and the top managers of 3−layer plants) demand fewer production workers. Although the increase in the communication cost does not directly affect the demand for middle managers, the top managers of 3−layer plants decreases their demand for middle managers as well, because if the top managers have fewer production workers, they will need fewer middle managers to manage them. Therefore, both the managers of 2−layer and 3−layer plants decrease their demand for subordinates.

The decrease in the demand for all subordinates (production workers in both 2−layer and 3−layer plants and middle managers) pushes down the wages of all subordinates. A decrease in the wage rate results in a change in subordinates' assignments to managers. The middle managers who are on the margin of being self-employed becomes self-employed when the wage rate of middle managers goes down since these middle managers always have the option of being self-employed and producing alone (without being affected by changes in communication cost). The most able top managers are going to be matched with middle managers whose knowledge level is lower than the previous middle managers. Since the knowledge of the most able middle managers decreases and the most able top managers reduce their demand for production workers, they run smaller organizations when communication cost increases.

The managers of 2−layer plants who are at the margin of running 3−layer plants hire middle managers and become the least able top managers of 3−layer plants when the communication cost increases. The reason they are able to hire middle managers is the decrease in the wage rate with higher communication costs. On the other hand, self-employed household members who are at the margin of being managers of 2−layer plants hire some production workers and start to run their own 2−layer organizations.

The wages of production workers in 3−layer plants decrease more than the wages of production workers in 2−layer plants when communication costs increase at the same rate for all managerial layers. This is because the increase in the communication cost hurts 3−layer plants more than 2−layer plants on average since there are more communication in complex organizations. Therefore, the most able production workers in 3−layer organizations start to work for 2−layer plants.

Figure 1.10 compares the benchmark matching functions and the matching functions when the communication costs increase. The solid black lines show the benchmark matching function and the dotted red lines are the resulting matching functions with the increase in communication costs.

Since the most able middle managers become self-employed household members, the most able top managers are now matched with the middle managers with lower knowledge compared to the benchmark case. The top managers who are at the margin of running 2−layer organizations in the benchmark are now able to hire middle managers with more knowledge since the wages of all middle managers go down when the communication cost increases. Although the average knowledge of middle managers decreases, the least able top managers hire middle managers who have more knowledge compared to the benchmark. The new middle managers who changed occupations from being the production workers at 2−layer plants to being middle managers of 3−layer plants are assigned to the top managers who switch from running 2−layer plants to the 3−layer plants.

The fraction of production workers in complex organizations, 3−layer plants, decreases with higher communication costs since the top managers demand less of them. The most able production workers in 3−layer organizations start to work with less able middle managers. On the other hand, all middle managers who have remained middle managers after the increase in communication cost are matched with more able production workers.

The most able managers of 2−layer plants become the top managers of 3−layer plants, and there are new $2-$layer plants which were self-employed household members in the benchmark case. The average knowledge of the managers and the production workers of $2-$layers plants decreases. However, the managers of $2-$layer plants who did not change their occupations after the increase in communication cost take advantage of the decrease in the wage rate by hiring more knowledgeable production workers.

Although some of the top managers and the managers of $2-$layer plants (who have remained in the same occupations after the change in communication costs) are matched with subordinates with more knowledge, most of them downsize their organizations because of the increase in the communication cost. Some of them may experience increases in their production depending on the abundance of production workers relative to the abundance of tasks they can solve. Additionally, the magnitude of the change in communication cost parameters have an important role in determining what fraction of the managers are better off with the increase in communication cost. In this particular experiment, where the communication costs in all managerial layers increase at the same rate, $2-$layer plant managers who were switched from being self-employed household members in the benchmark case take advantage of higher communication costs.

The resulting earning profiles for all occupations when the communication increases is shown in figure 1.11. In this graph, the solid-black line is again the benchmark earning profile, whereas the red line shows the earnings of household members when the communication costs at all managerial layers increases by the same percentage.

All household members except the self-employed and the least able managers of $2-$layer plants experience a decrease in earnings. The self-employed household members' earning profile does not change since they are not affected by the changes in communication cost because of producing alone. Moreover, the least able managers of 2−layer plants experience an increase in their earnings because of the reallocation of more able production workers at lower wages to them as described above.

1.7 From Model to Data

In this section, I present the model performance with different levels of size-dependent distortions and communication costs. In particular, I evaluate whether the size-dependent distortions and the communication cost differences are able generate income, mean size and the number of managers per plant in France and Italy.

I introduce size-dependent distortions in the following form

$$\tau_{SE} = \tau\left(1-\Delta\right), \quad \tau_{2L} = \tau, \quad \tau_{3L} = \tau\left(1+\Delta\right) \tag{1.25}$$

where τ stands for the distortion level and Δ controls the size dependency of distortions. When Δ equals to zero, there is no size-dependent distortion so all plants face the same distortion rate τ. However as Δ increases, the 3−layer plants face the highest distortion rate and the 2−layer plants are subject to distortions that are higher than the self-employed household members face. Moreover, higher communication costs are introduced in similar way with Section 1.6.2 where the communication costs parameters for all managers increase at the same rate. In particular, I increase all ϕ_i's at the rate ϵ where $i \in \{m, 2, 3\}$

The main goal here is to find (Δ, ϵ) pairs that generate the GDP per capita and the mean size of France and Italy. For this purpose, I express GDP per capita in France and Italy as a fraction of the GDP per capita in the U.S.. In order to make the model and the data comparable, I report the mean size and the number of managers per plant when the self-employed household members are considered as both managers and the plant owner. In particular, I add the self-employed households to both numerator and denumerator of Equation 1.21.

First column of Table 1.8 presents the results when $\tau = 0.05$ and ϕ_i's are at the benchmark levels, i.e. $\Delta = \epsilon = 0$. First column corresponds to the benchmark economy in terms of aggregate output, mean size and the managers per plant since equilibrium allocation is not affected by the uniform distortions as discussed in Section 1.6.1. GDP per capita in the model is presented as a fraction of the aggregate output in the benchmark economy and the aggregate output is normalized to 100 for comparison.

My results show that distortions are more size dependent in Italy than in France since Δ is greater in Italy. In other words, complex $3-$layer plants in Italy are distorted more than the complex $3-$layer plants in France. $3-$layer plants are subject to 6.1% distortion rate in France case but they face 6.9% distortion rate in Italy case. On the other hand, self-employed household members are distorted at 3.9% and 3.2% in France and Italy respectively. $2-$layer plants are subject to 5% distortion rate in both countries by the design of the experiment.

The communication costs are also higher in Italy, compared to France. Therefore, managers at all layers spend more time on communication in Italy. Managers in France have 3% higher communication cost parameter values compared to the benchmark economy. However, all managers in Italy, have 8% higher communication cost parameters compared to the benchmark, the U.S., economy.

While the model matches mean size for both countries successfully, output predictions for Italy is less than the one we observe in the data. Since I don't allow one manager to run two different plants in the model, the least number of managers per plant that I can generate in the model is 1. Therefore, the managers per plant predictions of the model is higher than the data for both countries since they have less than one managers per plant. Nevertheless, the model is able to predict the positive correlation between the GDP per capita and the number of managers per plant. Both France and Italy have lower GDP per capita and fewer managers per plant than the U.S..

To sum up, the size-dependent distortion and the communication cost differences can account for the differences on mean size. However, they can explain only some part of the variation in the number of managers per plant across countries which suggests that there may be also many other sources that generate the number of managers per plant differences across countries.

1.8 Conclusion

This study quantitatively examines the importance of determinants of production complexity on aggregate output and productivity. I relate production complexity with the number of managers in a plant on average. I then construct a dataset for the number of employees, managers and production workers of plants in a manufacturing industry for a set of developed countries. I document that the richer countries have more managers in a plant on average. Moreover, richer countries also have bigger plants in terms of number of employees whereas whereas there are lower numbers of production workers per manager in richer countries compared to other countries on average.

I then develop a knowledge-based hierarchy model where the communication costs are dependent on the knowledge of the subordinates and the managerial layer in the hierarchy. Different plant sizes and plants with multiple layers of management coexist in the model. I calibrate this model to the U.S. manufacturing data. The model successfully generates the mean size of plants, number of managers per plant, employment share of the plants with more than 100 employees and plant size distribution that we observe in the data.

I show that size-dependent distortions and higher communication costs between managers and workers reallocate output and talent from complex plants with multiple layers of management toward simpler production units where only one managerial layer exists. Once the organizational differences is taken into account by having different type of production units with multiple layers of management, the effects of the size-dependent distortions are amplified. Because the size-dependent distortions alter both the composition of the plants in terms of complexity and the matching patterns of subordinates to managers. In other words, the fraction of simpler plants and the share output accounted by them increase and the talented agents are reallocated to simpler units as a result of the size-dependent distortions.

I finish this paper by proposing possible directions for the future studies on the organization of production across countries. First extension would be incorporating capital into the production and having dynamic version of the model. This extension would increase the magnitudes of the effects of distortions and higher communications further.

In this paper, setting up any type of plants was assumed to be costless. In other words, any agent in the economy, for example, can set up a $3-$layer plant and she can switch to be a $2-$layer plant when faced by distortions or vice versa without any cost. Therefore, one possible extension is incorporating barriers of running and switching business types into the model. For example, it is natural to think that starting to new a business requires resources. Especially, building a complex production units would require more resources than running a simpler type of organization. Hence, the financial frictions and bureaucratic requirements can account for the differences in production complexity across countries.

Moreover, larger firms and enterprises possibly have multiple production units as well as multiple layers in each unit. That is, they operate on different locations and each location has hierarchical organization of production. Some branches are specialized in management such as headquarters whereas other branches are specialized in production. One interesting extension of this paper could be studying the effects of size-dependent distortions when managers are able to run multi-layer production units in multiple locations.

Finally, the distribution of the tasks and knowledge plays an important role on determining the matching subordinates to the managers and earnings of agents as well. I have numerically showed that matching the firm size distribution and the number of managers per plant is not specific to the assumed distributions by calibrating model parameters with different distributions in Appendix A.2. I think studying what kind of distributions will result in what kind of firm size and earning distributions is worth to explore in the future. Moreover, the effects of the possible knowledge distribution differences across countries (proxied by the years of schooling, for example) on the firm size distribution and the managers per plants could be another interesting study in the future.

Table 1.1: Parameter Values

Parameter	Description	Value
η_F	Pareto shape parameter for tasks	2.62
η_G	Pareto shape parameter for knowledge	1.47
$\bar{z}$	Highest value of knowledge and difficulty of tasks	16.6
ϕ_2	Communication cost for 2−layer managers	1.01
ϕ_m	Communication cost for middle managers	0.95
ϕ_T	Communication cost for 3−layer top managers	0.92

Notes: Value column shows the parameters values that generate the manager per plant and the plant size distribution of the U.S. manufacturing industry. Pareto distribution for both tasks and knowledge is a truncated distribution over the range $[1, \bar{z}]$. For more details about parameters and the moment conditions see Section 1.5 as well as Table 1.2.

Table 1.2: Calibration Performance: Targets and Model

	Data	Model
Mean size	20.3	20.7
Managers per plant	7.3	7.5
Fraction of plants		
1-19	0.69	0.69
20-99	0.22	0.22
Employment share of 100+	0.66	0.65
Fraction of Self-employed (non-employer) plants	0.55	0.56

Note: This table shows the calibration performance. The data column shows the target moment conditions for the U.S. economy. The number of employees and the fraction of plants at different size classes data comes from the CBP dataset. The fraction of self-employed data comes from the NES dataset. The model column shows how model results with the calibrated parameters reported in Table 1.1. The mean size calculation in the model includes self-employed plants whereas the managers per plant, fraction of plants at different size classes and the employment share of plants with 100 and more employees do not take self-employed plants into consideration in order to be consistent with the CBP dataset. See Section 1.5 for description of data and the moments in detail.

Table 1.3: Earning Profiles in the Benchmark Economy

	Average earnings	Fraction of agents
Production Workers in 3−layer plants	1	49.4%
Production Workers in 2−layer plants	1.31	32.6%
Middle Managers	1.41	13.3%
Self-employed	1.43	2.7%
Managers of 2−layer plants	2.15	1.9%
Top Managers of 3−layer plants	12.87	0.2%

Note: This table shows the average earning profiles and the fraction of household members in each occupations in the benchmark economy. The average earnings of the production workers in 3−layer plants is normalized to one. Hence, the average earnings of all other occupations are presented in terms of the average earnings of the production workers in 3−layer plants. The fraction of household members shows what fraction of household members belongs to each of the six different occupations. The sum of the fraction of household members may not add up to one due to the rounding. See Section 1.5.1 for more details.

Table 1.4: Effect of Communication Cost

	Benchmark Economy	10% Increase in Communication Costs	20% Increase in Communication Costs
Mean size	20.7	15.2	10.2
Managers per plant	7.5	7.4	5.4
Output	100	65.7	35.8
Output accounted by 3−layer plants	0.78	0.71	0.49
Output accounted by 2−layer plants	0.18	0.19	0.26
Output accounted by self-employed plants	0.04	0.10	0.25
Employment share of 100+	0.65	0.62	0.42
Frac. of self-employed plants	0.56	0.56	0.73
Frac. of middle managers (% among managers)	0.73	0.70	0.62

Note: This table shows that higher communication cost decreases the complexity of production by comparing the benchmark calibration with equilibriums results from higher communication cost. 10% and 20% increase in communication costs correspond to the case where the communication cost parameters for all managers increases at the same time. Output in the benchmark economy is normalized to hundred in order to make the comparison easy. All variables other than the mean size, the managers per plant is presented as percentages. See Section 1.6.2 for more details.

Table 1.5: Average Earnings with Higher Communication costs

	Benchmark Economy	10% Increase in Communication Costs	20% Increase in Communication Costs
Production Workers in 3−layer plants	1	0.956	0.869
Production Workers in 2−layer plants	1.314	1.290	1.234
Middle Managers	1.405	1.389	1.368
Self-employed	1.435	1.432	1.425
Managers of 2−layer plants	2.151	2.110	1.977
Top Managers of 3−layer plants	12.873	9.824	7.343

Note: This table shows the average earning profiles of the different occupations when the communication cost parameters for all managers increases at the same time. The average earnings of the production workers in 3−layer plants is normalized to one. Hence all other average earnings including the ones with higher communication costs presented in terms of the earnings of the production workers in 3−layer plants. See Section 1.6.2 for more detail.

Table 1.6: Effect of Size Dependent Distortions

	Benchmark	$\tau_{SE} = 0.1$ $\tau_{2L} = 0.1$ $\tau_{3L} = 0.1$	$\tau_{SE} = 0.1$ $\tau_{2L} = 0.1$ $\tau_{3L} = 0.2$	$\tau_{SE} = 0$ $\tau_{2L} = 0.1$ $\tau_{3L} = 0.2$
Mean size	20.7	20.7	16.0	6.7
Managers per plant	7.5	7.5	5.3	4.3
Output	100	100	66.6	32.3
Output accounted by 3−layer plants	0.78	0.78	0.65	0.28
Output accounted by 2−layer plants	0.18	0.18	0.27	0.27
Output accounted by self-employed plants	0.04	0.04	0.08	0.45
Employment share of 100+	0.65	0.65	0.57	0.26
Frac. of self-employed plants	0.56	0.56	0.51	0.75
Frac. of middle managers (% among managers)	0.73	0.73	0.67	0.45

Note: This table shows that the size dependent distortions decreases the complexity of production by comparing the benchmark calibration with equilibriums when size-dependent distortions are present.τ_{SE}, τ_{2L} and τ_{3L} stand for the distortion rates of self-employed, 2−layer and 3−layer plants respectively.. The output is normalized to 100 at the benchmark case in order to make comparison easy. See Section 1.6.1 for more details.

Table 1.7: Average Earnings and Size-Dependent Distortions

	Benchmark	$\tau_{SE} = 0.1$ $\tau_{2L} = 0.1$ $\tau_{3L} = 0.1$	$\tau_{SE} = 0.1$ $\tau_{2L} = 0.1$ $\tau_{3L} = 0.2$	$\tau_{SE} = 0$ $\tau_{2L} = 0.1$ $\tau_{3L} = 0.2$
Production Workers in 3−layer plants	1	0.900	0.741	0.727
Production Workers in 2−layer plants	1.314	1.183	1.162	1.160
Middle Managers	1.405	1.265	1.261	1.303
Self-employed	1.435	1.291	1.289	1.414
Managers of 2−layer plants	2.151	1.935	1.321	1.485
Top Managers of 3−layer plants	12.873	11.586	6.906	1.531

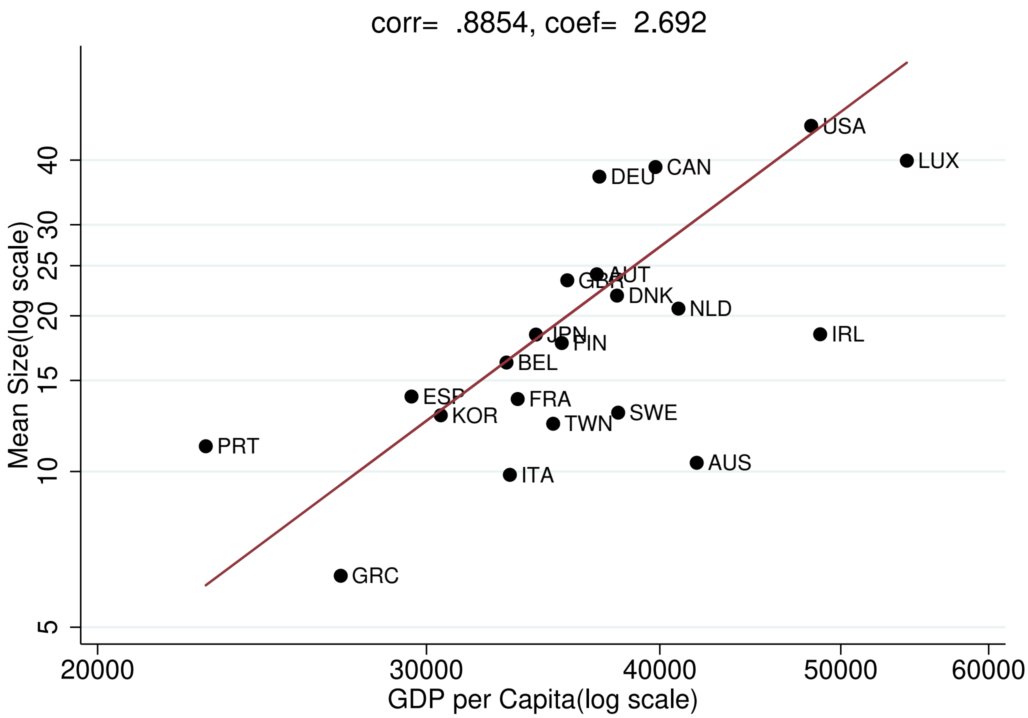
Note: This table shows the average earning profiles of the different occupations when there are size-dependent distortions in the economy. The average earnings of the production workers among 3−layer plants in the benchmark economy is normalized to one. Hence all other average earnings including the ones with size-dependent distortions presented in terms of the earnings of the production workers in 3−layer plants in the benchmark case. τ_{SE}, τ_{2L} and τ_{3L} stand for the distortion rates of self-employed, 2−layer and 3−layer plants respectively. See Section 1.6.1 for more detail.

Table 1.8: Model with Size-Dependent Distortions and High Communication Costs

	Benchmark	France		Italy	
Δ	0	0.22		0.37	
ϵ	0	0.03		0.08	
		Data	Model	Data	Model
GDP per capita	100	69	68	68	53
Mean Size	20.7	11.2	11.1	6.9	6.9
Managers per plant	3.8	0.54	2.5	0.31	1.9

Note: This figure presents mean size and output data in Italy and France as compared to the model's prediction with size-dependent distortions and higher communication costs. Benchmark column represents the calibration of model to the U.S. data. GDP per capita in the U.S. is normalized to 100 and the aggregate output is used for GDP per capita comparisons in the model. Δ controls the size dependency of distortions and ϵ controls the level of communication costs. Higher Δ indicates more size dependency of distortions and the higher ϵ increases communication cost parameters for all managerial layers at same percentage. Values of Δ and ϵ are chosen to match France and Italy's output compared to the U.S. and their mean plant size. Therefore, output is presented as a fraction of the U.S. GDP per capita in the data and as a fraction of the aggregate output in the benchmark economy. See Section 1.7 for more details

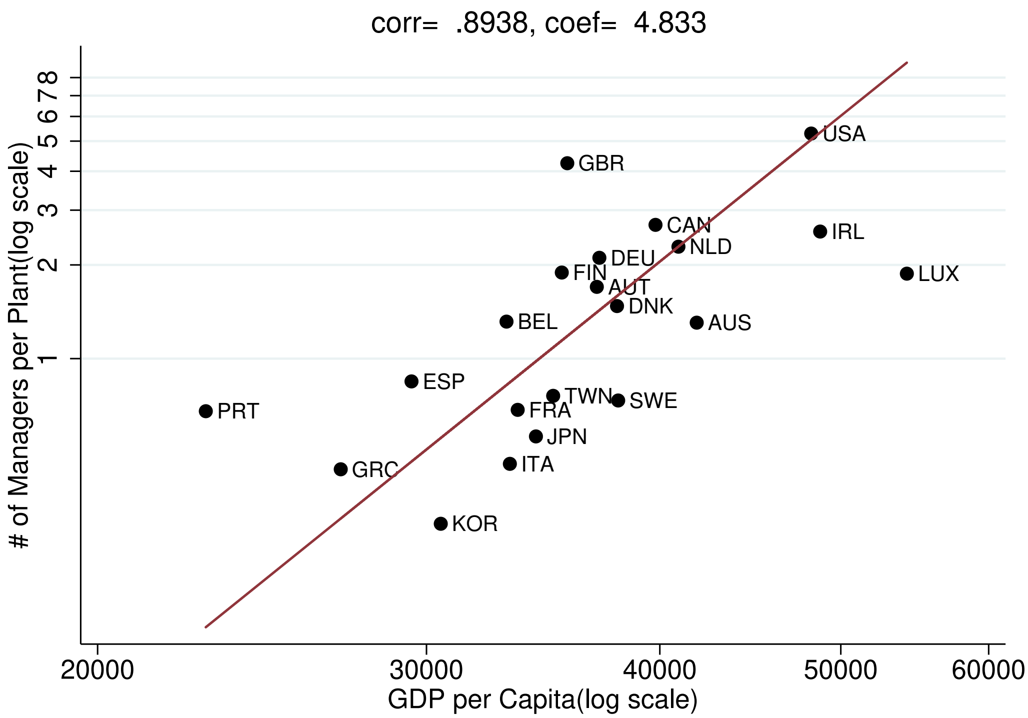
Figure 1.1: Mean Plant Size and GDP per Capita



Sources: SEA (2014), Timmer *et al.* (2018), Eurostat and countries' statistical agencies and PWT 9.0

Notes: This figure shows the relationship between the mean size and the GDP per capita (in log scale) at cross-country level. Each dot represents a country. Solid line is the simple weighted regression line where the GDP per capita is the dependent variable, the mean plant size is the independent variable and the countries are weighted according to their employment sizes. Both the mean size and the GDP per capita are averages over the period specified in Table A.1.1 for each countries. GDP per capita numbers are in PPP adjusted and reported in 2011 dollars.

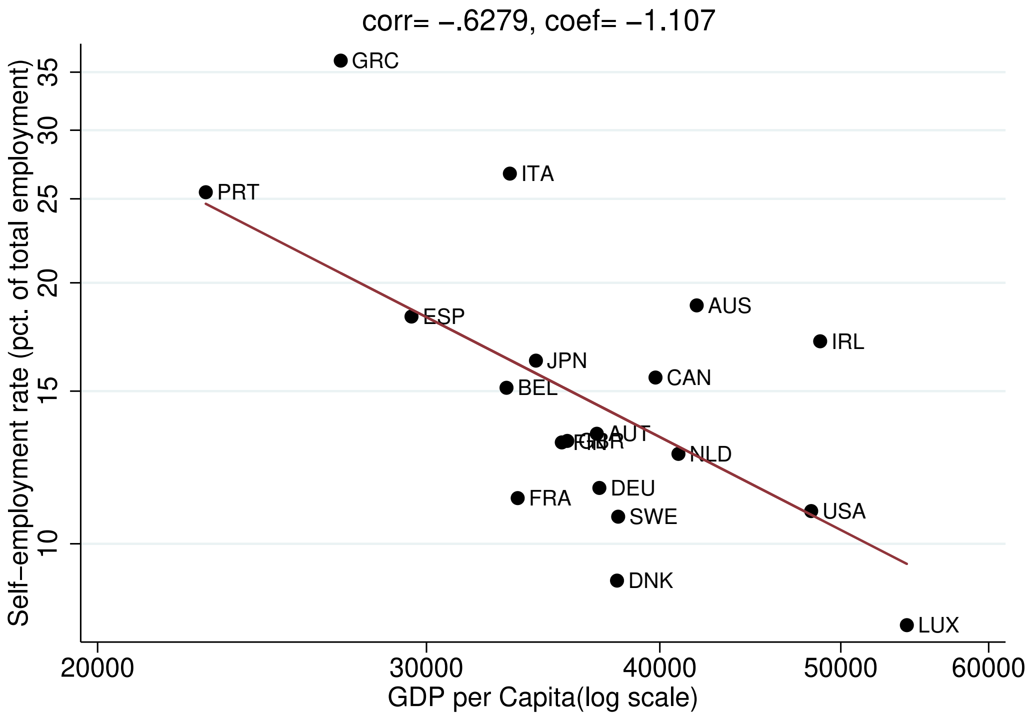
Figure 1.2: Managers per Plant and GDP per Capita



Sources: SEA (2014), Timmer *et al.* (2018), Eurostat and countries' statistical agencies and PWT 9.0

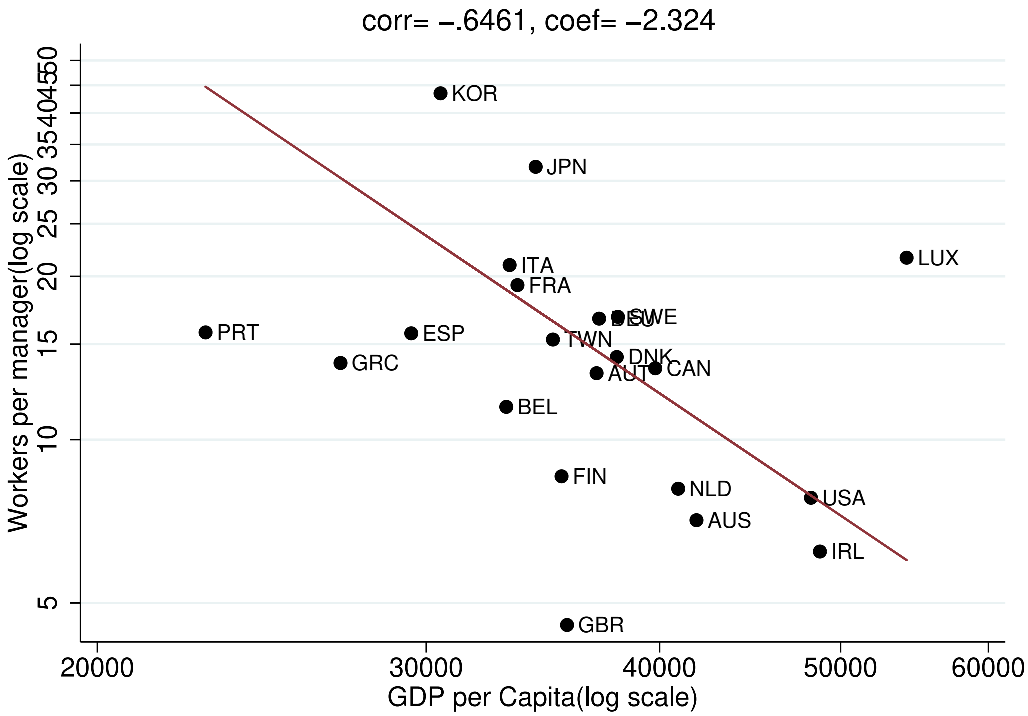
Notes: This figure shows the relationship between the mean size and the GDP per capita (in log scale) at cross-country level. Each dot represents a country. Solid line is the simple weighted regression line where the GDP per capita is the dependent variable, the mean plant size is the independent variable and the countries are weighted according to their employment sizes. Both the managers per plant and the GDP per capita are averages over the period specified in Table A.1.1 for each countries. GDP per capita numbers are in PPP adjusted and reported in 2011 dollars.

Figure 1.3: Self-employment Rate and GDP per Capita



Sources: ILOStat and PWT 9.0 Notes: This figure shows the relationship between the mean size and the GDP per capita (in log scale) at cross-country level. Each dot represents a country. Solid line is the simple weighted regression line where the GDP per capita is the dependent variable, the mean plant size is the independent variable and the countries are weighted according to their employment sizes. Both the workers per manager and the GDP per capita are averages over the period specified in Table A.1.1 for each countries. GDP per capita numbers are in PPP adjusted and reported in 2011 dollars.

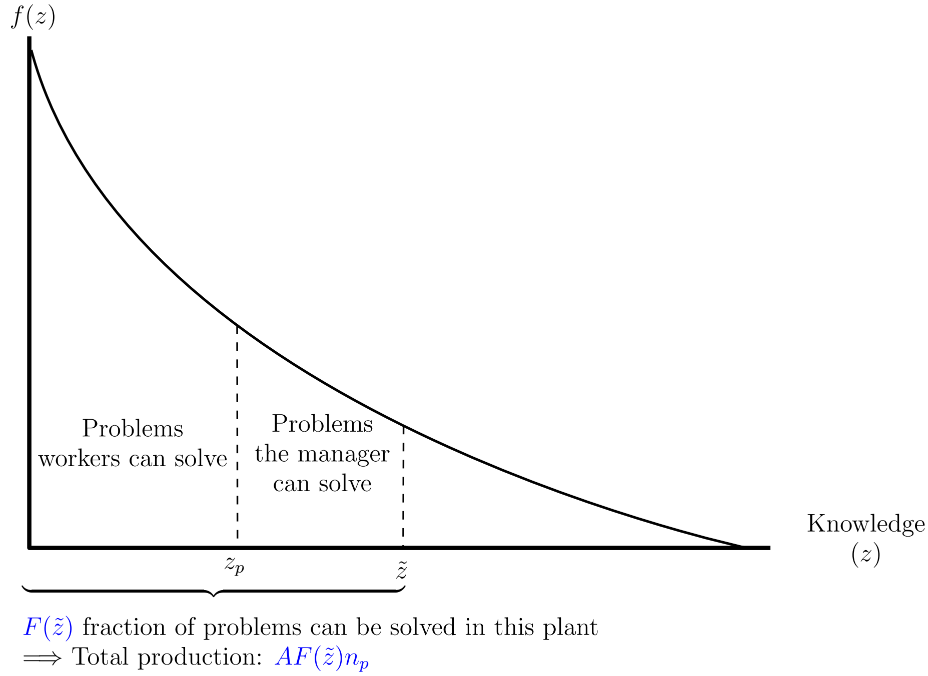
Figure 1.4: Workers per Manager and GDP per Capita



Sources: SEA (2014), Timmer *et al.* (2018), Eurostat and countries' statistical agencies and PWT 9.0

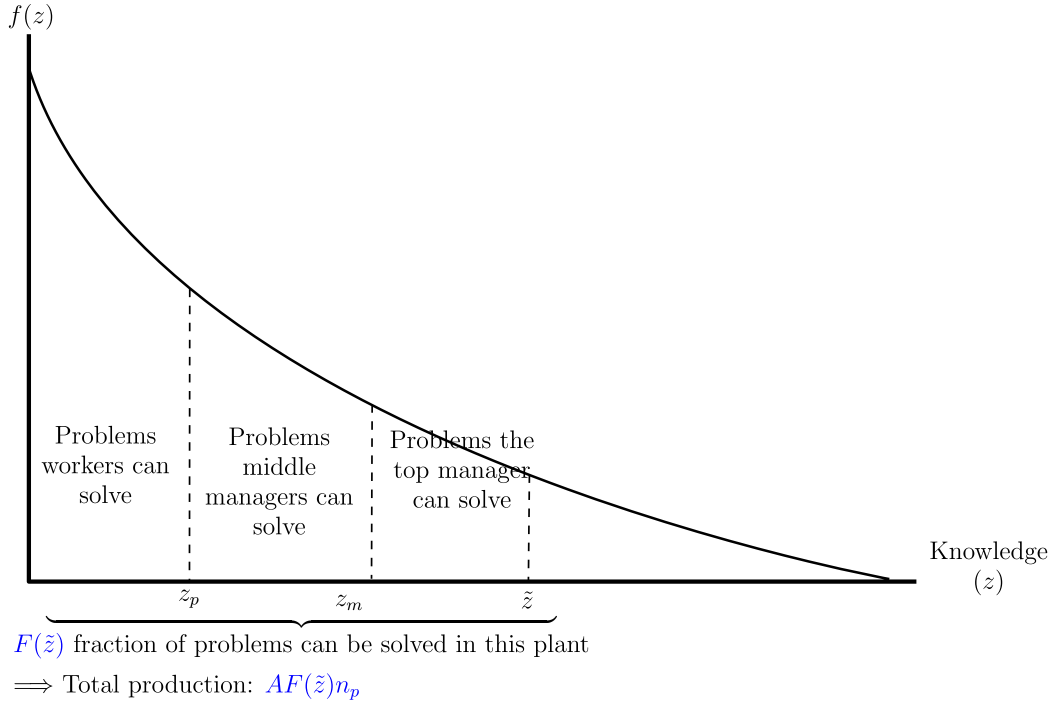
Notes: This figure shows the relationship between the workers per manager and the GDP per capita (in log scale) at cross-country level. Each dot represents a country. Solid line is the simple weighted regression line where the GDP per capita is the dependent variable, the workers per manager is the independent variable and the countries are weighted according to their employment sizes. The workers stands for all people in a plant other than the managers. Both the workers per manager and the GDP per capita are averages over the period specified in Table A.1.1 for each countries. GDP per capita numbers are in PPP adjusted and reported in 2011 dollars.

Figure 1.5: Production in the 2−layer Plants



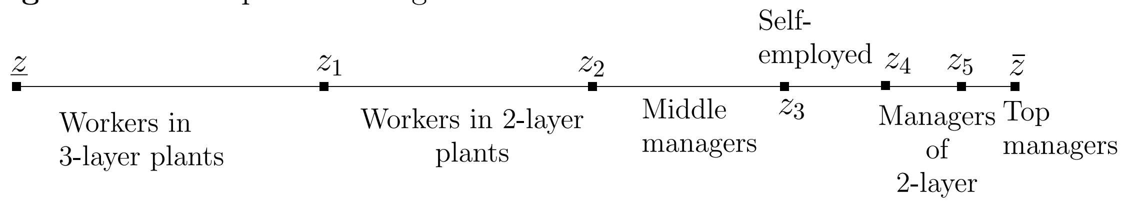
Notes: This figure shows how production is organized in a 2−layer plant where the manager has $\tilde{z}$ knowledge and n_p production workers have z_p knowledge. x-axis represents the knowledge of the agents and y-axis shows the density of tasks that can be solved by the associated knowledge. Each production worker draws problems from the distribution F and solves $F(z_p)$ fraction of them. The manager teaches how to solve $[F(\tilde{z}) - F(z_p)]$ fraction of problems to the production workers. As a result, $F(\tilde{z})$ fraction of the problems can be solved and $AF(\tilde{z})n_p$ output is produced in this plant. See Section 1.4 for more details.

Figure 1.6: Production in the 3−layer Plants



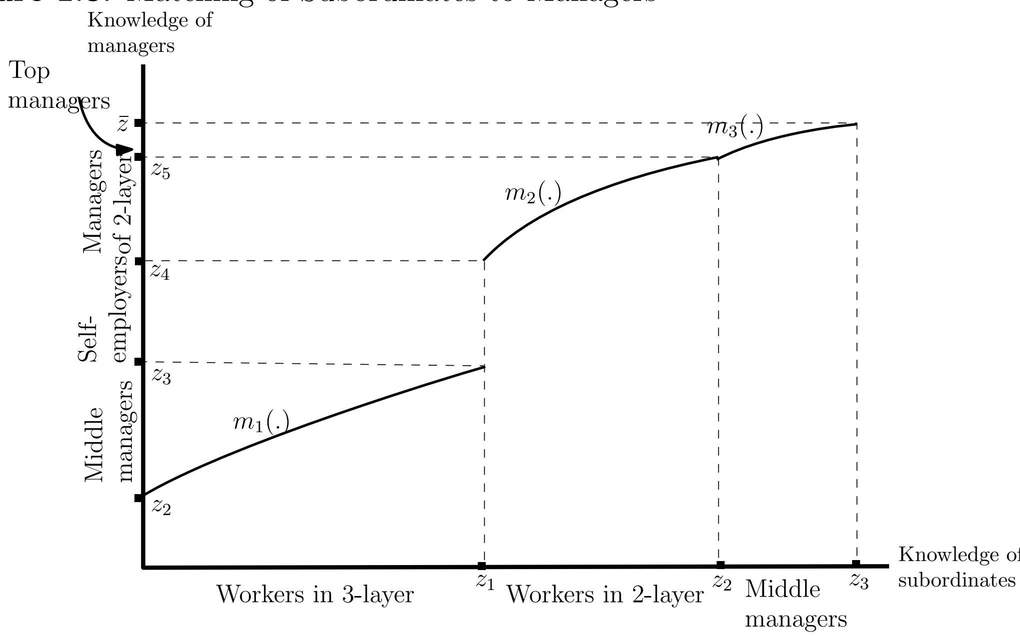
Notes: This figure shows how production is organized in a 3−layer plant where the top manager has $\tilde{z}$ knowledge, n_m middle managers have z_m knowledge and n_p production workers have z_p knowledge. x-axis represents the knowledge of the agents and y-axis shows the density of tasks that can be solved by the associated knowledge. Each production worker draws problems from the distribution F and solves $F(z_p)$ fraction of them. Middle managers teach production workers how to solve $[F(z_m) - F(z_p)]$ fraction of the problems. The top manager teach middle managers how to solve $[F(\tilde{z}) - F(z_m)]$ fraction of the problems and middle managers teach production workers how to solve that amount of problem. Finally, $F(\tilde{z})$ fraction of problems can be solved and $AF(\tilde{z})n_p$ output is produced in this plant. See Section 1.4 for more details.

Figure 1.7: Occupational assignments of the Household Members



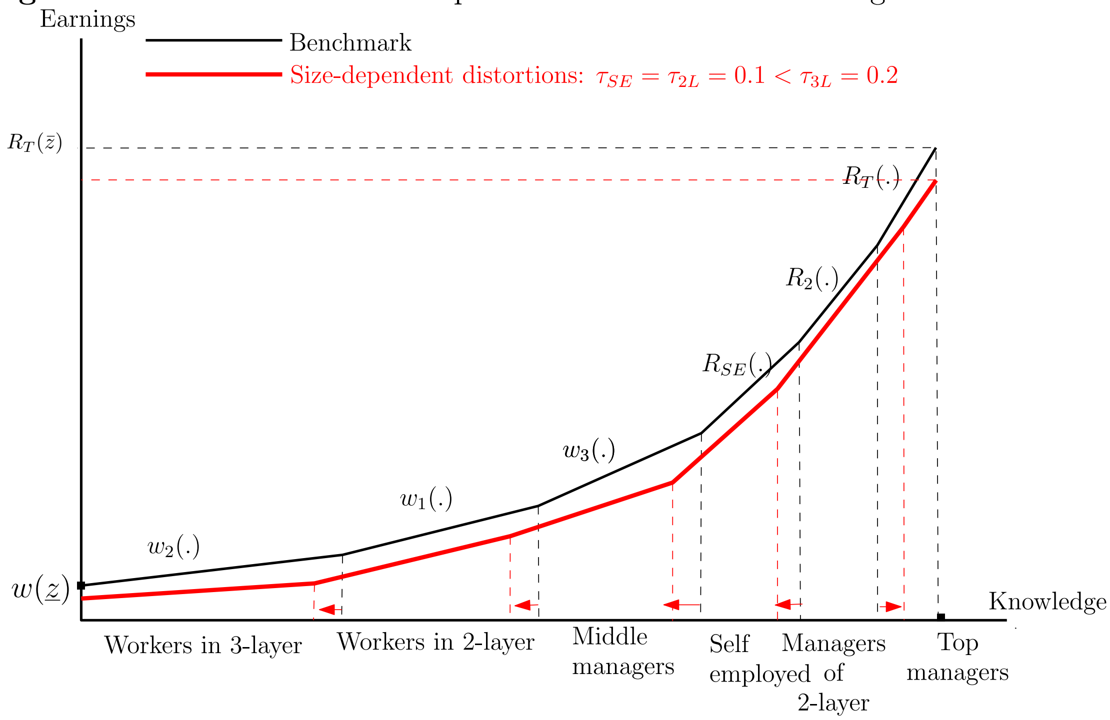
Notes: This figure shows how agents are assigned to the different occupations according to their knowledge in the equilibrium. Production workers have the least knowledge whereas managers are the most talented agents in this economy. Moreover, the equilibrium allocation has pyramidical structure such that the fraction of agents with lower knowledge is more than the fraction of agents with higher knowledge. See Section 1.4 for more details.

Figure 1.8: Matching of Subordinates to Managers



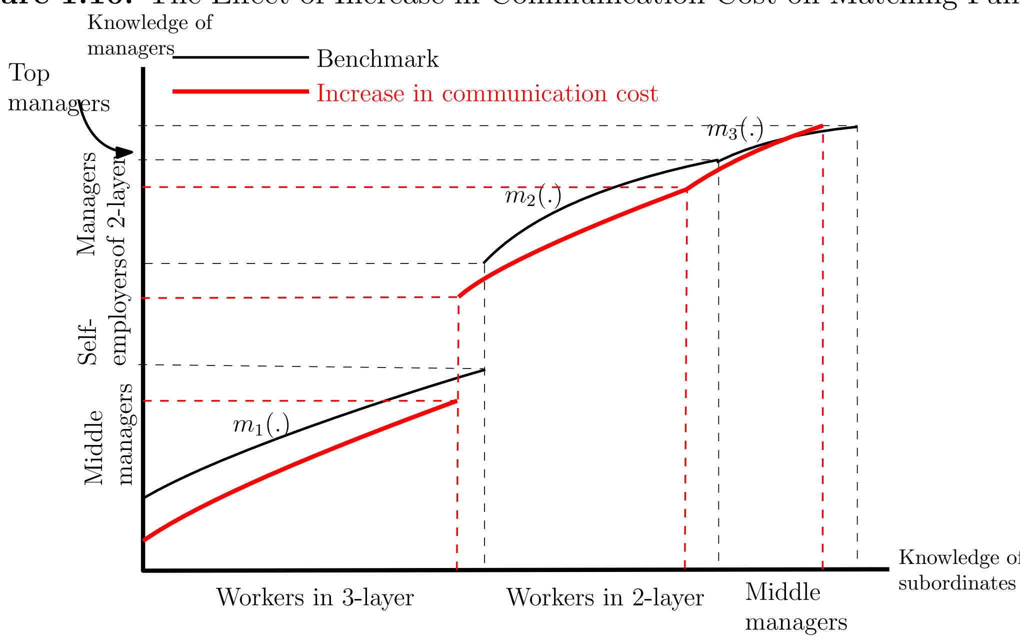
Notes: This figure shows how subordinates are matched to managers in equilibrium. x-axis is the knowledge of subordinates and y-axis is the knowledge of managers in equilibrium. Notice that middle managers are both subordinates (of the top managers) and managers (of the production workers in 3−layer plants). $m_i()$'s are the matching functions that match subordinates to managers such that the lowest able subordinates work for the lowest able corresponding managers and the highest able subordinates work with highest able managers. See Section 1.4 for more details.

Figure 1.9: The Effect of Size-dependent Distortions on Earnings



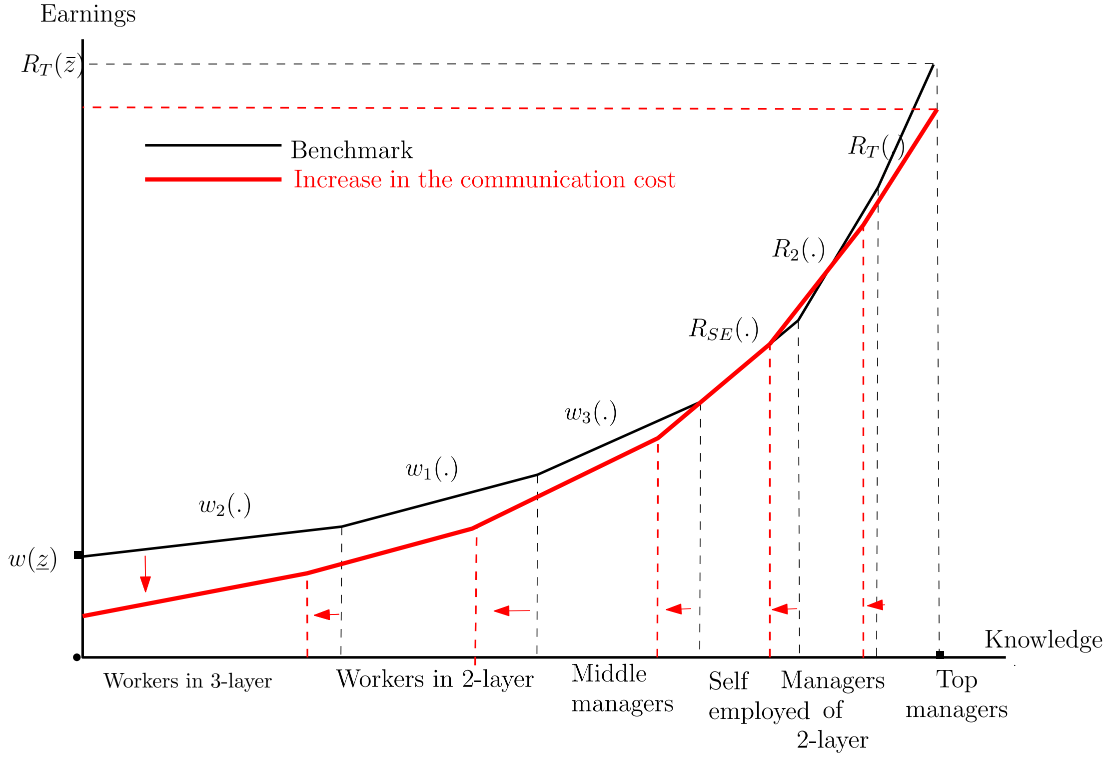
Notes: This figure compares the benchmark earnings with the earnings when size-dependent distortions are present. x-axis is the knowledge of the agents and y-axis stands for earnings. w_i's are the wage functions of the subordinates and R_i's are profits of managers. Black lines represents the benchmark earnings and red lines are earnings of agents with size-dependent distortions. Distortion rates are same for self-employed agents and $2-$layer plants whereas $3-$layer plants face higher distortion rates. Arrows indicate the direction of shifts in the occupational assignments after size-dependent distortions are introduced to the benchmark economy. See Section 1.6.1 for more details.

Figure 1.10: The Effect of Increase in Communication Cost on Matching Functions



Notes: This figure compares the benchmark matching functions with the matching functions when the communication costs increase. x-axis is the knowledge of subordinates and y-axis is the knowledge of managers in equilibrium. m_i's are the matching functions. Black curves represents the benchmark matching functions whereas red curves are the resulting matching functions when the communication cost parameters of all managers increase at same percentage. See Section 1.6.2 for more details.

Figure 1.11: The Effect of Increase in Communication Cost on Earnings



Notes: This figure compares the benchmark earnings with the earnings when the communication cost increases. x-axis is the knowledge of the agents and y-axis stands for earnings. w_i's are the wage functions of the subordinates and R_i's are profits of managers. Black lines represents the benchmark earnings and red lines are earnings of agents when communication cost parameters of all managers increase at same percentage. See Section 1.6.2 for more details.

Chapter 2

BRIBERY, PLANT SIZE AND SIZE DEPENDENT DISTORTIONS

2.1 Introduction

A growing literature have focused on the misallocation of resources in order to answer why some countries are poorer and have low productivity level [1] . There are two different approaches for quantifying the extent of misallocation: the direct and the indirect approach [2] . Guner *et al.* (2008) identifies the size dependent policies as one of the direct sources of misallocation. In this paper, I study the relationship between size dependent distortions and economic development in the presence of bribery opportunities.

I define bribery as a transfer from one party to government officials in order to 'get things done.' These 'things' can include acquiring valuable licenses and permits to operate or avoiding taxes. In this paper, I ask and quantitatively answer the following questions: What is the inferred magnitude of distortions when a model is disciplined to account for the plant size distribution and bribery data. What are the aggregate consequences of an increase in the size dependency of the distortions under the presence of bribery opportunity? Finally, how large are the possible gains from removing the distortions with and without the bribery opportunities? These questions have not been answered by the previous literature, even though bribery is prevalent among developing countries. Answers to these questions provide a better understanding of the relationship between bribery, plant size distribution and GDP

[1] See Restuccia and Rogerson (2008), Guner *et al.* (2008) and Hsieh and Klenow (2009).

[2] See Restuccia and Rogerson (2017b) for a survey of literature.

per capita and the effects of various policies, such as removing the bribery mechanism and removing the distortions, on an economy.

Firstly, I document the facts related with bribery and plant size distribution in a typical developing country, Turkey in this paper. Using Enterprise Survey (ES) data, I show that while bigger enterprises pay higher bribes, they spend a lower fraction of their output on bribery. More specifically, 41.7% of big plants and 18.1% of small plants [3] in Turkey experienced a bribery request in 2013. However, big enterprises spent 2.5% of their output on bribery, whereas small enterprises spent 8.3% of their output on bribery. Moreover, according to the Annual Industry and Services Statistics of Turkey, 99.55% of all plants are small. However, big plants who are only 0.45% of the total plants employ 43.6 % of all employment.

Given these facts, this paper asks what the effects of the interplay between size-dependent distortions and bribery are on the plant size distribution and aggregate output. To answer this question, I build a model based on the environment of Guner *et al.* (2008) which uses Lucas (1978) span of control framework. Agents in the model are heterogeneous in terms of their managerial ability and they can either be a worker or a manager. The innovation is that agents are assigned to a corrupt official with some probability, depending on their ability level. Managers who encounter the corrupt official, face size dependent distortions as well as the fixed cost. In other words, managers who are encountered to the corrupt official have to pay the fixed cost and they are subject to a distortion (output tax) depending on their production level. However, since there is a bribery opportunity (the official is corrupt), managers can choose to decrease the distortion level by paying a bribe. Although the existence of the corrupt official is exogenous, the amount of the bribe paid by a manager is

[3]Big plants refer to the plants who employ more than 100 workers and small plants refer to the plants with less than 100 employees.

endogenously chosen by each manager.

There are two key mechanisms that govern an optimal bribe for a production unit (plant): the return on the bribe and the distortion rate. The return on the bribe shows how effective the bribery mechanism is. For example, a high return on a bribe indicates an effective bribery mechanism, where managers are able to 'get things done' with small bribes. On the other hand, a low return on a bribe prevents managers from solving problems that they face with small bribes. Therefore, they need to spend more resources on bribery. Similarly, high distortion rates lead managers to spend more resources on bribery activities, because there are more problems to solve. Since managers with high output level will face higher distortion rates, they pay higher bribes than other managers with low output level.

Existence of the corrupt official creates misallocation of resources in two different channels: First, it distorts the managers' optimal input decisions. To be more specific, the managers who are assigned to the corrupt official demand less inputs as they face a distortion. Second, the corrupt officials distort the optimal occupational sorting of the agents. Since agents who are assigned to the corrupt official, have to pay output tax and fixed cost, their managerial income would be smaller than the agents who have same ability level but who are not assigned to the corrupt official. Therefore, some of the agents become workers instead of managers.

In order the quantify the interplay between the size-dependent distortions and the bribery, I design two quantitative experiments. First, I calibrate model parameters to generate the U.S. plant size distribution by assuming the U.S. is free of distortions. Then I introduce the size-dependent distortions with and without having bribery opportunities separately. The purpose of this exercise is to measure the effect of size-dependent distortions in the presence of bribery opportunities and to compare it with the previous literature. In second quantitative exercise, I calibrate model parameters including distortion rates and the fix cost by taking advantage of the bribery payment data in Turkey. The goal of this exercise is to measure the level of distortions as well as the bribery.

First, the U.S. exercise shows that bribery opportunities reversed the effect of size-dependent distortions on the mean size and decrease the negative effect of it on the output. Since the bigger plants have more resources to spend on bribery, they are able to circumvent to the distortions. Hence the smaller plants are more distorted when all plants have access to bribery technology.

For the second quantitative exercise, I use the data on bribery payments of big and small plants, as well as plant size distribution of Turkey, in order to calibrate key parameters of the model including the size-dependent distortion rate and the return on bribe parameter. The inferred distortion levels are sizable: while the small plants face 39.3% distortion rate on average, the big plants are subject to 49.8% of distortion even after the bribery payments on average. The small plants pay almost all of their bribe for the associated fix costs since the estimated return on bribe is low for them. Hence, they don't choose the lower the size dependent distortions by paying further bribes. However, the return on bribe is high enough for the big plants since they are subject to higher distortion rates. They pay bribes in the form of fix costs as well as for decreasing the size-dependent distortions they face.

My results indicate that first, given the opportunity of bribery, size dependent distortions become less distortionary in the Turkey exercise as well. Since the manager can decrease the distortion level (i.e., the manager can solve 'problems' by paying a bribe), the average effective tax rate (distortion rate after bribery) for the big enterprises decreases to 49.8% from 65.9% and the average effective tax rate for small enterprises roughly stays constant at 39.3%.

Second, the change in the level of the distortions has little effect on the aggregate variables such as output and mean size. Since managers try to decrease the distortion levels as much as possible, they adjust their bribery expenditures as the distortion level changes. For example, even if the distortion rate for big firms increases to 80.2%, they are able to reduce it back to 60.3% by increasing their bribery expenditure.

Third, removing the distortions results in substantial increase in the output and mean size. Since the size-dependent distortions affect bigger plants more than small plants, bigger plants increase their input demand more than small plants by removal of the distortions. As a result, aggregate output grows more than 12% percent and mean size almost doubles.

The rest of the paper is organized as follows. The next section provides the literature review. Section 2.3 describes the datasets and summarizes the facts related to bribery, plant size and economic development, at the cross-country level and in Turkey. Section 2.4 demonstrates the model and derives key equations to compare the different steady-state equilibria. Section 2.5 describes the calibration of the parameters and discusses the model's behavior with the calibrated values. Section 2.6 presents the counterfactual experiment results and Section 2.7 concludes.

2.2 Related Literature

This paper relates misallocation literature with the corruption-bribery literature. As I mention before there are two approaches to understand implications of misallocation. This paper contributes to the misallocation literature by estimating the size of the distortions using the bribery payments of the different plant size groups. There are also other studies which try to identify direct sources of the misallocation. For example, Guner *et al.* (2008), Bhattacharya *et al.* (2013) and Guner *et al.* (2015) studies the effect of size-dependent policies which limits plant sizes. Ranasinghe (2017) uses the fraction of plants who are exposed to the extortion in order to identify the misallocation. He shows that weak property rights which increase the extortion can be associated by 10% decrease in the aggregate output. In addition to the direct approach, many researchers have studied the plant size distribution across countries. Bento and Restuccia (2017b) and Poschke (2014) demonstrate that there is a positive correlation between a small plant size and GDP per capita. Garcia-Santana and Ramos (2015) measure distortions with the Ease of Doing Business Index. They show that countries with larger distortion have more unproductive and smaller plants.

Corruption can be defined as the misuse of public power for private gain (Svensson (2005)). There are two sides of corrupt activities, corrupt officials that are asking bribes to 'get things done' and bribe payers. Bribery defined in this paper is the activity of bribe payers to solve their 'problems'. The corruption literature mainly focuses on the relationship between corruption and economic development rather than specifically on the relationship between bribery and economic development. Early examples of the rent-seeking literature focuses on a choice of agents that either want to be a (corrupt) official or an entrepreneur (Krueger (1974), Ackerman (1978), Murphy *et al.* (1991), Murphy *et al.* (1993), Shleifer and Vishny (1993) and Acemoglu (1995)). In addition, Ehrlich and Lui (1999) show that investment in socially unproductive capital (political capital) creates a non-linear negative relationship between growth and bureaucratic corruption by developing an endogenous growth model in which agents choose to invest in either political or human capital. My paper is different from the literature in the sense that there is no choice in being a corrupt official in my model. I only focus on bribery choice of managers, given that there are corrupt officials. Moreover, Aghion *et al.* (2016) develop an endogenous growth model where tax revenues cannot be spent on infrastructure due to corruption. Since infrastructure is necessary for firm innovation and productivity, corruption negatively affects economic growth.

It is difficult to measure how pervasive corruption is in the economy due to its secrecy and illegality. More specifically, people may not want to reveal that they paid or received a bribe. In addition, endogeneity of corruption with major macroeconomic variables, such as GDP, requires strong instruments. Despite all, there are empirical studies that examine the relationship between corruption and economic growth. Mauro (1995) show that corruption decreases investment, so that economic growth decreases. Kaufmann and Wei (1999) show that the amount of a bribe that a firm pays, the amount of time spent dealing with bureaucrats and the cost of capital are all positively correlated. That is to say, corrupt officials cause more problems to exploit bribes from firms [4] .

Lopez (2014) conduct a similar study with my paper. It is the first attempt (to my knowledge) to incorporate bribery with aggregate variables, using the neoclassical growth model. In the open economy environment, bureaucratic corruption is exogenous and firms can pay a bribe for lower tax rates. However there are financial frictions that not only prevent some productive agents from being managers, but also prevent managers from paying the bribe, since bribery is costly. On the other hand, in this paper, I show that the existence of the bribery opportunity distorts the allocation of resources and the entrepreneurial choices, without financial friction in a closed one sector neoclassical growth model.

My calibration strategy is similar to the strategy in Leal (2014), which investigates the relationship between the informal sector and misallocation. In his model, firms choose to be small for tax evasion purposes, because big firms cannot escape tax enforcement. Leal (2014) calibrates the model for the Mexican economy with distortions. However, distortion level is defined as the total tax revenue over the

[4] An extensive discussion of the corruption literature is presented in the survey papers such as Bardhan (1997), Svensson (2005) and Olken and Pande (2012).

value added associated with the formal sector, instead of calibrating distortion level itself. My calibration strategy differs from Leal (2014) in terms of estimating the distortion levels. I calibrate the distortion level by using the firm-level bribery data and plant-size distribution in Turkey. Since bribery is illegal and secret, I cannot use the total tax revenue-value added ratio as the distortion rates in my paper. In addition, I focus on 'solving problems' or 'getting things done', instead of only focusing on tax evasion.

2.3 Bribery and Plant Size in Turkey

2.3.1 Bribery

There have been many corruption and governance indices created by the World Bank and independent institutions, such as Corruption Perception Index of Transparency International. These indices primarily depend on people's perception about how corrupt their country is and the cost of doing business there, rather than direct measures of bribery. However, I will use ES to analyze bribery, because it consists of data on whether a firm was asked to pay a bribe or not by government officials. ES has been conducted by the World Bank and provides detailed information about firm-level data from interviews with top managers/owners. Questions vary from government-firm relationships to employee-employer relationships. The ES has interviewed more than 127,000 firms in 139 countries since 2005. There are numerous questions about bribery (i.e., informal gift or payment) in the ES. Six of the questions are asked to managers in all countries, to make cross-country comparisons. These questions include whether any informal gift or payment was requested during the tax inspection or meeting with tax officials, as well as during the application process for electricity, water, construction related permits, import and operating licenses. The percentage of firms in a given country that experienced at least one bribe payment request is called the bribery incidence by ES.

ES interviewed 1,344 randomly selected top managers or business owners in Turkey in 2013. Along with these 6 questions (i.e., bribery incidence questions) asked globally, there were other questions asked that are related to bribery for the Turkish enterprises. These questions include what percentage of the contract value was paid in informal payments or gifts to secure government contracts and what percentage of the total annual sales or value was paid to the government officials 'to get things done.' After removing misreports (e.g., enterprises reporting negative employee or sales numbers or more than 100% of the total value as a bribery payment), data for 687 enterprises remained.

Table 2.1 and 2.2 report the summary statistics of bribery in Turkey. Overall, 524 of 687 enterprises employ less than 100 workers. The remaining 163 enterprises have more than 100 employees. The first columns in the tables indicate the enterprise size, which shows whether the statistics belong to small enterprises (enterprises with 5-99 employees) or big enterprises (more than 100 employees). Table 2.1 displays the statistics of the bribery incidence variables. For example, the third column shows that 8.8% percent of the total enterprises in the dataset were asked to pay an informal payment or gift when they applied for a water connection. Among the small enterprises, 9.56% were asked to pay a bribe; however, 1.29% of the big enterprises reported that they were asked to pay a bribe. Therefore, we can conclude that small enterprises are facing more difficulty in obtaining a water connection. Hence, except for an operating license and an electrical connection, small enterprises experience more bribery requests than big enterprises.

Table 2.2 summarizes the other bribery measures along with the bribery incidence itself. The other bribery measures include the cases where enterprises experience bribery requests other than the cases included in the bribery incidence. The second column is the bribery incidence that we already defined. The third column shows what percentage of enterprises were asked to pay a bribe to secure a government contract, when they are doing business with the government. Managers were also asked what percentage of their annual sales or values are spent on bribery. Thus, the Other Bribes column presents the percentage of enterprises who answered a positive amount to that question, but said no to the previous bribery questions. That is to say fourth column in Table 2.2 shows what percentage of enterprises were asked to pay bribes in situations other than the previously asked 7 cases. The Total Bribe Rate column reports the percentage of enterprises which declared that they were asked to pay a bribe in any case. The last two columns in Table 2.2 show what percentage of annual values are spent on bribery. The Total Bribe to Total Sales Ratio indicates the ratio of the total bribe payments of the 687 enterprises who answered that they paid bribes, to the total values of all of the interviewed enterprises. The last column shows the bribe to value ratio, given that the enterprise pays the bribe. In other words, it is the bribe to the sales ratio of the enterprises who admitted that they paid bribes.

Although the bribery incidence rate in Turkey is low, compared to other countries (see Figure 2.1), Table 2.2 shows that 39.1% of the big enterprises and 8.6% of the small enterprises admitted that they were asked to pay a bribe, to secure a government contract. The Other Bribes column implies that the big enterprises almost do not pay bribes, other than in the cases described for bribery incidence and for securing a government contract. However, 4.8% of the small enterprises declared that there were other cases where they were asked to pay a bribe, without specifying which cases they were. Overall, 19.2% of the surveyed enterprises, 41.7% of the big enterprises and 18.9% of the small enterprises, were asked to pay an official a bribe.

The bribery data reveals that the big enterprises pay larger bribes than small enterprises. However, the bigger enterprises' bribery payments, compared to the their annual values is smaller than the small enterprises' bribery payment proportion to their output. When we calculate the total bribe to total value ratio, 0.74% percent of the total value of the enterprises was spent on the bribery. However, if we only consider the enterprises who were asked to pay the bribe, they spent 8.21% of their total value on the bribery. The difference between small and big enterprises' bribes to the value ratio is remarkable. Although 41.7% of the big enterprises and 18.1% of the small enterprises experience bribery requests, small enterprises spent 8.27% of their value on bribery, while big enterprises only spent 2.47% of their value on bribery. This observation concurs with the results in Bai *et al.* (2016) who show that as Vietnamese firms grow, they pay less of a bribe, compared to their size. Thus, we can conclude that while big enterprises pay more of a bribe compared to small enterprises, their bribe payment is less than that of the small enterprises, when compared to their size. In other words, although big enterprises experience more bribery requests, they can solve these problems with a small proportion of their value. That being said, this does not mean that the amount of their bribe payment is less than that of the small enterprises. On the contrary, the amount of the big enterprises' bribery payment is higher than that of the small enterprises.

Plant Size

Since ES interviewed enterprises with more than 5 employees and Turkish enterprises usually consist of less than 5 employees, I cannot use the ES dataset to analyze the plant size distribution of Turkey. Instead, I use the Annual Industry and Services Statistics provided by the Turkish Statistical Institute which is confidential data and consists of detailed information about all of the enterprises in Turkey. However, TurkStat annually reports their summary statistics, instead of providing micro data. Table 2.3 reports the plant size distribution in Turkey and the US. Note that these numbers are the average over the period of 2009-2014 for Turkey and 2009-2015 for the US. In addition, the unit of observation is the enterprise in Turkey whereas it is the establishment in the US.

The mean plant size in Turkey is almost one forth of that in the US. Given that the unit of observation in Turkey is the enterprise whereas it is the establishment in the US, this difference would be bigger if establishments could be measured in Turkey. This is because enterprises may contain more than one establishment. There are only 3.6 employees in an enterprise, on average, in Turkey. 97.32% of enterprises have 19 employees at most and 99.55% of all enterprises employ less than 100 workers. However, enterprises with more than 100 employees employ 43.6% of all workers.

Compared to the US, the plant-size distribution in Turkey is skewed to the left. However, the employment size distribution of the big plants is similar to that of the US. The frequency of plants with employees between 20 and 99 people is only 2.23% in Turkey but it is 13.21% in the US. Turkey's plant size distribution is an example of the "missing middle" literature proposed by Tybout (2000) and Krueger (2007) because there are very few middle sized firms, and employment is concentrated in a few big firms and a large number of small firms.

2.4 Model

Environment is similar to that in Guner *et al.* (2008) which puts forward a Lucas (1978) span-of-control framework in a growth model. The innovation in this paper is that there are exogenous corrupt officials who create distortions and it is possible to decrease some of the distortions by paying (endogenously chosen) bribery. There is a single infinitely-lived representative household which consists of a continuum of members of total size L_t. Household size grows at a constant rate g_n $\left(\frac{L_{t+1}}{L_t} = 1 + g_n\right)$ and household has a preference over the stream of consumption, C_t, discounts the future with $\beta \in (0,1)$ and maximizes:

$$\sum_{t=0}^{\infty} \beta^t L_t \log\left(\frac{C_t}{L_t}\right) \tag{2.1}$$

Each household member has one unit of time in every period and z units of managerial ability. The managerial abilities are distributed according to a distribution function, $F(z)$, and have a support $\bar{z}$. Household members can be a worker or a manager. The worker supplies labor inelastically and the worker's wage income becomes W no matter what the worker's ability level is.

Managers have access to the span-of-control technology and the manager devotes all of their time to production:

$$y = Az^{1-\gamma}\left(k^{\nu} n^{1-\nu}\right)^{\gamma} \tag{2.2}$$

where γ is the span-of-control parameter, A is the technology parameter which is common to all managers and grows at a constant rate g_A $\left(\frac{A_{t+1}}{A_t} = 1 + g_A\right)$, k is capital and n is labor used in the production process.

2.4.1 Distortion, Bribery and Manager's Problem

In this economy, agents are assigned to a corrupt official with some probability depending on their realization of z at birth. That is to say, agents with ability $z < \hat{z}$ are assigned to the corrupt official with probability α_0 and agents with ability $z \geq \hat{z}$ are assigned to the corrupt official with probability α_1. Meeting the corrupt official creates size dependent distortions in the form of output tax as well as fixed cost $\tilde{b}$. Hence, a manager encountered to a corrupt official has to pay the fixed cost and the output tax. However, managers have access to a bribery technology which lowers distortions by bribery payments. To be more specific, I assume average tax rate for the manager who produces output y and pays bribe b, is

$$T(y,b) = 1 - \lambda \left(y - v(y,b)\right)^{-\tau}$$

where τ is the parameter that controls size dependency, $v(y,b) = y\dfrac{\phi b}{1+\phi b}$ is the bribery technology and ϕ is the return on bribe. [5] Notice that when $\tau = 0$ average tax rate becomes $(1-\lambda)$ which is same for all managers regardless of their output level. However, when $\tau > 0$, the managers who produce more, have higher output taxes. If a manager decides not to pay any bribes, she faces an average tax rate of $(1-\lambda y^{-\tau})$ (because $v(y,0) = 0$). On the other hand, If a manager devotes a large amount of output for the bribery, she will have an average tax rate of $(1-\lambda)$ (because $\lim_{b\to\infty} v(y,b) = y$). To sum up, as the output increases, the managers faces higher distortion rates and they pay higher bribes.

A manager with ability z who faces and corrupt official chooses how much labor to hire, how much capital to rent and how much of a bribe to pay in order to maximize her profit. Hence, the managerial income, $\pi_c(z,W,R)$, is:

$$\pi_c(z,W,R) = \max_{\{k,n,b\}} \left(1 - T(y,b)\right) y - Wn - Rk - b - \tilde{b} \tag{2.3}$$

Optimal labor and capital demand and bribery payments can be derived from the first order conditions of (2.3)

$$n_c(z,W,R) = \left[A\gamma\nu\lambda^{\frac{1}{1-\tau}} \left(\tau\phi\right)^{\frac{\tau}{1-\tau}} \left(1-\tau\right)\right]^{\frac{1}{1-\gamma}} \left(\frac{1-\nu}{\nu}\right)^{\frac{1-\nu\gamma}{1-\gamma}} \left(\frac{1}{R}\right)^{\frac{\nu\gamma}{1-\gamma}} \left(\frac{1}{W}\right)^{\frac{1-\nu\gamma}{1-\gamma}} z \tag{2.4}$$

[5]Size-dependent distortions in the form of $T(y) = 1 - \lambda y^{\tau}$ is first used by Benabou (2002) and it has been used by Guner *et al.* (2015), Bento and Restuccia (2017b) and many others in the development literature for size dependent distortions. Here I introduce the bribery technology to the proposed functional form of size-dependent distortions.

$$k_c(z,W,R) = \left[A\gamma\nu\lambda^{\frac{1}{1-\tau}}(\tau\phi)^{\frac{\tau}{1-\tau}}(1-\tau)\right]^{\frac{1}{1-\gamma}}\left(\frac{1-\nu}{\nu}\right)^{\frac{\gamma(1-\nu)}{1-\gamma}}\left(\frac{1}{R}\right)^{\frac{1-\gamma(1-\nu)}{1-\gamma}}\left(\frac{1}{W}\right)^{\frac{\gamma(1-\nu)}{1-\gamma}} z \tag{2.5}$$

$$b(z,W,R) = \left[\lambda\tau^{1-\gamma(1-\tau)}(\phi^{\tau}A)^{(1-\tau)}\right]^{\frac{1}{(1-\tau)(1-\gamma)}}[\gamma(1-\tau\nu)]^{\frac{\gamma}{1-\gamma}}\left(\frac{1-\nu}{\nu}\right)^{\frac{\gamma(1-\nu)}{1-\gamma}}\left(\frac{1}{R}\right)^{\frac{\nu\gamma}{1-\gamma}}\left(\frac{1}{W}\right)^{\frac{\gamma(1-\nu)}{1-\gamma}} z - \frac{1}{\phi} \tag{2.6}$$

On the other hand, a manager with ability z who is not assigned to the corrupt official chooses only how much labor to hire and how much capital to rent since she does not face any distortions. Therefore, her managerial income , $\pi_{nc}(z,W,R)$ is:

$$\pi_{nc}(z,W,R) = \max_{\{k,n\}} \quad y - Wn - Rk \tag{2.7}$$

Optimal labor and capital demand for this manager again can be derived from first order conditions of (2.7):

$$n_{nc}(z,W,R) = [A\gamma\nu]^{\frac{1}{1-\gamma}}\left(\frac{1-\nu}{\nu}\right)^{\frac{1-\nu\gamma}{1-\gamma}}\left(\frac{1}{R}\right)^{\frac{\nu\gamma}{1-\gamma}}\left(\frac{1}{W}\right)^{\frac{1-\nu\gamma}{1-\gamma}} z \tag{2.8}$$

$$k_{nc}(z,W,R) = [A\gamma\nu]^{\frac{1}{1-\gamma}}\left(\frac{1-\nu}{\nu}\right)^{\frac{\gamma(1-\nu)}{1-\gamma}}\left(\frac{1}{R}\right)^{\frac{1-\gamma(1-\nu)}{1-\gamma}}\left(\frac{1}{W}\right)^{\frac{\gamma(1-\nu)}{1-\gamma}} z \tag{2.9}$$

After the managers choose their optimal bribery amounts, they pay $1-\lambda(y^* - v(y^*, b^*))$ (effective tax rate) fraction of their output to the government where y^* and b^* are the optimal output and the optimal bribery amount chosen by a manager respectively. The government collects taxes (i.e., the effective taxes) and returns it to the household. That is to say, the government revenue is the net of the tax revenue out of the bribery and this revenue goes back to the household in a lump-sum manner every period:

$$T_t = G_t \quad \forall t \tag{2.10}$$

where G_t denotes the government revenue and T_t denotes the lump-sum transfers to the household.

2.4.2 Household's Problem

In every period, the representative household chooses how much of the goods will be consumed, C_t, how much of them will be carried to the next period, K_{t+1}, what fraction of the household members will be workers and managers among the agents who are assigned to the corrupt official, $\tilde{z}_{c,t}$ and, what fraction of the household members will be workers and managers among the agents who are not assigned to the corrupt official, $\tilde{z}_{nc,t}$ to maximize (2.1):

$$\max_{\{C_t, K_{t+1}, \tilde{z}_{c,t}, \tilde{z}_{c,t}\}_0^\infty} \sum_{t=0}^{\infty} \beta^t L_t \log\left(\frac{C_t}{L_t}\right)$$

s.t

$$C_t + K_{t+1} = I_t(\tilde{z}_{c,t}, \tilde{z}_{nc,t}, W_t, R_t)L_t + (1-\delta+R_t)K_t + T_t$$

where $K_0 > 0$ given, $\tilde{z}_{c,t}$ is the threshold level for managerial ability to be a manager for household members who are encountered to the corrupt official, $\tilde{z}_{nc,t}$ is the threshold level for managerial ability to be a manager for household members who are not encountered to the corrupt official, T_t denotes transfers and $I_t(\tilde{z}_{c,t}, \tilde{z}_{nc,t}, W_t, R_t)$ is the income of the household members:

$$\begin{aligned} I_t(\tilde{z}_{c,t}, \tilde{z}_{nc,t}, W_t, R_t) = W_t\left(\alpha_0 F(\tilde{z}_{c,t}) + (1-\alpha_0)F(\tilde{z}_{nc,t})\right) + \\ \alpha_0 \int_{\tilde{z}_{t,c}}^{\hat{z}} \pi_c(z_t, W_t, R_t) f(z)dz + (1-\alpha_0)\int_{\tilde{z}_{t,nc}}^{\hat{z}} \pi_{nc}(z_t, W_t, R_t) f(z)dz + \\ \int_{\hat{z}}^{\bar{z}} \left(\alpha_1 \pi_c(z_t, W_t, R_t) + (1-\alpha_1)\pi_{nc}(z_t, W_t, R_t)\right) f(z)dz \end{aligned} \tag{2.11}$$

The first line on the right-hand side in equation (2.11) represents the wage income of workers and the second line stands for the total profit of the managers whose ability level is less than $\hat{z}$ and last line denotes the total managerial income of household members with ability level more than $\hat{z}$. Let λ_t be the Lagrangian multiplier associated with the households budget constraint at time t. The first order conditions with respect to C_t, K_{t+1}, $\tilde{z}_{c,t}$ and $\tilde{z}_{nc,t}$ are

$$\beta^t L_t \frac{1}{C_t} = \lambda_t \tag{2.12}$$

$$\lambda_{t+1}(1 - \delta + R_{t+1}) = \lambda_t \tag{2.13}$$

$$W_t = \pi_c(\tilde{z}_{c,t}, W_t, R_t) = \pi_{nc}(\tilde{z}_{nc,t}, W_t, R_t) \tag{2.14}$$

by combining equation (2.12) and (2.13), we can derive the usual intertemporal Euler equation:

$$\frac{C_{t+1}/L_{t+1}}{C_t/L_t} = \beta(1 - \delta + R_{t+1}) \tag{2.15}$$

Equations (2.14) and (2.15) characterize the household's problem. Equation (2.14) requires that the agent with managerial ability $\tilde{z}_c$ and $\tilde{z}_{nc}$ (threshold ability levels for being a manager or being a worker for agents who are assigned to a corrupt official and who are not assigned, respectively) must be indifferent between becoming a manager or a worker. Equation (2.15) has a well-known interpretation: the household must be indifferent between consuming one more unit this period and saving and consuming that unit in the next period.

2.4.3 Equilibrium

In the equilibrium, given prices, distortions and transfers $\{W_t^*, R_t^*, \lambda, \tau, T_t^*\}_0^\infty$, the household maximizes her utility by choosing optimal $\{C_t^*, K_{t+1}^*, \tilde{z}_{c,t}^*, \tilde{z}_{nc,t}^*\}_0^\infty$ such that the allocation solves the mangers' problem. The government budget is balanced and all of the markets clear. The market clearing condition for the labor market is:

$$\begin{aligned}\alpha_0 F(\tilde{z}_{t,c}^*) + (1-\alpha_0)F(\tilde{z}_{t,nc}^*) = \alpha_0 &\int_{\tilde{z}_{t,c}^*}^{\hat{z}} n_c^*(z, W_t^*, R_t^*) f(z) dz + \\ (1-\alpha_0) &\int_{\tilde{z}_{t,nc}^*}^{\hat{z}} n_{nc}^*(z, W_t^*, R_t^*) f(z) dz + \\ &\int_{\hat{z}}^{\bar{z}} \left(\alpha_1 n_c^*(z, W_t^*, R_t^*) + (1-\alpha_1) n_{nc}^*(z, W_t^*, R_t^*)\right) f(z) dz \quad (2.16)\end{aligned}$$

where $F(\tilde{z}_{c,t}^*)$ and $F(\tilde{z}_{nc,t}^*)$ are the labor supply of household members who are assigned to the corrupt official and who are not assigned to the corrupt official respectively, and $n_c^*(z, W_t^*, R_t^*)$ is the labor demand by a manager with ability z who is encountered to the corrupt official and $n_{nc}^*(z, W_t^*, R_t^*)$ is the labor demand by a manager with ability z who is not encountered to the corrupt official. Therefore the right hand side of the equation (2.16) is the labor demand in the economy. The market clearing condition for the capital is :

$$\begin{aligned}K_t^* = \alpha_0 \int_{\tilde{z}_{t,c}^*}^{\hat{z}} k_c^*(z, W_t^*, R_t^*) f(z) dz + (1-\alpha_0) \int_{\tilde{z}_{t,nc}^*}^{\hat{z}} k_{nc}^*(z, W_t^*, R_t^*) f(z) dz + \\ \int_{\hat{z}}^{\bar{z}} \left(\alpha_1 k_c^*(z, W_t^*, R_t^*) + (1-\alpha_1) k_{nc}^*(z, W_t^*, R_t^*)\right) f(z) dz \quad (2.17)\end{aligned}$$

where K_t^* is the supply of the capital and $k_c^*(z, W_t^*, R_t^*)$ is the demand for the capital by a manager with ability z who is encountered to the corrupt official and $k_{nc}^*(z, W_t^*, R_t^*)$ is the capital demand by a manager with ability z who is not encountered to the corrupt official. Hence the right hand side of the equation (2.17) is the total demand for the capital in the economy. The goods market equilibrium is:

$$C_t^* + K_{t+1}^* = \alpha_0 \int_{\tilde{z}_{t,c}^*}^{\hat{z}} y_c^*(z, W_t^*, R_t^*) f(z) dz + (1 - \alpha_0) \int_{\tilde{z}_{t,nc}^*}^{\hat{z}} y_{nc}^*(z, W_t^*, R_t^*) f(z) dz +$$
$$+ \int_{\hat{z}}^{\bar{z}} \left(\alpha_1 y_c^*(z, W_t^*, R_t^*) + (1 - \alpha_1) y_{nc}^*(z, W_t^*, R_t^*) \right) f(z) dz + (1 - \delta) K_t^* \quad (2.18)$$

Discussion

In this section, the properties of the model in the steady-state equilibrium are presented in details. The rental rate is constant and per capita consumption, output and wage grows at a constant rate of $g(g_A)$, over time. Also aggregate capital, consumption and output grow at a constant rate $(1 + g_n)(1 + g)$. The first observation is that the rental rate, R^*, is constant over the steady-state equilibria. To observe this, we can arrange the Euler equation (2.15) as follows:

$$R^* = \frac{1 + g}{\beta} + \delta - 1 \quad (2.19)$$

Next, the capital-labor ratio of managers who are encountered to the corrupt official and who are not encountered to the corrupt official, is found by dividing equation (2.5) into equation (2.4) and by dividing equation (2.9) into equation (2.8)

$$\hat{k} \equiv \frac{k_c^*(z, W, R)}{n_c^*(z, W, R)} = \frac{k_{nc}^*(z, W, R)}{n_{nc}^*(z, W, R)} = \frac{\nu}{1 - \nu} \frac{W}{R} \quad (2.20)$$

Despite the fact that capital-labor ratios are same for all managers regardless of being assigned to the corrupt official or not, managers who are assigned to the corrupt official demand less capital and labor than managers who have same ability but are not assigned to the corrupt official. In order to see this, for example, divide equation (2.4) by equation (2.8):

$$\frac{n_c(z,W,R)}{n_{nc}(z,W,R)} = \left[\lambda^{\frac{1}{1-\tau}} \left(\tau\phi\right)^{\frac{\tau}{1-\tau}} \left(1-\tau\right)\right]^{\frac{1}{1-\gamma}} < 1$$

This is the first source of the misallocation that the existence of the corrupt official creates. In other words, managers who encounter the corrupt official demand less inputs and produce less output.

The second source of misallocation associated with the existence of corrupt official is through the selection of managers. Consider the first order conditions of the household, equation (2.14). Since $\pi_c(z,W,R) < \pi_{nc}(z,W,R)$ for any values of z, threshold value for agents who are assigned to the corrupt official, to be a manager is higher than the threshold value of agents who are not assigned to the corrupt official: $\tilde{z}_c > \tilde{z}_{nc}$. Therefore, some of the agents who would be managers if they were not assigned to the corrupt official become workers.

2.5 Calibration

First, I calibrate the model in order to match the U.S. plant size distribution by assuming that the U.S. is free of distortion and bribery. Then, I also calibrate this model to match Turkey's not only the plant size distribution but also the bribery payments of different size groups.

For the U.S. I borrow following parameters from Guner *et al.* (2008) : $g_n = 0.011$ (population growth rate), $g_A = 0.0255$ (productivity growth rate), $\nu = 0.406$, $\beta = 0.9357$, $\delta = 0.04$ and $\gamma = 0.802$. Then I assume composite lognormal-Pareto distribution for the distribution of managerial ability, $F(z)$. Composit lognormal-Pareto distribution characterized by three parameters: standard deviation of lognormal distribution,σ, shape parameter of Pareto distribution, s, and threshold value for distributions, $\hat{z}$. [6] I use mean size of the plants, fraction of plants with 1-49

[6]See Scollnik (2007) for more details.

employees and proportion of workers in big plants. Table 2.4 and 2.5 display the calibrated parameter values and the model performance.

For the calibration of the Turkish economy, I borrow some of the parameters from the literature and I calculate some of them using National Income and Product Accounts. I choose the share of capital, $\alpha\gamma = 0.34$, depreciation, $\delta = 0.055$ and discount rate, $\beta = 0.95$ consistent with Atesagaoglu *et al.* (2017) and Atiyas and Bakış (2014). These parameters are used in the Penn World Tables to make cross-country comparisons. Then I calculate the average population growth rate, $g_n = 0.0209$, over the period of 1950-2014. I set the productivity growth rate, $g_A = 0.0256$, to match the average annual output growth rate as 4.65% over the same period.

Guner *et al.* (2008) estimate the span of control parameter, $\gamma = 0.802$ for the US in which the mean establishment size is 17.09 employees. In addition, Leal (2014) estimates the same parameter for Mexico whose mean establishment size is 5.5 employees and finds $\gamma = 0.76$. Since Turkey's mean enterprise size is 3.6 employees, I choose $\gamma = 0.7$. Given γ, the value of α can be determined as $\alpha = 0.34/\gamma = 0.486$

Next, I again assume a composite lognormal-Pareto distribution for the distribution of managerial abilities. For the distortions, I have six additional parameters to estimate: λ, τ, ϕ, α_0, α_0 and $\bar{b}$. Since I focus on enterprises with less than, or more than, a hundred employees, I choose $\hat{z} = 0.9955$. Finally, I have nine parameters (i.e., three for ability distribution and six for size-dependent distortions) to estimate: σ, s, $\hat{z}$, λ, τ ϕ, α_0, α_1 and $\tilde{b}$. In addition, I have nine moments from data to match: the mean plant size, the fraction of plants with 1-49 employees, the fraction of plants with 50-99 employees, the employment share of plants with 50-99 employees, the employment share of plants with more than 100 employees, bribes as a percentage of the output of small plants and big plants among the plants who paid bribes and bribes as a percentage of the total output of small plants and big plants regardless of being paid bribery. I use the average of the 2009-2014 data for the plant size distribution moments and I use the 2013 ES for bribery moments. Tables 2.6 and 2.7 summarize the parameter values and the calibration performance.

The assumed distribution function is able to generate the U.S. plant size distribution. Moreover, although there is some room for the improvement with more data and careful parametrization, the model is able to generate not only the plant size distribution of Turkey but also the relative bribery payments of different size groups. Estimated average effective tax rate for small and big plants are 39.3% and 49.8% respectively. Even if one cannot directly relate the fraction of the plants who accept that they paid bribe in the data and the probability of being assigned to the corrupt official in the model, inferred probabilities are far from the fractions that we obtain from the data. In an alternative setting, one can assume probabilities are equal to the fraction of plants who accept that they paid bribe and calibrate the rest of the parameters.

2.6 Results of Experiments

In this section, the results of the experiments are presented. First, I introduce the size dependent distortions and the bribery opportunities to the U.S. economy. Then I run experiments with Turkey's economy which is calibrated with the size dependent distortions and the bribery opportunities. These involve analyzing the effects of changing the size dependency of the distortions, the return on bribe and the probability of a meeting with the corrupt official. Then I discuss the consequences of removing the bribery and the distortions. I compare the new steady-state values of the output, mean size, employment share of big enterprises, tax wedge, average effective tax rate and bribery expenditure with the benchmark steady-state values. Tax wedge is defined as following

$$\frac{1 - T\left(5\bar{y}, 5\bar{b}\right)}{1 - T\left(\bar{y}, \bar{b}\right)} \tag{2.21}$$

where $\bar{y}$ and $\bar{b}$ indicate average values of output and bribe, respectively. It was, first, defined by Guner *et al.* (2015) and has following useful interpretation: Tax wedge compares distortion rate for the manager who produces 5 times more than the average output and distortion rate for the manager who produces the average output level. If the distortions are same for all the managers ($\tau = 0$), tax wedge is equal to one and it decreases with the level of size dependency of distortions.

Tables 2.8 and 2.9 report the results of the experiments with the U.S economy. In each table output at the benchmark steady state is normalized to 100, in order to easily compare the experimental results. In addition, λ equals to one in each of the tables. Table 2.8 shows the results of increase in the size dependency without any bribery opportunity. However, Table 2.9 displays the same experiment with bribery opportunities. In Table 2.9, probabilities of the meeting with corrupt official, α_0 and α_1 are equal to one, the return on bribe, ϕ, is set to 0.2 and fixed cost of being assigned to a corrupt official, $\tilde{b}$, is equal to the 2.3 % of the mean output of small plants.

As Table 2.8 illustrates, increase in the size dependency (increase in τ) distorts bigger plants more, relative to the small plants. This can be observed by the decrease in the tax wedge or increase in the difference between average tax rate by small and big plants. As a result, size dependent distortions reallocate resources from bigger plants to the small plants, which yields that mean size of the plants, aggregate output and employment share of the big plants decreases gradually. These results are in line with the previous literature such as Guner *et al.* (2008), Bhattacharya *et al.* (2013) and Guner *et al.* (2015) and shows the well known effects of size dependent distortions.

On the other hand, table 2.9 shows similar experiments with the bribery. Since bigger plants face bigger distortion levels and they have more resources to pay the bribe, they face lower average effective tax compared to the previous case where there was no bribery opportunity. Therefore, big plants' employment share increases. Moreover, since there is a fixed cost associated with being assigned to the corrupt official, small plants on the margin are not able to operate and they become workers. As a result, the mean size and the employment share of big plants increase whereas the aggregate output decreases. In addition, increase in the degree of size dependency of distortions, decreases aggregate variables, such as the mean size and the aggregate output but the effects are relatively smaller than the case without bribery. For example, when τ increases from 0.02 to 0.05, mean size decreases 9% when there is bribery opportunity whereas it decreases 34% when there is no bribery.

Effects of size dependency in the Turkish economy where managers have an access to bribery technology are presented in the Table 2.10. Notice that other than τ, all parameters are held constant at the values shown in the Table 2.6. That is to say, only 4% of the big plants and 79% of the small plants are distorted. As size dependent distortion increases, all the managers especially in bigger plants are exposed to higher distortion rates. Although they increase their bribery payments, average effective tax rate for both big and small plants increase. Hence some of the managers who cannot afford high tax rates become worker and remaining managers decrease their labor demands, which decreases wage rate. Decrease in the wage rate increases labor demand of managers who are not meeting the corrupt official. Since 96% of the big plants are not meeting the corrupt official whereas only 26% of small plants are not assigned to the corrupt official, increase in the big plants' labor demand is more than the increase in the labor demand of small plants. As a result, the mean size slightly increases and the aggregate output decreases while the employment share of big plants stays roughly constant as size dependency increases.

Table 2.11 reports the effect of increase in the size dependent distortions without bribery opportunities. That is to say, managers who are assigned to the corrupt official are still have to pay fixed cost and they are not able to decrease tax rate by bribing. The mean size, the aggregate output and the employment share of big plants have the same trend with the last experiment. However, average effective tax rates are higher in the case when managers are not allowed to bribe the corrupt official. In addition, the difference between average taxes for big and small is bigger now.

The return on bribe shows the effectiveness of the bribery mechanism. Table 2.12 shows the effect of change in the return on bribe. The mean size, the aggregate output and the employment share of big plants almost stay constant. Also, the average effective tax and the average bribery payments of small plants do not change. However, big plants increase their bribery spendings with more effective bribery mechanism. In return, they have lower average effective tax rates. Hence, increase in the return on bribe decreases the size dependency of the distortions.

Although the existence of corrupt official is exogenous in this economy, we can see the effect of change in the probability of being assigned to the corrupt official in table 2.13. In this experiment, I increase the probability of meeting the corrupt official for both size groups together from left to right of the table. As the probability increases, more agents are assigned to the corrupt official in the steady state. The newly assigned managers with low ability levels become workers and the newly assigned managers with high ability levels decrease their input demands. Since decrease in the labor demand occurs at the bigger plants, wage rate decreases in the new equilibrium. Hence managers who are not assigned to the corrupt official increase their demand for inputs. As a result, the mean size and the employment share of big plants increase and the aggregate output decreases.

Table 2.14 reports the steady-state values without bribes and distortions. When all bribery opportunities in the economy are removed, the aggregate output decreases slightly, and the mean size and the employment share of big plants remain constant. Without a distortion, there is no incentive for bribery and no fixed cost. Therefore, the aggregate output increases 12.64%, compared to the benchmark case. While the employment share of big plants decreases, the mean size almost doubles.

2.6.1 Discussion

Experiments conducted with different returns on bribes, distortion rates and probabilities for the U.S. and the Turkish economy have three primary conclusions: bribery decreases the size dependency of distortions, if bribery opportunities exits, change in distortion levels has little effect on the aggregate output and removing distortions can decrease output substantially.

The first conclusion is that size dependent distortions becomes less effective in the presence of bribery opportunities. Bigger plants face higher distortions, but they are able to spend more resources on bribery. Hence, they reduce their distortion levels more than the small plants do. As a result, the difference in distortion rates of small and big plants becomes negligible in the presence of the bribery opportunities. If the return on bribes increases, the effective tax rates decrease to even lower values because the managers can solve whatever problem they face with a small amount of bribery. Therefore, the effectiveness of bribery only determines how much of their output will be spent on the bribery.

The second conclusion is that changes in the distortion levels have little impact on the economy. Consider the case when the τ increases from 0.09 to 0.15: the output decreases by 1.1% and the change in the mean size is almost zero. Also the employment share of big firms remains nearly constant. There are two reasons for this. First, as τ increases all the managers face higher distortions but increase in the plants' distortions is relatively higher than the increase in the small plants distortion rates. However, only 4% of big plants are distorted whereas 79% of the small plants are assigned to the corrupt official. Hence, the effects of the increase in the τ are small. That being said, second, big firms can rule out the effects of an increase in the distortion level by a small increase in their bribery expenditures. Since they are able to devote a larger amount of output to the bribery, they face lower distortions.

Compared the U.S. economy experiment, the increase in the size dependency of the distortions have the opposite effect in case of Turkish economy experiments. As τ increases, the mean size increases in Turkish economy whereas it decreases in the U.S. economy. The reason for this is the existence of extensive margin in Turkish economy. In other words, there are managers who are not assigned to the corrupt official in Turkish economy however the U.S. economy experiments conducted with the assumption of all agents are assigned to the corrupt official. When there is extensive margin in the economy, there are managers who take advange of the decrease in the wage rates. Especially, 96% of the big plants and the 21% of the small plants are not assigned to the corrupt official in Turkish economy. So increase in the labor demand by big plants is more than the increase in the labor demand by small plants. That is why Turkish economy experience bigger mean size with the increase of the size dependent distortions.

The third conclusion is that removing distortions can increase aggregate output and mean size while it decreases employment share of the big firms substantially. The aggregate output increases more than 12%, the mean size doubles and the employment share of the big plants decreases from 43% to 38% In the benchmark case, even if the managers are able to bribe, the small plants and the big plants face 39.3% and 49.8% effective tax rates in addition to the fixed cost.

There are two consequences of being assigned to the corrupt official: the distortions in the form of an output tax and the fixed cost. Managers are able to decrease the distortion rate however they are not able to avoid fixed cost associated with meeting the corrupt official. Removal of bribery opportunities does not have big impact on the economy. The mean size and the employment share of the big plants stays constant and the aggregate output decreases only 0.17% percent. This result shows that the effectiveness of the bribery mechanism is low and the effect of the fixed cost is higher.

Overall, the results hold when we consider the distortions as given. Since the bribery activities or the existence of bribery opportunities does not affect the level of distortion rates, bribery may look beneficial to the managers. It is important to note that there are no government officials in this model. Hence I am considering bureaucratic corruption to be exogenous. However, an alternative setting as Svensson (2005) points out that if corruption and distortions are caused by the same set of factors, we cannot remove the bribery and keep all the distortions as they are at the same time. In fact, corrupt officials may create problems to exploit bribery opportunities (Myrdal (1968)). Therefore, my conclusion differs if the level of corruption and distortion can be endogenized in a model where government officials create more distortions to exploit bribery and the agents sort themselves into three different careers: worker, manager and government official. This model environment can result in different conclusions from mine because of two reasons: some of the high ability agents can choose to be government officials to enjoy bribery and corrupt officials may increase the distortion levels, as managers pay bribes. As a result, the aggregate output and mean size will decrease.

2.7 Conclusion and Future Work

In this study, I show that bigger plants in Turkey spend less fraction of their output on bribery compared to that of small plants do. I then extend the model of

Guner *et al.* (2008), by allowing managers to bribe officials to decrease the tax rate which is imposed based on their plant size. After I calibrate this model to match the Turkish plants size distribution and bribery payments of different size groups, I quantify the anti-bribery and anti-distortion policies on the aggregate output, mean size, employment share of big enterprises, average effective tax and average bribe rate response. Given that bribery opportunities exist, effect of size dependent distortions become small, as managers can decrease them with bribery. In addition, changes in the distortion level do not have huge effects on the aggregate economy, as they can be ruled out by bribery. By removing the distortions, the output level may increase by more than 12% and mean size may double.

Despite the fact that bribery can lower distortions for bribe payers, it can be costly for those who are not involved in the bribery. For example, politically connected firms rather than most able firms, can acquire public resources through bribery (Khwaja and Mian (2005); Fisman (2001)). The case of a manager that has to pay a bribe to acquire an operating license, can have two social consequences: it can limit some managers from starting to do business because of high entry costs and since government officials can delay the administrative process to attract more bribes (Svensson (2005); Myrdal (1968)). In addition, effects of changes in the government policies on the economy can be different from what is aimed by the government under the presence of bribery opportunities. For instance, the policy that increases tax rates for big enterprises will not have a big impact on neither the aggregate output nor the tax revenues collected, since enterprises can decrease the effective tax rates by increasing their bribery payments.

Although this study uses the most detailed data about plant size distribution and bribery payments in Turkey, there is still room for increasing the quality of the dataset by focusing on the size distribution of small enterprises and by having a large sample by including small firms in bribery surveys. Hence, future studies can conduct more precise calibrations with more detailed datasets for both plant size and bribery payments.

Future research can also focus on three different extensions of this model. The first extension is about the relationship between bribery and aggregate variables such as, GDP per capita, mean size and managerial quality at the cross-country level. We know that bribery incidence is negatively correlated with these aggregate variable. Therefore having a model which incorporates with these cross country facts can give us a better understanding the relation between development, bribery and the corruption.

Second, the relationship between managerial skill accumulation and bribery is worth investigation. Managers exposed to more bribery requests tend to spend more time and resources to 'get things done'. Instead, they can also use these resources to accumulate their managerial skills and increase their profits. For example, they may spend their time and income getting an MBA degree, instead of spending their time on making connection with officers and bribing them. Thus, if the environment of Bhattacharya *et al.* (2013) where managers can accumulate skills and the setup of this paper are integrated, research can focus on the effects of bribery on managerial skill accumulation.

Third, the level of distortions can be endogenized by allowing agents to choose whether or not to be (corrupt) government officials. With this extension, some of the high ability agents can choose to be a government official, depending on bribery returns. In addition, they can increase the distortion levels to enjoy more bribery returns. As a result, a bribery opportunity may have the opposite effect from the conclusion of this study.

Table 2.1: Bribery Incidence Variables in Turkey, 2013

Enterprise size	Electrical connection	Water connection	Construction permit	Tax inspection	Import licence	Operating Licence
All	5.46%	8.80%	5.47%	2.16%	4.43%	2.22%
5-99	5.32%	9.56%	5.81%	2.19%	4.76%	2.07%
100+	7.83%	1.29%	2.47%	1.64%	3.42%	4.19%

Notes: Each entry shows the percentage of plants who experienced an informal payment or gift request when they contacted government officials to apply for the corresponding column. Statistics are provided in three categories: All enterprises (All), enterprises who have less than 100 (5-99) and more than 100 employees (100+).

Source: Enterprise Survey.

Table 2.2: Other Bribery Measures in Turkey, 2013

Enterprise Size	Bribery incidence	Bribe to secure government contract	Other Bribes	Total Bribe Rate	Total Bribe to Total Value Ratio	Bribe to Value Ratio
All	4.53%	10.12%	4.48%	19.24%	0.74%	8.21%
5-99	4.55%	8.62%	4.82%	18.08%	0.77%	8.27%
100+	4.30%	39.09%	0.00%	41.68%	0.05%	2.47%

Notes: Each entry shows the percentage of plants. Bribery incidence column shows the percentage of plants who experieced at least one bribery payment request among the applications provided in Table 2.1. Bribe to secure government contract column shows what percentage of firm are asked bribe to secure government contract. Other Bribes denotes the percentage of firms who experience bribe request other than previously mentioned cases. Total Bribe Rate shows the percentage of firms who are asked to pay bribes. Total Bribe to Total Value Ratio is the percentage of total bribes in terms of total value of interviewed enterprises. Bribe to Value Ratio shows the percentage of total bribes in terms of total value of enterprises who admitted that they pay bribes.

Source: Enterprise Survey.

Table 2.3: Plant Size Distribution in Turkey and US

	Turkey (Enterprises-Average 2009-2014)	US (Establishments-Average 2009-2015)
Mean size	3.62	15.65
Size distribution		
1-19	97.32%	86.13%
20-49	1.75%	8.64%
50-99	0.48%	2.92%
100-249	0.31%	1.65%
250+	0.15%	0.67%
Employee distribution		
1-19	33.07%	24.89%
20-49	14.47%	16.61%
50-99	8.86%	12.79%
100-249	12.77%	15.80%
250+	30.83%	29.92%

Sources: Turkey data is from TurkStat-Annual Industry and Services Statistics. US data is from Census-County Business Pattern.

Notes: This table compares plant size distributions in Turkey and US. Unit of observation is the enterprise in Turkey and the establishment in US. Mean size shows the average number of employees in a plant. Size distribution categories displays what percentage of plants belong to that category. Employee distribution demonstrates each categories' employment rate as the percentage of total employment.

Sources: TurkStat and County Business Dynamics

Table 2.4: Parameter Values for the U.S.

Parameter	Value
σ	2.61
s	0.93
$F(\hat{z})$	0.54

Notes: Value column shows the parameters values which generate the plant size distribution in the U.S. economy.

Table 2.5: Calibration Targets and Model for the U.S.

	Data	Model
Mean size	17.09	17.18
Fraction of enterprises		
1-19	84.7%	85.8 %
20-49	9.4%	8.2 %
50-99	3.2%	2.8 %
100+	2.6%	3.2 %
Employment share of 100+	44.95%	44.11%

Note: This table shows the calibration performance. The data column shows the target moment conditions for the U.S. economy which are borrowed from Guner *et al.* (2008). The model column shows how model results with the calibrated parameters reported in Table 2.4.

Table 2.6: Parameter Values for Turkey

Parameter	Value
τ	0.09
λ	0.75
ϕ	0.24
α_0	0.79
α_1	0.04
$\tilde{b}/\bar{y}_c^0$	0.07
σ	1.84
s	2.49
$F(\hat{z})$	0.42

Note: Value column shows the parameters values which generate the key variables in the Turkish economy. $\bar{y}_c^0$ denotes the average output of small plants who encounter the corrupt official.

Table 2.7: Calibration Targets and Model for Turkey

	Data	Model
Mean size	3.62	3.62
Fraction of enterprises		
1-49	99.1%	99.6%
50-99	0.48%	0.24%
Employment share of plants 50-99	8.9%	4.6%
Employment share of plants 100+	43.6%	42.7%
Bribe by 100− (as % of value)	0.8%	0.3%
Bribe by 100+ (as % of value)	0.05%	0.03%
Bribe by 100− (as % of value)/given paid bribe	8.3%	8.0%
Bribe by 100+ (as % of value)/given paid bribe	2.5%	4.5%

Note: This table shows the calibration performance. The data column shows the target moment conditions for Turkish economy. The model column shows how model results with the calibrated parameters reported in Table 2.6.

Table 2.8: Size Dependent Distortions in the U.S. Economy without Bribery

	Benchmark	$\tau = 0.01$	$\tau = 0.02$	$\tau = 0.05$
Mean Size	17.18	14.51	12.40	7.95
Output	100	96.54	93.13	83.34
Emp. Share 100+	0.44	0.38	0.33	0.19
Tax wedge	1.00	0.984	0.968	0.923
Avg tax-small		0.041	0.078	0.170
Avg tax-big		0.075	0.143	0.314

Note: This table summarize the effect of increase in the size dependency of distortions in the U.S. economy when there is no bribery opportunity. The output at the benchmark is normalized 100 so that the numbers in this row compare output with the benchmark case. Tax wedge is calculated according to the equation (2.21). Small and big refer to the plants with less than 100 workers and the plants with more than 100 workers, respectively.

Table 2.9: Size Dependent Distortions in the U.S. Economy with Bribery

	Benchmark	$\tau = 0.01$	$\tau = 0.02$	$\tau = 0.05$
Mean Size	17.18	26.86	25.54	23.36
Output	100.00	97.96	94.91	87.27
Emp. Share 100+	0.44	0.47	0.46	0.45
Tax wedge	1	0.990	0.985	0.978
Avg tax-small		0.047	0.089	0.197
Avg tax-big		0.061	0.107	0.215
Avg Bribe-small		0.030	0.035	0.051
Avg Bribe-big		0.009	0.018	0.039

Note: This table summarize the effect of increase in the size dependency of distortions in the U.S. economy when there a bribery opportunity. The output at the benchmark is normalized 100 so that the numbers in this row compare output with the benchmark case. Tax wedge is calculated according to the equation (2.21). Small and big refer to the plants with less than 100 workers and the plants with more than 100 workers, respectively.

Table 2.10: Size Dependent Distortions in the Turkish Economy with Bribery

	Benchmark			
	$\tau = 0.09$	$\tau = 0.10$	$\tau = 0.11$	$\tau = 0.15$
Mean Size	3.62	3.64	3.65	3.70
Output	100	99.72	99.53	98.90
Emp. Share 100+	0.43	0.43	0.43	0.43
Tax wedge	0.87	0.85	0.84	0.79
Avg. tax-small	0.393	0.408	0.421	0.470
Avg. tax-big	0.498	0.519	0.537	0.603
Avg bribe-small	0.080	0.082	0.084	0.087
Avg bribe-big	0.045	0.048	0.051	0.060

Note: This table summarize the effect of increase in the size dependency of distortions in the Turkish economy when there is a bribery opportunity. The output at the benchmark is normalized 100 so that the numbers in this row compare output with the benchmark case. Tax wedge is calculated according to the equation (2.21). Small and big refer to the plants with less than 100 workers and the plants with more than 100 workers, respectively.

Table 2.11: Size Dependent Distortions in the Turkish Economy without Bribery

	$\tau = 0.09$	$\tau = 0.10$	$\tau = 0.11$	$\tau = 0.15$
Mean Size	3.62	3.64	3.65	3.70
Output	99.83	99.58	99.40	98.80
Emp. Share 100+	0.43	0.43	0.43	0.43
Tax wedge	0.867	0.851	0.838	0.786
Avg. tax-small	0.393	0.409	0.421	0.470
Avg. tax-big	0.659	0.695	0.723	0.802

Note: This table summarize the effect of increase in the size dependency of distortions in the Turkish economy when there is no bribery opportunity. The output at the benchmark is normalized 100 so that the numbers in this row compare output with the benchmark case. Tax wedge is calculated according to the equation (2.21). Small and big refer to the plants with less than 100 workers and the plants with more than 100 workers, respectively.

Table 2.12: Role of Return on Bribe in the Turkish Economy

			Benchmark	
	$\phi = 0.10$	$\phi = 0.15$	$\phi = 0.24$	$\phi = 0.35$
Mean Size	3.62	3.62	3.62	3.62
Output	99.95	99.97	100	100.03
Emp. Share 100+	0.43	0.43	0.43	0.43
Tax wedge	0.868	0.868	0.870	0.872
Avg. tax-small	0.393	0.393	0.393	0.393
Avg. tax-big	0.538	0.519	0.498	0.478
Avg bribe-small	0.080	0.080	0.080	0.080
Avg bribe-big	0.041	0.043	0.045	0.046

Note: This table summarize the effect of increase in the return on bribe in the Turkish economy. The output at the benchmark is normalized 100 so that the numbers in this row compare output with the benchmark case. Tax wedge is calculated according to the equation (2.21). Small and big refer to the plants with less than 100 workers and the plants with more than 100 workers, respectively.

Table 2.13: Role of Corrupt Officials in the Turkish Economy

		Benchmark		
	$\alpha_0 = 0.75$	$\alpha_0 = 0.79$	$\alpha_0 = 0.85$	$\alpha_0 = 0.9$
	$\alpha_1 = 0.035$	$\alpha_1 = 0.04$	$\alpha_1 = 0.045$	$\alpha_1 = 0.05$
Mean Size	3.29	3.62	5.21	7.77
Output	108.02	100	99.20	97.90
Emp. Share 100+	0.40	0.43	0.49	0.55
Tax wedge	0.869	0.870	0.869	0.869
Avg. tax-small	0.393	0.393	0.391	0.389
Avg. tax-big	0.498	0.498	0.498	0.498
Avg bribe-small	0.080	0.080	0.081	0.081
Avg bribe-big	0.045	0.045	0.045	0.045

Note: This table summarize the effect of increase in the probability of a meeting the corrupt official in the Turkish economy. The output at the benchmark is normalized 100 so that the numbers in this row compare output with the benchmark case. Tax wedge is calculated according to the equation (2.21). Small and big refer to the plants with less than 100 workers and the plants with more than 100 workers, respectively.

Table 2.14: Removal of Bribery Opportunities and Distortions in the Turkish Economy

	Benchmark	No Bribery	No Distortion
Mean Size	3.62	3.62	7.21
Output	100	99.83	112.64
Emp. Share 100+	0.43	0.43	0.42
Tax wedge	0.870	0.867	
Avg. tax-small	0.393	0.393	
Avg. tax-big	0.498	0.659	
Avg bribe-small	0.080		
Avg bribe-big	0.045		

Note: This table summarizes the result of removing bribery and removing distortions. The output at the bencmark case is normalized to 100 so that the numbers in this row compare output with the benchmark case. Tax wedge is calculated according to the equation (2.21). Small and big refer to the plants with less than 100 workers and the plants with more than 100 workers, respectively.

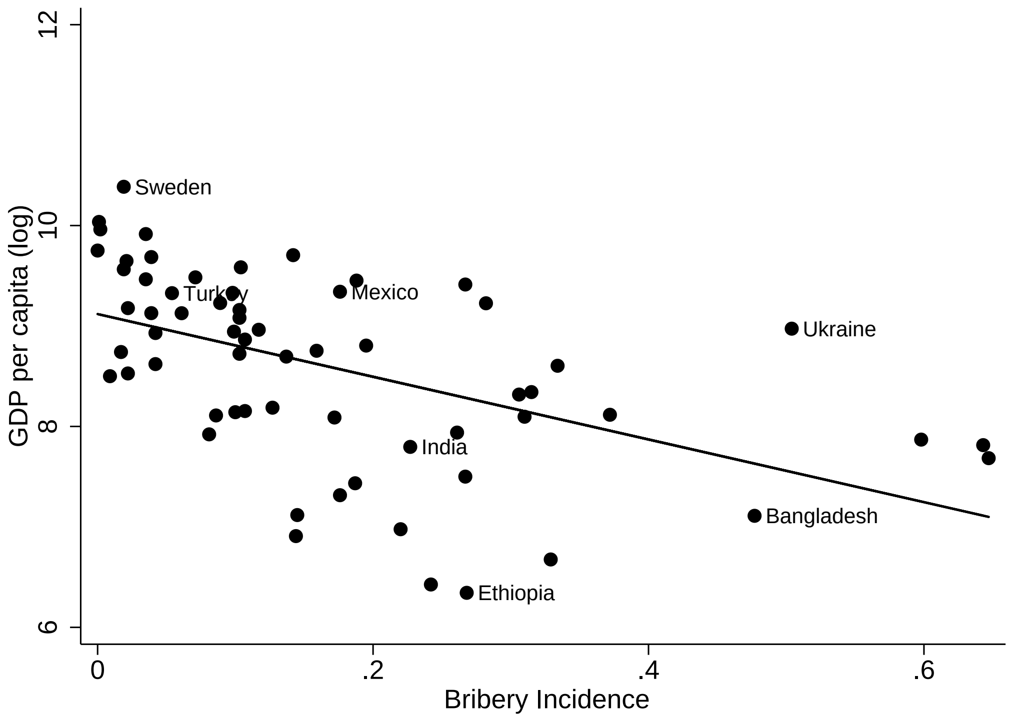


Figure 2.1: Bribery and GDP per Capita

Sources: Enterprise Survey and Penn World Table

Notes: This figure shows the relationship between the bribery incidence and the GDP per capita (in log scale) at cross-country level. Each dot represents a country. Solid line is the simple regression line where the GDP per capita is the dependent variable and the bribery incidence is the independent variable.

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APPENDIX A

SUPPLEMENTARY MATERIAL FOR CHAPTER 1

A.1 Data Sources for the Number of Plants

Table A.1.1: Data Sources for Number of Plants in Manufacturing Sector

Country	Years	Source
Australia	2003-2015	Australian Bureau of Statistics
Austria	1995-2016	1995-2007 OECD,2007-2016 EuroStat
Belgium	1999-2016	1999-2007 OECD,2007-2016 EuroStat
Canada	2001-2016	Statistics Canada (CANSIM)
Denmark	2000-2016	2000-2016 www.statbank.dk,2007-2015 EuroStat
Finland	1995-2015	1995-2007 OECD, 2007-2015 EuroStat
France	1996-2016	1996-2007 OECD,2007-2016 EuroStat
Germany	1999-2016	1999-2007 OECD,2007-2016 EuroStat
Greece	1997-2015	1997-2007 OECD, 2008-2015 EuroStat
Ireland	2008-2011	EuroStat
Italy	1996-2015	1996-2007 OECD,2007-2015 EuroStat
Japan	2001;2004;2006	Statistics Japan
Korea	2006-2016	Statistics Korea
Luxembourg	1995;1998;2003-2015	1995;1998;2003-2007 OECD, 2007-2015 EUROSTAT
Netherlands	1995-2016	1995-2007 OECD,2007-2016 EuroStat
Portugal	1995-2016	1995-2007 OECD,2007-2016 EuroStat
Spain	1995-2016	1995-2007 OECD,2007-2016 EuroStat
Sweden	1996-2015	1996-2007 OECD,2007-2015 EuroStat
Taiwan	1996;2001;2006;2010	Taiwan Industry and Service Census
United Kingdom	1995-2015	1995-2007 OECD, 2007-2015 EuroStat
United States	1995-2016	County Business Patterns

A.2 Robustness

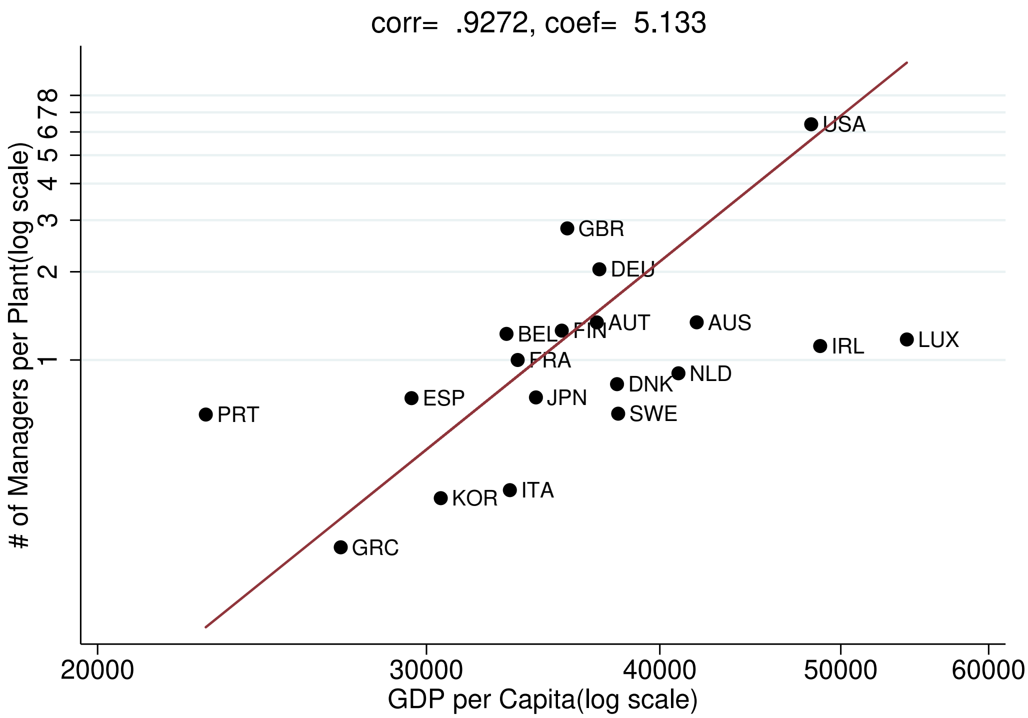
In this section, I show that the positive correlation between the number of managers per plant and the GDP per capita is robust to choice of data set and the usage of the employees instead of employment.

A.3 Model with $L-$layers

In this section, I present the model with $L-$layers. Environment is similar to the one that is described in Section 1.4. However, there are at most $L-$layer of organizations exist in the economy. In other words, plants with 1, 2, . . . , $L-1$ and $L-1$layers coexists in this economy.

The problem of the top manager in the $L-$layer organization is to choose how many and what type of middle managers and production workers to hire. Thus

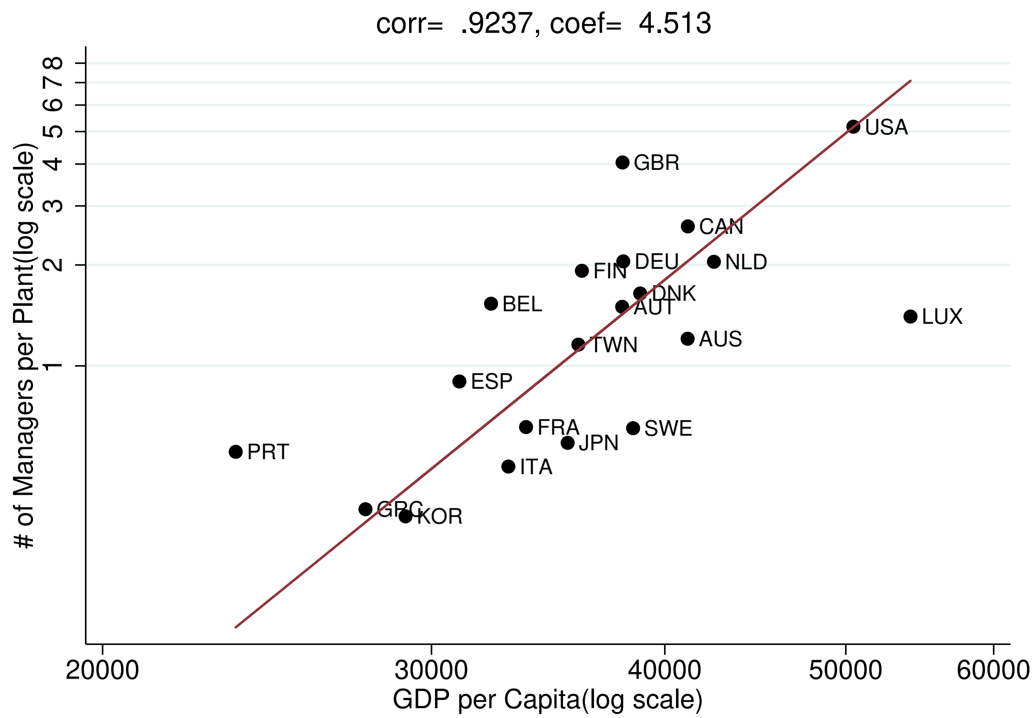
Figure A.2.1: Managers per Plant and GDP per Capita Using ILO Database



Sources: ILOstat, Eurostat and countries' statistical agencies and PWT 9.0

Notes: This figure shows the relationship between the number of managers per plant and the GDP per capita (in log scale) at cross-country level using ILO database. Each dot represents a country. Solid line is the simple weighted regression line where the GDP per capita is the independent variable, the number of managers per plant is the dependent variable and the countries are weighted according to their employment sizes. Both the workers per manager and the GDP per capita are averages over the period 2000-2017 depending on availability on ILO database. GDP per capita numbers are in PPP adjusted and reported in 2011 dollars.

Figure A.2.2: Managers per Plant and GDP per Capita in 2006



Sources: ILOstat, Eurostat and countries' statistical agencies and PWT 9.0

Notes: This figure shows the relationship between the number of managers per plant and the GDP per capita (in log scale) at cross-country level in 2006. Each dot represents a country. Solid line is the simple weighted regression line where the GDP per capita is the independent variable, the number of managers per plants is the dependent variable and the countries are weighted according to their employment sizes. GDP per capita numbers are in PPP adjusted and reported in 2011 dollars.

income of a top manager of $L-$layer organization with knowledge z, $R_L(z)$, is total output produced minus the wages that are paid to the middle managers and the production workers:

$$R_L(z) = \max_{\{n_l, z_l\}_{l=1}^{L-1}} AF(z)n_0 - \sum_{l=1}^{L-1} n_l w(z_l) \tag{A.1}$$

s.t

$$h_L(z_{L-1})\left[1 - F(z_{L-1})\right] n_1 = 1$$

$$h_{L-1}(z_{L-2})\left[1 - F(z_{L-2})\right] n_1 = n_{L-1}$$

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$$h_3(z_2)\left[1 - F(z_2)\right] n_1 = n_3$$

$$h_2(z_1)\left[1 - F(z_1)\right] n_1 = n_2$$

$F(z)$ is the fraction of problems that is solved in this plant and n_1 is the number of production workers which is also equals to the number of questions drawn. $w(.)$ is the wage rate and it is a function of knowledge of subordinate. First constraint is the time constraint of the top manager. The top manager has 1 unit of time. There are n_1 questions drawn and middle managers at one layer below of top managers cannot solve $[1 - F(z_{L-1})]$ fraction of them. The direct subordinates of the top manager ask $n_1 [1 - F(z_{L-1})]$ questions to the top manager and each question takes $h_L(z_{L-1})$ unit of time. Last constraint is the time constraint of middle managers at 1st layer. The right hand side of the time constraint is the total available time of layer-1 middle-managers. There are n_1 production workers and they can not solve $[1 - F(z_1)]$ fraction of the n_1 problems and communicating each of them takes $h_1(z_1)$ unit of time.

The number of subordinates demanded can be written as a function of their knowledge. The number of production workers, n_1, determined by the knowledge of the direct subordinates of the top manager. It can be shown using the time constraint of the top manager in problem (A.1):

$$n_1 = \frac{1}{h_L(z_{L-1})\left[1 - F(z_{L-1})\right]} \tag{A.2}$$

The more knowledge middle managers at the layer $L-1$ ask less questions and telling an answer to them takes less time of top manager because they are better at understanding. Moreover, the more knowledge middle managers at layer $L-1$ can answer more questions of subordinates of them in multi-layer organizations. Therefore they can help top managers to run bigger plants by having more production workers.

The demand for middle managers is a function of the knowledge of the direct subordinates of them and the knowledge of middle managers at layer $L-1$. More specifically, the number of middle managers at layer l demanded can be written as following using the time constraints:

$$n_l = \frac{h_l(z_{l-1})\left[1 - F(z_{l-1})\right]}{h_L(z_{L-1})\left[1 - F(z_{L-1})\right]}, \quad l \in \{2, 3, ..., L-1\} \tag{A.3}$$

The relationship between the number of middle managers and the knowledge of middle managers at layer $L-1$ is same as the relationship between the number of production workers and the knowledge of middle managers at layer $L-1$. Since they can answer more questions, the more knowledge middle managers can manage more of the subordinates. On the other hand, the number of middle managers at layer l is negatively related with the knowledge of their direct subordinates at layer $l-1$ as the numerator of the equation (A.3) shows. In other words, the demand for the number of middle managers decreases as the knowledge of the direct subordinates of the middle managers increases since more knowledge subordinates ask less questions and communication with them takes less time.

The problem of the top manager can be reduced to choose the knowledge of the subordinates by substituting equations (A.2) and (A.3) into problem (A.1) as following

$$R_L(z) = \max_{\{z_l\}_{l=1}^{L-1}} \left[AF(z) - w(z_1) - \sum_{l=2}^{L-1} h_l(z_{l-1}) \left[1 - F(z_{l-1})\right] w(z_l) \right] \frac{1}{h_L(z_{L-1}) \left[1 - F(z_{L-1})\right]} \tag{A.4}$$

There are $L - 1$ first order conditions that characterize the choice of the top managers at L-layer organizations. The following system of differential equations can be derived from the first order conditions of the top manager.

$$w'(z_1) = \left[h_2'(z_1) \left[1 - F(z_1)\right] - h_2(z_1) f(z_1)\right] w(z_2)$$

$$w'(z_l) = \frac{h_{l+1}(z_l) f(z_l) - h_{l+1}'(z_l) \left[1 - F(z_l)\right]}{h_l(z_{l-1}) \left[1 - F(z_{l-1})\right]} w(z_{l+1}), \quad l \in \{2, ..., L-2\} \tag{A.5}$$

$$w'(z_{L-1}) = \left[\frac{AF(z) - w(z_1) - \sum_{l=2}^{L-2} h_l(z_{l-1}) \left[1 - F(z_{l-1})\right] w(z_l)}{h_{L-1}(z_{L-2}) \left[1 - F(z_{L-2})\right]} - w(z_{L-1}) \right] \left[\frac{h_L(z_{L-1}) f(z_{L-1}) - h_L'(z_{L-1}) \left[1 - F(z_{L-1})\right]}{h_L(z_{L-1}) \left[1 - F(z_{L-1})\right]} \right]$$

There exist L different type of plants in an economy where the most complex plants have $L-$layer. Some of the plants have L layers, some of them have $(L - 1)$-layers, some of them have $L - 2$-layers and so on. And finally, there are some plants who has only 1 layer which is the manager itself producing alone. Moreover, there are

$\sum_{l=1}^{L} l$ number of different occupations in this economy: top managers of the $L-$layer plants, middle managers at the $L-1$th layer of $L-$layer plants, middle managers of at the $L-2$th layer of $L-$layer plants and so on until the fist layer where production workers are at. Moreover, there are $L-1$ occupations in the $(L-1)-$layer plants and $L-2$ different occupations in the $(L-2)-$layer plants and so on. And finally there is only one type of occupation in $1-$layer plants which is self-employed managers work alone.

A.3.1 Equilibrium

The household collects all the incomes of household members and consumes it. Therefore, she chooses the maximum number of layers and the occupation of household members in order to maximize her total income.

Positive sorting of subordinates to the managers is described by the matching function $m(z)$. It is an increasing mapping from the set of knowledge of subordinates at layer l, S_l, to the set of corresponding managers, M_l [1] . Hence, the labor market clearing condition is for each subordinates' layer, l and for each $z \in S_l$:

$$\int_{S_l} g(z')dz' = \int_{M_l} \frac{n(z')}{n(m(z'))} g(z')dz' \tag{A.6}$$

where $n(z)$ be the number of subordinates demanded by a manager with knowledge z. Left hand side of labor market clearing condition denotes the supply of subordinates for each type. Right hand side is the demand for subordinates for each type. More specifically, it is the total subordinates demanded divided by the total number of direct managers demanded. Because $n(z')$ number of subordinates are managed by $n(m(z'))$ number of direct managers of them. Notice that $n(m(z'))$ is equal one if

[1] Set of subordinates (production workers and middle managers), self-employed, and top managers are connected. See Garicano and Rossi-Hansberg (2006) for the proof

$m(z')$ is the top manager of the organization.

The equilibrium in an $L-$layer economy is the set of thresholds for each occupations at for all type plants, wage function $w()$, and the matching function $m()$ such that

- The household chooses assigns each household member to the occupations in order to maximize her total income Y which is the sum of all wage income of subordinates and the profits of plant owners (top managers).
- Top managers choice of number and type of subordinates is consistent with the household's decisions.
- The labor market clears for all subordinates' layer, i.e equation (A.6) holds for all layers of subordinates, l.

A.4 Calibration with Different Distributions

In this section, I present the calibration of the parameters of the model with $3-$layers using different distributions apart from the truncated Pareto distribution that is used in the main body.

Uniform Distributions

I assume both the distribution of knowledge and tasks follows uniform distribution over the same range $[1, 0]$. The communication cost functions are specified in Equation (1.19). This model has 3 communication cost parameters to calibrate. I choose the mean size, the managers per plant and the employment share of plants who has at least 100 employees as my target moment. The calibration result and the parameters as follows:

Table A.4.2: Calibration Performance and Parameter Values with Uniform Distributions

	Data	Model
Mean Size	20.3	20.4
Managers per plant	7.3	7.3
employment share of 100+	0.66	0.66
Parameters		
ϕ_2		1.0
ϕ_m		0.38
ϕ_T		0.26

Truncated Gamma and Truncated Exponential Distributions

I assume the distribution of knowledge follows truncated gamma distribution and the distribution of tasks follows the truncated exponential distribution over the same range $[0.1, \bar{z}]$:

$$G(z; \alpha, \beta, 0.1, \bar{z}) = \frac{\gamma_L(\alpha, \beta z) - \gamma_L(\alpha, 0.1\beta)}{\gamma_L(\alpha, \beta \bar{z}) - \gamma_L(\alpha, 0.1\beta)} \text{ and}$$

$$F(z; \lambda, 0.1, \bar{z}) = \frac{\exp(-0.1\lambda) - \exp(\lambda z)}{\exp(-0.1\lambda) - \exp(-\lambda \bar{z})} \quad \text{(A.7)}$$

where $\gamma_L(.)$ is lower incomplete gamma distribution. Given functional forms by Equation (1.19), I have 7 parameters $\{\lambda, \alpha, \beta, \phi_2, \phi_m, \phi_T, \bar{z}\}$. And I choose 7 moment conditions to match: The mean size, the fraction of plants with 1-9, 10-19, 20-49, 50-99 employees and the employment share of plants with at least 100 employees. The calibration results and the parameters as follows:

The calibration results with truncated uniform-truncated exponential, truncated Pareto-truncated exponential for the distribution of knowledge-task respectively are also available upon request.

Table A.4.3: Calibration Performance and Parameter Values with Truncated Gamma

	Data	Model
Mean Size	20.3	21.5
Managers per plant	7.3	9.0
Fraction of		
1-9	0.54	0.54
10-19	0.15	0.22
20-49	0.15	0.09
50-99	0.07	0.08
Employment share of 100+	0.66	0.64
Parameters		
λ		2.93
α		0.001
β		0.30
$\bar{z}$		3.04
ϕ_2		0.94
ϕ_m		0.64
ϕ_T		1.00

A.5 Solution Algorithm for the Model 3−layers

The solution algorithm follows Sattinger (1993) and Garicano and Rossi-Hansberg (2006). It is derived from the characterization of the equilibrium:

1. Guess

    - 5 threshold knowledge levels: $z_{3w}^{2w}, z_{2w}^{mm}, z_{mm}^{se}, z_{se}^{2m}, z_{2m}^{Tm}$
    - 3 initial conditions for wages: $w_2(\underline{z}), w_1(z_{3w}^{2w}), w_3(z_{2w}^{mm})$

2. Find three matching functions by solving three differential equations (1.13), (1.16), (1.17)

    - use the initial conditions implied by the threshold guesses:

$$m_1(\underline{z}) = z_{2w}^{mm} m_2(z_{3w}^{2w}) = z_{se}^{2m} \text{ and } m_3(z_{2w}^{mm}) = z_{2m}^{Tm}$$

3. Find wage functions by solving system of differential equations (1.12) and (1.15).

    - use three initial conditions for wages given in Step 1

4. Check whether indifference conditions and assignment of top subordinates to the top managers conditions satisfy:

$$m_1(z_{3w}^{2w}) \stackrel{?}{=} z_{mm}^{se} \qquad m_2(z_{2w}^{mm}) \stackrel{?}{=} z_{2m}^{Tm}$$
$$m_3(z_{mm}^{se}) \stackrel{?}{=} \bar{z} \qquad w_2(z_{3w}^{2w}) \stackrel{?}{=} w_1(z_{3w}^{2w})$$
$$w_1(z_{2w}^{mm}) \stackrel{?}{=} w_3(z_{2w}^{mm}) \qquad w_3(z_{mm}^{se}) \stackrel{?}{=} R_{SE}(z_{mm}^{se})$$
$$R_{SE}(z_{se}^{2m}) \stackrel{?}{=} R_2(z_{se}^{2m}) \qquad R_2(z_{2m}^{Tm}) \stackrel{?}{=} R_T(z_{2m}^{Tm})$$

5. If the eight conditions in Step 4 is satisfied, then you are done. If not, go back to Step 1 to update your guesses and continue this until all the conditions in Step 4 are satisfied.

A.6 Effect of Technology Parameter, A

Proposition 1. *In the knowledge-based hierarchies model, changes in the technology parameter, A, which is common to all type of organizations do not affect neither the allocation of household members into the occupations nor the assignment of subordinates to the managers. However, changes in the technology parameter change the total output and the earnings of household members at the same direction with itself.*

Sketch of Proof: Consider a plant owner at the margin of forming another plant by increasing or decreasing the number of layers that she has. Increase in the technology parameter does not affect her choice since it is common to all plants. However, changes in the technology parameter is going to change the wages of all subordinates at the same rate since the plant owners' production is affected by A. Moreover, the matching functions are not affected by the changes in A so that assignments of subordinates to the managers is not affected as well.

As a result, aggregate output (see equation 1.22) and earnings of all agents change in same direction and same rate with changes in A.

A.7 Size-Dependent Distortions With Single Type of Organizations

Proposition 2. *If there is only one type of organizations exists in the knowledge-based hierarchies economy, the size-dependent distortions that distorts bigger plants at higher rate do not have any effect neither on the allocation of agents into occupations nor on the matching of subordinates to the managers. While the total output produced in the economy stays the same, such distortions reallocate earning from high knowledge plant owners toward low knowledge subordinates.*

Proof. Consider an economy where there are only $L-$layer organizations. Hence, there are L different occupations in the economy. The equilibrium assignments are characterized by $L-1$ matching functions. The equilibrium occupational assignments are determined by $L-1$ threshold knowledge levels which can be find by solving $L-1$ matching functions which are irrelevant from earning dynamics. Since the earning schedule has to be consistent with the equilibrium assignment and the larger plants want to decrease their labor demand more than the smaller ones in the presence of size-dependent distortions, demand for agents with lower knowledge increases. Since the equilibrium assignment is unique, wages of the agents with lower knowledge increases while the earnings of the higher able plant owner decreases. □

The proof relies on the existence and uniqueness of the equilibrium. See Garicano and Rossi-Hansberg (2006) for the proof of existence and uniqueness.

Proposition 2 shows that the equilibrium boils down to an assignment equilibrium when there is only one type of organizations. Hence, the assignment of agents to the occupations and assignments of subordinates to the managers can be determined without knowing the wage schedule. However the wage schedule must support the matching of subordinates to the managers in the equilibrium. See Rosen (1982) and Sattinger (1993) for more details in assignment equilibrium models.