

ESSAYS ON PRODUCTIVITY AND RESOURCE  
REALLOCATION

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## ABSTRACT

My thesis consists of four chapters that examine how productivity is affected by government policies and market regulations. In particular, I study the impact of policy reforms on productivity through their effect on: (a) the allocation of resources across heterogeneous establishments, and (b) productivity at the establishment-level via technology adoption. In chapter one, I develop a theoretical model to analyze the effect of environmental policies on industry productivity and market competition. In my model, environmental regulations affect not only the allocation of resources across incumbent firms but also the incentive of firms to invest in pollution-abatement technologies. My findings imply that environmental regulations raise both environmental quality (by incentivizing the adoption of “cleaner” technologies), and industry productivity (by reallocating resources to more productive firms). In chapters two and three, using micro-level data from Indian manufacturing plants, I study total factor productivity (TFP) growth, and the contribution of firm-level subsidies to overall TFP growth. My analysis recognizes that while size-dependent subsidies may induce technology adoption for recipient firms, they also generate misallocation of resources across firms. I focus on the India subsidy program initiated in 2005 in Iron and Steel Industry. In chapter two, my growth accounting provides evidence of an acceleration of TFP growth after 2005 but primarily among plants that adopted more productive technologies. In chapter three, using a general equilibrium model with heterogeneous firms and a technology choice at the firm-level, I examine the impact of size-dependent subsidies on industry productivity. I show that while the induced

misallocation tends to reduce productivity, technology adoption raises it. In the context of this model, the policy contributed about 20% to the observed productivity growth. In chapter four, I assess the effect of labor market reforms on measures of productivity across Indian states. Using a state-level labor reform index, and plant-level data, I show that large plants, in labor intensive industries, operating in the states with flexible labor market are more likely to gain from labor market reforms through an improvement in TFP and labor productivity.

## DEDICATION

I would like to dedicate this dissertation to my wife FARIBA and my son KIA for all of their love and support.

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# CHAPTER 1

## The Impact of Environmental Policies on Productivity and Market Competition

### 1.1 Introduction

According to the traditional view of environmental policy, regulations impose additional costs on firms and force them to devote some of their resources to abatement activities. As a result, the overall global competitiveness of regulated firms deteriorates in comparison to non-regulated firms (Palmer et al., 1995). This conventional paradigm was challenged by Michael Porter (Porter, 1991) and Porter and van der Linde (1995) who suggest that pollution is often a waste of resources, and a well-designed environmental policy can actually spur innovation at the firm-level, leading the regulated firms to gain higher efficiency and competitive advantage over their unregulated rivals.

Among the growing body of work on environmental policies, two sets of studies have emerged. The focus of the first set has been on the impact of environmental policies on innovation (Jaffe and Palmer, 1997). This literature suggests that environmental regulations provide strong incentives for firms to invest in R&D which utilizes production process or reduces cost of inputs at the firm-level. However, since these studies did not assess whether the benefits of innovation are higher than the

cost of policy, they are described as the “weak” version of the Porter Hypothesis.<sup>1</sup> In contrast, the “strong” form of the environmental policies suggests that innovation induced by the environmental regulations can benefit firms by more than fully offsetting the cost of the policy. In this literature, the overall impacts of environmental regulations are quantified by measuring the performance of firms in such areas as higher productivity and profit or lower production and input costs (Xepapadeas and Zeeuw, 1999; Yokoo, 2009; Berman and Bui, 2001; Alpay et al., 2002).

Although the strong form of the Porter Hypothesis is well regarded in the literature, the impact of environmental policies on market performance is not conclusive and thus the assessment of this potential “win-win” situation remains an open research question. For example, a review of the existing literature on the effect of environmental policies reveals that less attention has been given to understanding the channels through which environmental regulations lead to competitiveness. In the Porter Hypothesis, lack of innovation and technology diffusion are the main sources of inefficiency in economic activities. The Total Factor Productivity (TFP) of an unregulated economy can be potentially higher because firms are not using the frontier abatement technologies. A well-designed environmental policy induces innovation at the firm-level which increases productivity of individual firms and the whole economy thereafter. If the induced technological change is the primary source

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<sup>1</sup> For example, if the innovation is beneficial, then the unregulated firms would also take the advantage of the opportunity and invest in the R&D projects.

of productivity gain, then the environmental regulations must lead to a Pareto improvement or a “win-win” situation by not only protecting the environment, but also enhancing aggregate productivity and competitiveness.

In the assessment of the link between environmental regulations and competitiveness, the role of market competition is central. Competition is desirable since it contributes to the efficiency of economic activities and knowledge spillover (Aghion et al. 2005; Herrendorf and Bai, 2009). A study by Holmes and Schmitz (2010) shows that firms that survive in an intensified competitive environment are most likely to have larger productivity gains, and those gains often account for the majority of the overall industry benefits. The link between competition and competitiveness is also well regarded in the literature. While competition is about the nature and quality of rivalry, competitiveness refers to the outcome of competition. Therefore, competitiveness involves the ability of firms to face competition on a sustainable basis. It should be noted that, while markets work fairly well much of the time, the effective competition is not automatic, and can be damaged by policy distortions. Therefore, environmental policies will lead to a higher market efficiency and competitive advantage of firms only if the regulations enhance the competitive environment too.<sup>2</sup>

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<sup>2</sup> Herrendorf and Bai (2009) argue that the relationship between competition and productivity across various industries depends on how competition differs. If a larger market size leads to more competition in an industry, then firms become more productive. However, if a lower entry cost leads to tougher competition, then firms may either choose lower or higher productivity levels.

In this study, I examine the impact of environmental regulations on measures of competition and productivity. A lower average price or a larger number of competing firms are characterized as an intensified competition. To incorporate endogenous mark-ups that respond to the toughness of competition, the choice of consumer preferences is crucial. The standard Dixit-Stiglitz preferences feature a constant elasticity of substitution across varieties and are not well suited for studying the degree of competition.<sup>3</sup> Despite the simplicity and convenient analytical properties of the CES utility function, it implies a constant distribution of mark-ups which are unaffected by any exogenous policy change. For example, an increase in emission tax will have no effect on the average market price, or number of firms, which could potentially reflect tougher competition.<sup>4</sup> So, my study adopts consumer preferences with a linear demand system and horizontal product differentiation following Ottaviano et al. (2002) and Melitz and Ottaviano (2008). This utility function is tractable and features variable mark-ups in the way that more productive firms will charge higher

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<sup>3</sup> See Melitz (2003) for the benchmark model of monopolistic competition with heterogeneous firms; and Yokoo (2009) for an application to environmental policy

<sup>4</sup> Some scholars adopted other forms of preferences with endogenous mark-ups. In a study on the relationship between competition and productivity, Herrendorf and Bai (2009) incorporated a Lancaster utility function. The demand derived from the Lancaster preferences responds to market size but it is non-linear. Bergin et al. (2001, 2007) used a symmetric translog expenditure function, which implies a demand system with unitary income elasticity and non-constant price elasticity. It is a homothetic function with no closed-form solution for the direct utility function. The problem with the translog utility function is that there is no explicit solution for the market price.

mark-ups. Average productivity is endogenously determined through the selection and allocation of resources across surviving firms.

To introduce the environmental concerns, I assume that pollution is a negative externality. Firms do not fully measure the economic costs of their emission produced during production. Hence, the profit inaccurately portrays firms action as positive, leading to an inefficiency of resource allocation. I consider a production technology that follows closely that of Levinson and Taylor (2003). In the context of this technology, production process yield pollution as a side effect; however, firm can reduce pollution through abatement activities. Firms do so by allocating a fraction of their resources to production and the rest to abatement. To give a role for environmental policy and study its impact on abatement technology, I extend the model to allow for an endogenous investment in a clean abatement technology. Adopting a cleaner abatement technology entails a higher cost than adopting a more polluting technology but it increases productivity of abatement activities.

To regulate pollution, the government can select between economic and administrative policies. In particular, the government can use an emission tax policy or introduce an emission standard that directly restricts a firm's level of emission. Under an emission tax, firms pay tax per unit of emission produced during production, whereas, under an emission standard, each firm is required to keep its emission-output ratio below an exogenous level determined by the government. The emission standard is the maximum rate of pollution that is legally allowed. A stricter environmental policy takes the form of a higher emission tax or a higher emission standard.



The findings of this study imply that a stringent environmental policy leads to an increase in average productivity and environmental quality but it reduces competition in the market. However, the main source of productivity gain resulted from environmental regulations is attributed to the general equilibrium effect (selection effect) rather than the induced abatement technology change at the firm-level. In particular, the policy has a primary positive impact on productivity at the firm-level because regulations provide strong incentives for firms to adopt a cleaner abatement technology. A stringent environmental policy also indirectly affects productivity and market competition through the general equilibrium effect (secondary effect). Technology adoption is costly and increases marginal cost. Thus the expected profit prior to entry decreases. The least productive firms exit the market and inputs are reallocated to surviving firms which are more productive on average. In contrast to the standard model of firm heterogeneity in which high productivity firms set lower prices, my model predicts that the surviving firms pass a part of higher marginal cost to consumers by setting higher prices. Furthermore, a stringent environmental policy has a negative impact on social welfare by lowering the number of varieties produced in equilibrium.

The rest of this chapter is organized as follows: Section 2 describes the model with an emission tax policy. Section 3 evaluates the impact of emission tax on social welfare. Section 4 assesses the effect of an emission standard policy. Section 5 concludes.

## 1.2 Model

Consider an economy consists of  $L$  consumers with identical preferences. Labor is the only factor of production. Each consumer is endowed with one unit of labor and  $x_0^c$  unit of numeraire good.

### Consumer Preferences

Consumer preferences  $V$  is given by,

$$V = U + Z \tag{1.1}$$

where  $U$  is a function of consumer utility and  $Z$  is environmental quality. The environmental quality has no affect on the consumer optimization problem. The utility function is defined over a continuum set of differentiated goods plus a homogeneous good taken to be a numeraire.

$$U = x_0^c + \beta \int_{\Omega} x_i^c di - \frac{1}{2}\gamma \int_{\Omega} (x_i^c)^2 di - \frac{1}{2}\eta \left( \int_{\Omega} x_i^c di \right)^2 \tag{1.2}$$
$$\beta, \gamma, \eta > 0$$

where  $x_i$  indexes the quantity of variety  $i$  and  $x_0$  is the quantity of the numeraire.  $\beta$  denotes the intensity of preferences for the differentiated goods.  $\beta$  and  $\eta$  determine the substitution pattern between the differentiated varieties and the numeraire. An increase in  $\beta$  or a decrease in  $\eta$  shift out the demand for the differentiated varieties relative to the numeraire.  $\gamma$  denotes the degree of product differentiation between varieties. If  $\gamma = 0$ , then consumers only care about their aggregate consumption level over all varieties.  $\Omega$  is the set of intermediate goods.

The budget constraint of a representative consumer is defined over the numeraire good and other varieties as,

$$I = x_0^c + \int_{\Omega} p_i x_i^c di \quad (1.3)$$

where  $I$  represents the indexed total of a consumer's income and  $p_i$  denotes the price of variety  $i$ . Maximizing utility function (1.1) subject to the budget constraint (1.3) gives demand for each intermediate good. With a positive demand for the numeraire good, the inverse demand function for the variety  $i$  is given by,

$$p_i = \beta - \gamma x_i^c - \eta X \quad (1.4)$$

where  $X = \int_{\Omega} x_i^c di$  is the aggregate quantity of all varieties. If only a subset of the intermediate goods are consumed in equilibrium ( $\Omega^* \in \Omega$ ), the inverted demand equation for variety  $i$  changes to,

$$x_i^c = \frac{\beta}{\eta N + \gamma} - \frac{1}{\gamma} p_i + \frac{\eta N}{\eta N + \gamma} \frac{1}{\gamma} \bar{p} \quad (1.5)$$

where  $\bar{p}$  is the average price of all the varieties  $N$  in  $\Omega^*$ . With  $L$  consumers in the economy, the aggregate demand for a particular variety  $x_i^c$  is simply  $Lx_i^c$ . Hence, the aggregate demand becomes,

$$x_i = \frac{\beta L}{\eta N + \gamma} - \frac{L}{\gamma} p_i + \frac{\eta N}{\eta N + \gamma} \frac{L}{\gamma} \bar{p} \quad (1.6)$$

In equation (1.6), the demand for variety  $i$  is linear in price  $p_i$  and the average market price.  $x_i$  also is determined by the size of the market and the elasticity of

substitution between varieties. The maximum price that a consumer is willing to pay for a particular variety is the price that drives demand for that variety to zero. This price threshold  $p_{max}$  is calculated as,

$$p_{max} = \frac{\gamma\beta + \eta N\bar{p}}{\eta N + \gamma} \quad (1.7)$$

By the standard argument, a tougher competition is characterized by a lower average price or a larger number of competing firms, both of which reduce the price threshold. Then, the demand system can be written in terms of  $p_{max}$  as,

$$x_i = \frac{L}{\gamma}(p_{max} - p_i) \quad (1.8)$$

## Production Technology

I combined the production technology used by Levinson and Taylor (2003) with the heterogeneous firm environment of Melitz (2003). There are a continuum number of firms that are heterogeneous with respect to productivity level. To enter the industry, firms must pay the irreversible fixed entry cost  $f_e$ . Once a firm enters the market, it draws its productivity  $\varphi$  between 0 and  $\infty$  from a known and exogenous distribution function. The productivity level of individual firms remains constant across time. Since each firm produces a single variety, I follow the literature and use  $\varphi$  to index operating firms in the market hereafter. Hence, the index of varieties  $i$  and firm level productivity  $\varphi$  are identical.

Labor is the only factor of production and is inelastically supplied in a competitive market. The numeraire good is produced under constant returns to scale

at unit cost; its market is also competitive. Firms devote a fraction of their input (labor)  $1 - \theta$  to production and the rest  $\theta$  to abatement. Each differentiated good is produced under constant returns to scale technology by firm  $\varphi$  which is given by,

$$x(\varphi) = \varphi (1 - \theta_\varphi) l_\varphi \tag{1.9}$$

Production process also yields pollution as a side effect. However, firms can reduce pollution by allocating the remaining labor input  $\theta_\varphi$  to abatement. Firms can also invest in advanced abatement technologies that increase the productivity of pollution reduction activities. The pollution production function is modeled under constant returns to scale technology as,

$$z(\varphi) = f_\varphi^{\frac{1}{\alpha}}(b) (1 - \theta_\varphi)^{\frac{1}{\alpha}} l_\varphi \tag{1.10}$$

where  $b$  is technology parameter and  $f_\varphi^{\frac{1}{\alpha}}(b)$  denotes the abatement technology adopted by a firm with productivity  $\varphi$  such that  $f_\varphi(b) > 0$ ,  $f'_\varphi(b) < 0$ , and  $f''_\varphi(b) > 0$ . The convexity of the abatement technology indicates that as a firm with productivity draw  $\varphi$  adopts a cleaner technology, its marginal effect decreases.<sup>5</sup>  $\alpha$  is exogenous and captures the effectiveness of abatement activities. A larger  $\alpha$  indicates lower abatement efficiency.

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<sup>5</sup> This study rules out pollution generated during consumption.

For tractability, the abatement technology is defined as  $f_\varphi(b) = 1/b_\varphi$  where  $b_\varphi \in (0, 1)$  and is summarized by the cost function  $c_\varphi(b)$ , where  $1/b_\varphi$  denotes the level of abatement technology and  $x(\varphi)$  refer to the firms' output.<sup>6</sup>

$$c_\varphi(b) = \begin{cases} \frac{1}{b_\varphi} \frac{x_\varphi}{\varphi} & 0 < b_\varphi < 1 \\ 0 & b_\varphi = 1 \end{cases} \quad (1.11)$$

The optimal investment in the abatement technology is described as follows. After firms observe their productivity level, they have access to a standard abatement technology which is not environmentally friendly but is free. This standard technology is captured by  $b_\varphi = 1$ . With the standard abatement technology, the emission production function converts to the one in Levinson and Taylor (2003). Firms can also invest in an advanced level of abatement technology at a cost that depends on output size and productivity draw. Not all firms would be willing to use the more advanced abatement technology since it would require them to cope with the higher costs and complexity of a technology which needs highly specialized employees and inputs. Thus, only more productive firms would be able to invest in clean abatement technology. If the productivity draw demonstrates a low level of productivity relative to the technology advancement, firms may select a simple abatement technology.<sup>7</sup>

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<sup>6</sup> Mansfield (1993) shows that large firms tend to use more expensive forms of technologies because they have more resources and are better able to take risks than their smaller rivals.

<sup>7</sup> It can be shown that the results are independent of the form of the abatement technology cost as long as the cost function satisfies the properties of  $f_\varphi(b)$  and  $c_\varphi(b)$ .

Now, the joint production function of intermediate goods and pollution is calculated by combining production of intermediate goods (1.9) and production of pollution (1.10) through substituting for  $1 - \theta$ .

$$x(\varphi) = \frac{1}{b_\varphi} \varphi z_\varphi^\alpha l_\varphi^{1-\alpha} \quad (1.12)$$

The joint production function takes the form of a Cobb-Douglas production function. The pollution is incorporated as an additional factor of production implying that production needs pollution as an undesirable input<sup>8</sup>. The joint production technology features two productivity parameters: the firm's productivity level ( $\varphi$ ) which is exogenous and the abatement technology parameter ( $1/b_\varphi$ ) which is endogenously determined.

### **Environmental Policy**

Governments can use many forms of emission reduction policies including voluntary actions, regulatory mechanisms, and price incentive policies. However, there is a growing agreement among economists that putting a price on emissions is essential to reduce pollution. An emission tax imposes a direct fee on the pollution that a firm emits. The government can also use a regulatory mechanism to enforce an emission reduction policy by setting a limit on level of emissions. In this study, I examine the impact of both an emission tax policy and an emission standard policy on the performance of firms.

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<sup>8</sup> We can think of  $z$  as the energy input to production of other goods which directly leads to pollution.

First, let's consider that the government introduces an emission-reduction regulation in form of an ad valorem tax  $\tau$  on pollution. Under a relatively low emission tax rate, no abatement occurs and  $\theta$  remains zero. Therefore, I assume that the emission tax is high enough to motivate firms to engage in abatement activities.

Within a competitive labor market, firms hire labor at wage  $w$  and emit at cost  $\tau$  to produce intermediate goods. The standard cost minimization problem determines demands for labor and pollution.

$$\begin{aligned} & \min_{\{l,z\}} \{wl_\varphi + \tau z_\varphi\} \\ \text{s.t. } & x(\varphi) = \frac{1}{b_\varphi} \varphi z_\varphi^\alpha l_\varphi^{1-\alpha} \end{aligned}$$

$$l(\varphi) = \frac{x_\varphi}{\varphi} b_\varphi \left(\frac{\alpha}{1-\alpha}\right)^{-\alpha} \left(\frac{w}{\tau}\right)^{-\alpha} \quad (1.13)$$

$$z(\varphi) = \frac{x_\varphi}{\varphi} b_\varphi \left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha} \left(\frac{w}{\tau}\right)^{1-\alpha} \quad (1.14)$$

The relative factor prices for a firm with productivity  $\varphi$  is independent of the firm's productivity level, and the abatement technology and is given by,

$$\frac{w}{\tau} = \frac{1-\alpha}{\alpha} \frac{z}{l} \quad (1.15)$$

The substitution of equation (1.9) into (1.15) gives the optimal resource allocation as,

$$1 - \theta_\varphi = \frac{1}{b_\varphi} \left[ \frac{\alpha}{1-\alpha} \frac{w}{\tau} \right]^\alpha \quad (1.16)$$



The optimal fraction of labor devoted to production  $1 - \theta$  depends on the level of clean technology as well as the emission tax rate. With a cleaner technology, firms can allocate less labor to abatement and maintain the same level of emissions. In addition, at a given abatement technology, a stricter environmental policy reduces the allocation of primary input (labor) to production.

### Profit Maximization Problem

Consider a monopolist firm with productivity level  $\varphi$  that faces market demand  $x(\varphi)$ , pollution tax  $\tau$ , and wage rate  $w$ . The maximum one period profit function subject to (1.8), (1.9), (1.10), and (1.11) must satisfy,

$$\pi(\varphi) = \max_{\{p,b\}} \{p_\varphi x_\varphi - w l_\varphi - \tau z_\varphi - c_\varphi - f_e\}$$

Conditional upon remaining in operation, the firm with productivity  $\varphi$  chooses the optimal abatement technology and price of intermediate good such that,

$$p(\varphi) = \left(\frac{1}{2}\right)p_{max} + \frac{1}{\varphi}\alpha^{-\frac{\alpha}{2}}(1 - \alpha)^{-\frac{1-\alpha}{2}}w^{\frac{1-\alpha}{2}}\tau^{\frac{\alpha}{2}} \quad (1.17)$$

$$1/b^* = \alpha^{-\frac{\alpha}{2}}(1 - \alpha)^{-\frac{1-\alpha}{2}}w^{\frac{1-\alpha}{2}}\tau^{\frac{\alpha}{2}} \quad (1.18)$$

The optimal level of abatement technology is independent of the firm's productivity level  $\varphi$ . Hence, all firms choose the same level of abatement technology ( $1/b^*$ ) in equilibrium. Prices in the market are directly associated with productivity levels of competing firms. Hence, the firm that sets the highest price in the market is the one with the lowest level of productivity or so called cut-off productivity  $\varphi^*$ . Firms with productivity draw below this cut-off can not stay in the market and exit. From (1.17), the price bound is calculated,

$$p_{max} = \frac{2}{\varphi^*} (1/b^*)^{\frac{1}{2}}$$

substitution of  $p_{max}$  in (1.17) gives a new expression for the price in terms of the cut-off productivity level and abatement technology.

$$p(\varphi) = (1/b^*)^{\frac{1}{2}} \left[ \frac{1}{\varphi^*} + \frac{1}{\varphi} \right] \quad (1.19)$$

Output, income, and profit of each producer are given by,

$$x(\varphi) = \frac{L}{\gamma} (1/b^*)^{\frac{1}{2}} \left[ \frac{1}{\varphi^*} - \frac{1}{\varphi} \right] \quad (1.20)$$

$$r(\varphi) = \frac{L}{\gamma} (1/b^*) \left[ \left( \frac{1}{\varphi^*} \right)^2 - \left( \frac{1}{\varphi} \right)^2 \right] \quad (1.21)$$

$$\pi(\varphi) = \frac{L}{\gamma} (1/b^*) \left[ \frac{1}{\varphi^*} - \frac{1}{\varphi} \right]^2 - f_e \quad (1.22)$$

## Equilibrium

Following Melitz (2003), and Melitz and Ottaviano (2008), I assume that productivity distribution follows the Pareto Distribution given by,<sup>9</sup>

$$G_m(\varphi) = 1 - \left( \frac{m}{\varphi} \right)^k ; k > 1 \quad (1.23)$$

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<sup>9</sup> The Pareto Distribution provides a good fit for the observed firm size distribution, and this assumption yields closed form solutions for the productivity cut-offs and other endogenous variables of the model. The Pareto Productivity Distribution is also used in the studies of Helpman et al. (2004) and Arkolakis et al. (2008).

where  $m$  is the minimum possible level of productivity and  $k$  is the shift parameter. Firms only learn about their productivity levels after paying the fixed cost. Hence, the distribution of productivity conditional on entry becomes,

$$G_{\varphi^*}(\varphi) = 1 - \left(\frac{\varphi^*}{\varphi}\right)^k$$

### Free Entry Condition

The free entry condition implies that any firm can pay the fixed cost and enter the market. Prior to their entry, each monopolistic producer observes their expected profit of production and compares it to the fixed entry cost. A firm enters the market only if the expected profit is greater than the entry cost. As long as some firms produce, the expected profit is driven to zero. Firms continue to enter until,

$$(1 - G_m(\varphi^*)) \int_{\varphi^*}^{\infty} \pi_{\varphi} dG_{\varphi^*}(\varphi) = f_e$$

where  $(1 - G_m(\varphi^*))$  is the ex post distribution of the productivity level after a successful entry. Solving for  $\varphi$  gives the cut-off productivity equation,

$$\varphi^* = \varphi_f^* (1/b^*)^{\frac{1}{k+2}} \tag{1.24}$$

where,

$$\varphi_f^* = \left(\frac{2Lm^k}{\gamma(k+1)(k+2)f_e}\right)^{\frac{1}{k+2}}$$

The cut-off productivity crucially determines the distribution of resources across firms. The cut-off productivity threshold increases if the market becomes larger, the emission tax goes up, the entry cost decreases, or products become less substitutable (an increase in  $\gamma$ ). The labor market clearing condition features the distribution of income among consumers as,

$$wL = N \int_{\varphi^*}^{\infty} r_{\varphi} dG_{\varphi^*}(\varphi) \quad (1.25)$$

It is straightforward to calculate number of competing firms in equilibrium as,

$$N = \frac{L}{(k+1)f_e} \left( \frac{m}{\varphi^*} \right) \quad (1.26)$$

In this equation,  $L/(k+1)f_e$  is the total number of entrants and  $m/\varphi^*$  is the probability of successful entry. The number of competing firms goes up with the size of the market. An increase in the emission tax reduces probability of successful entry and the number of competing firms accordingly. The average productivity is calculated as the weighted averages of the firms' productivity levels and is given by,

$$\bar{\varphi} = \frac{k}{k-1} \varphi_f^* (1/b^*)^{\frac{1}{k+2}} \quad (1.27)$$

A higher emission tax has a primary impact on average productivity since firms adopt a cleaner technology. The policy also has a secondary impact on average productivity through selection effect (general equilibrium effect). A higher emission tax reduces the expected profit and increases cut-off productivity. With a higher productivity threshold, only more productive firms can enter the market and average productivity goes up. An increase in the market size also induces a larger allocation of labor among surviving firms which leads to an increase in the average productivity.

Using the equation for the density function, it can be shown that the weighted average of a firm's performance is determined by the cut-off productivity level, abatement technology, and the distribution of productivity across firms. In particular, the average price, average output, and average pollution are given by,

$$\bar{p} = \frac{2k+1}{k+1} \varphi_f^* (1/b^*)^{\frac{-k}{k+2}} \quad (1.28)$$

$$\bar{x} = \frac{L}{\gamma(k+1)} \varphi_f^* (1/b^*)^{\frac{k}{k+2}} \quad (1.29)$$

$$\bar{\pi} = \frac{f_e}{m^k} \varphi_f^* (1/b^*)^{\frac{-k}{k+2}} \quad (1.30)$$

In equations (1.28) to (1.30), the cut-off productivity completely summarizes the performance of firms in the economy. Several results can be obtained from these equations. The effect of market size on productivity and other performance measures is similar to the Krugman (1980) argument. The number of firms in the industry goes up with an increase in the market size. The larger market pushes the cut-off productivity up which leads to the exit of less productive producers. However, because the number of new entrants outweighs the exit rate, the average productivity and average output (or size of each producer) is higher. In a larger market, firms set lower prices, produce more output and make a smaller profit, all of which demonstrate intensified competition in the economy.

Similar to the effect of market size, a lower entry fee enhances competition. With a lower entry cost, more firms can operate in the market. The average prices and

profits are lower but on average, firms produce less output. When products are more substitute (smaller  $\gamma$ ), consumers only care about the overall consumption rather than the consumption of each variety. Firms will expect lower profits and only highly productive producers could remain in operation (selection effect). Hence, there are less firms operating in equilibrium, and the average output and average productivity are higher.

The effect of environmental regulation on the market is different. A higher emission tax encourages firms to invest in a cleaner abatement technology which has a positive primary impact on productivity. However, regulations impose additional cost on firms. The policy decreases the expected profit of each producer upon entry. With a lower probability of successful entry, the cut-off productivity goes up in the favor of higher productivity firms. Since, the total number of entrants remains unchanged  $L/(k+1)f_e$ , fewer firms successfully enter the market. The reallocation of resources from less productive firms to more productive firms enforces the least productive producers to exit. The average productivity increases because less productive producers exit the market and the surviving firms are those with highest levels of productivity (secondary effect). Consequently, tougher environmental regulations make the market more concentrated. The output share of each producer goes up, firms set higher mark-ups and make larger profits. This results are consistent with the recent empirical works of Peters (2011) and De Loecker and Warzynski (2009). De Loecker and Warzynski (2010) examined the relationship between markups and export behavior using plant-level data. They show that high productivity firms (exporters) have higher markups on average than low productivity firms.

### 1.3 Welfare Analysis

Environmental policy is expected to impact social welfare through change in market performance. The welfare of consumers in this study depends on the consumer's preferences which features a continuum set of differentiated goods. To get the impact of the policy on the utility function, let's denote the variance of the market price by  $var(p)$  and variance of the output by  $var(x)$ . By standard arguments, they are defined as,

$$\begin{aligned} var(p) &= \frac{1}{N} \int (p_\varphi - \bar{p})^2 di \\ var(x) &= \frac{1}{N} \int (x_\varphi - \bar{x})^2 di \end{aligned}$$

From equation (1.4), the variance of market price can be written in terms of the variance of output as,

$$var(p) = \gamma^2 var(x)$$

The average demand for variety  $i$  produced by a firm  $\varphi$  is also given by  $\bar{x} = \frac{\beta - \bar{p}}{\gamma + N\eta}$ . Now, the indirect utility function is evaluated as,

$$U = x_0^c + \beta N \bar{x} - \frac{N}{2} \left( \frac{1}{\gamma} var(p) - \bar{x}(\beta - \bar{p}) \right)$$

The total of a consumer's income is denoted by  $I^c$  and it is easy to show that  $I^c = x_0^c + N\bar{p}\bar{x} - \frac{N}{\gamma} var(p)$ . Then, the indirect utility function can be written as,

$$U = I^c + \frac{N}{2} \left( \frac{1}{\gamma} var(p) + (\gamma + N\eta)\bar{x}^2 \right) \quad (1.31)$$

where the variance of market price is defined:  $var(p) = x_0^c + N\bar{p}\bar{x} - \frac{N}{\gamma} var(p)$ .

Equation (1.31) implies that the indirect utility function increases with a decline in the average prices and its variance, as the consumers re-optimize their consumption by shifting expenditures towards lower priced varieties as well as the numeraire good.

In addition, the indirect utility function exhibits “love of variety” implying that the welfare is enhanced by an increase in the number of varieties produced in the economy.<sup>10</sup>

To examine the impact of an emission tax on the indirect utility function, I substitute average price from (1.28), average output from (1.29), and variance of market price in (1.31). With some calculation (see Appendix A), it can be shown that,

$$U = I^c + \frac{N}{2\gamma} \left( \frac{\beta}{k+1} (\varphi_f^*)^{-1} (1/b^*)^{\frac{k}{k+2}} - \frac{2}{k+2} (\varphi_f^*)^{-2} (1/b^*)^{\frac{2k}{k+2}} \right) \quad (1.32)$$

Social welfare remains increasing with a lower entry cost and higher degree of product substitution. However, an environmental policy impacts welfare through two channels: (1) welfare is enhanced by a stricter environmental policy since regulation induce firms to adopt a cleaner abatement technology (lower  $1/b^*$ ), (2) the policy reduces welfare because a higher emission tax harms competitive environment. A tough environmental policy leads to the exit of less productive producers (higher  $\varphi_f^*$ ). The number of varieties decreases in equilibrium. The surviving firms have

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<sup>10</sup> Love of Variety was first introduced in international trade theory by Krugman (1980) and Dixit-Stiglitz (1977) as a monopolistic competition model. It is widely used in general equilibrium modeling of trade flows with product differentiation. It assumes that a representative consumer loves variety in the sense that each additional variety is as valuable as the last.



more market power and set higher prices accordingly. This dominates the positive effect of abatement technology adoption and welfare drops in the economy.

#### 1.4 Emission Standard Policy

As it was discussed, the government can impose an emission standard policy instead of an emission tax policy to regulate pollution. For simplicity, I assume that only one abatement technology is available for all producers represented by  $b = 1$ . To meet the regulations, firms are required to keep their emission-output ratio below an exogenous level  $s$  determined by the government. The emission standard requirement is defined as,

$$\frac{z_\varphi}{x_\varphi} \leq s \quad (1.33)$$

Combining this with equations (1.9) and (1.10) gives a new expression for the pollution-output ratio as,

$$\frac{z_\varphi}{x_\varphi} = \frac{1}{\varphi} (1 - \theta_\varphi)^{\frac{1}{\alpha} - 1} \leq s \quad (1.34)$$

Firms with a higher level of productivity naturally benefit from a lower emission-output ratio. Let us define  $\varphi_s$  the level of productivity that just meets the emission standard requirement. Firms with productivity below  $\varphi_s$  are not permitted by law to operate in the market. Here  $\varphi_s$  represents the new productivity threshold.

$$\frac{1}{\varphi_s} (1 - \theta_\varphi)^{\frac{1}{\alpha} - 1} = s$$

A monopolist producer maximizes profit  $p_\varphi x_\varphi - w l_\varphi$  subject to the joint production technology (1.12), demand for variety (1.8), and emission ratio constraint.

The first order conditions determine the allocation of resources to production and abatement according to the pricing rule given by,

$$p(\varphi) = \frac{1}{2} \left( p_{max} + \varphi^{\frac{1}{\alpha-1}} s^{\frac{\alpha}{\alpha-1}} w \right)$$

A firm with the lowest level of productivity ( $\varphi_s$ ) charges the maximum price that consumers are willing to pay ( $p_{max}$ ).

$$p_{max} = \varphi_s^{\frac{1}{\alpha}-1} s^{\frac{\alpha}{\alpha-1}} w \tag{1.35}$$

The substitution of (1.35) back in the pricing rule gives the market price in terms of cut-off productivity as,

$$p(\varphi) = \frac{1}{2} s^{\frac{\alpha}{\alpha-1}} w \left( \varphi_s^{\frac{1}{\alpha-1}} + \varphi^{\frac{1}{\alpha-1}} \right) \tag{1.36}$$

Output and profit become,

$$x(\varphi) = \frac{L}{2\gamma} s^{\frac{\alpha}{\alpha-1}} w \left( \varphi_s^{\frac{1}{\alpha-1}} - \varphi^{\frac{1}{\alpha-1}} \right) \tag{1.37}$$

$$\pi(\varphi) = \frac{L}{2\gamma} s^{\frac{2\alpha}{\alpha-1}} w \left( \varphi_s^{\frac{1}{\alpha-1}} + \varphi^{\frac{1}{\alpha-1}} \right)^2 \tag{1.38}$$

With a tougher emission standard, firms set higher prices, produce more, and make larger profits. Given the Pareto distribution of productivity, the free entry condition implies that,

$$\varphi_s = \left( \frac{Lm^k s^{\frac{-2\alpha}{1-\alpha}}}{4\gamma(k + \frac{1}{1-\alpha})(k + \frac{2}{1-\alpha})f_e} \right)^{\frac{1-\alpha}{k(1-\alpha)+2}} \tag{1.39}$$

where  $\varphi_s$  is the new expression for the cut-off productivity with emission-standard policy. The labor market clearing condition determines the equilibrium number of firms,

$$N = \left(\frac{m}{\varphi_s}\right)^k \left(\frac{L}{\left(\frac{2}{1-\alpha}\right)\left(k + \frac{1}{1-\alpha}\right)f_e}\right) \quad (1.40)$$

where  $\left(\frac{m}{\varphi_s}\right)^k$  is the probability of successful entry and the second expression is total number of entrants to the market. A higher emission standard has no effect on the number of new entrants but reduces the probability of successful entry and expected profit. This increases the cut-off productivity level in favor of high productivity firms and forces less productive producers to exit the market. The average productivity and average market price are given by,

$$\bar{\varphi}_s = \frac{k+1}{k} \varphi_s \quad (1.41)$$

$$\bar{p} = \frac{1}{2} s^{\frac{\alpha}{\alpha-1}} \left(1 + \frac{k}{k - \frac{1}{\alpha-1}} \varphi_s^{\frac{1}{\alpha-1}}\right) \quad (1.42)$$

Surviving firms respond to the emission-standard by setting higher prices to maintain mark-ups. Hence, the average prices are higher with a higher emission standard. In contrast to some studies that show that emission standards and emission taxes have different impacts on a firm's performance, this study finds that both policies enhance average productivity in the market but also harm the competitive

environment. Thus, the impact of an emission-standard policy on welfare is similar to the emission tax policy and is negative.<sup>11</sup>

## 1.5 Conclusion

This study proposed to understand the link between environmental regulations, average productivity, and market competition. In the literature surrounding the Porter Hypothesis, the lack of innovation is the main source of the inefficiency and a well-designed environmental policy must trigger innovation that increases productivity of individual firms and competitiveness of the economy. The results of this study suggest that if an environmental policy leads to a higher level of productivity through induced innovation then the policy will sustain environmental quality and competitive advantage of the economy too. However, if the productivity gain is attributed to reallocation of resources across firms through selection effect, then, it is important to account for the subsequent changes in the competitive environment and social welfare.

In this study, I developed a tractable model with firm heterogeneity that incorporates endogenous mark-ups that respond to the toughness of competition. In the model, average productivity is determined by distribution of firm-level productivity

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<sup>11</sup> For example, Li and Shi (2010) show critical differences between an emission tax and emission standard on how they affect average productivity. Their findings state that while an emission tax has no impact on average productivity, an emission standard policy imposes a more stringent constraint on the plants with low productivity than on plants with high productivity.

and allocation of resources across firms as well as the abatement technology. I assessed the impact of two different environmental policies: an emission tax and an emission standard. My overall findings imply that environmental regulations induce firms to adopt a cleaner abatement technology which improves environmental quality, and average productivity. However, the regulations harm competitive environment by increasing market concentration and the average prices.

Without environmental legislation enforced, abatement will not occur in the economy and firms will have no incentive to invest in a cleaner abatement technology. When the market is regulated, firms choose a level of clean technology so that they could devote fewer resources to abatement activities. The cost of abatement technology increases overall marginal cost of production and this increase in the cost is partially passed to consumer in the form of higher average prices.

The higher marginal cost reduces expected profit of firms prior to entry. The policy forces less productive producers to exit and the remaining inputs are reallocated to more productive firms. The surviving firms in the concentrated market will have stronger market power which enables them to set higher prices. Hence, the market becomes more productive on average but less competitive. The welfare is increasing with adoption of a cleaner abatement technology. However, because environmental regulation harms market competition by reducing number of operating firms in equilibrium, the welfare goes down.

This chapter contributes to the existing literature by studying the links between environmental policies, measures of productivity and market competition. The results of this study also include important insights into the debates surrounding the Porter Hypothesis.

## **CHAPTER 2**

### **Growth Accounting and Productivity Decomposition in India's Iron and Steel Industry**

#### **2.1 Introduction**

Over the past decade, a number of empirical studies have used micro-level data to study heterogeneity in firm-level productivity and find the proximate sources of the low or high aggregate TFP across and within countries. In this context, a growing body of recent literature has focused on the extent to which reallocation of capital and labor across firms can have large effects on aggregate TFP (Hsieh and Klenow 2009, Restuccia and Rogerson, 2008).

For a deeper understanding of the proximate sources of TFP dispersion, in this chapter, I perform a growth accounting to study the impact of the National Steel Policy on Iron and Steel Industry in India using micro-level data. India's remarkable growth over the last decade has made it one of the fastest growing economies in the world and an interesting subject of study. I use plant-level data from the Indian Annual Survey of Industries (ASI) to study TFP effects of National Steel Policy initiated in 2005 in India's Iron and Steel Industry. For a first pass, using the ASI plant-level data from 1999 to 2008 and the index number approach developed by Petrin and Levinsohn (2005), I calculate aggregate industry TFP growth before and after the policy change in 2005. Then, I decompose the aggregate TFP growth into a within-plant efficiency component and a reallocation component to find the

proximate sources of aggregate TFP growth. Later, in chapter three, I will use a quantitative framework to measure the impact of the policy on industry TFP.

The results of the growth accounting show an acceleration of productivity growth after 2005: the growth rate of aggregate TFP more than doubled, increasing from 1.72% over 1999-2004 (before the reform) to 3.61% over 2005-2008 (after the reform). TFP decomposition also reveals that despite an increase in the share of reallocation growth from 4.7% in 1999-2004 to 14% in 2005-2008, the largest chunk of the aggregate TFP growth is attributed to the within-plant efficiency component rather than the reallocation term. In particular, within-plant efficiency growth contributed about 95% to the aggregate TFP growth in the industry before the policy change and 86% after the policy change.

Given that the within-plant efficiency is the main contributor to the aggregate TFP growth, I consider technology change at the establishment-level as a potential engine of the productivity growth. To study the role of technology change in aggregate TFP growth, I take into account the technologies that plants use in the production process. The iron and steel-making technologies operated by firms in India's Iron and Steel sector can be classified into "standard" or "efficient" technologies. The standard technology uses coal as the main fuel input while the efficient technology uses fuels other than coal (e.g. gas and electricity). It is widely acknowledged that the standard technology is less productive (less fuel-efficient) than the



efficient technology.<sup>1</sup> Since, the ASI data does not provide any information about which production technology is operated at the plant-level, I use the information reported by plants on their fuel expenditures to infer which technology is used by each plant. I calculate the share of each primary input in total fuel expenditure. If a plant used coal as a primary input and its cost accounted for at least 90% of the total fuel expenditure in that plant, I classify the plant as a standard producer. If the plant used one of the other primary inputs (gas, electricity or hydrocarbons) with at least 90% share in the total fuel expenditures, I classify it as an efficient plant. With this mapping, I repeat the growth accounting and I calculate TFP growth rates and its components (within-plant and reallocation) for units in each of the two technology categories.

The technology-wise growth decomposition shows that the within-plant productivity growth is accounted for mainly by plants operating fuel-efficient technologies (efficient producers) as opposed to coal-based, high-energy intensive technologies (standard producers). In addition, the reallocation induced TFP growth after 2005 is accounted for by the initially coal-based plants. The share of the reallocation growth in the TFP growth of the standard producers increased from 8.9% in 1999-04 to 33.9% in 2005-08.

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<sup>1</sup> See also the Technology Road-map Research Program for the Steel Industry published by the American Iron and Steel Institute in 2010 and available at [www.steel.org](http://www.steel.org).

## 2.2 India' Iron and Steel Industry

Steel is a crucial element in the economy of developing countries and is considered as an indicator of industrial progress. The level of per capita consumption of steel is also an important sign of socio-economic development and living standard.

In India, Iron and Steel Industry is a key sector to many small and medium scale industries from communication to transportation and construction. The Iron and Steel sector plays very important role in the Indian economy and contributes to about 2% of the Gross Domestic Product (GDP). The Iron and Steel Industry in India consists of primary (integrated) and secondary producers. The primary producers are large firms with multiple production units that handle several production stages, from the extraction of iron ore to the production of iron and steel. The complexity of the production process in the integrated units requires the use of advanced technologies that are heavily dependent on energy inputs. In contrast, the secondary producers are smaller firms with less complicated technologies that produce relatively simple products from low-priced materials.

Earlier development of India's Iron and Steel Industry was subject to government control. In 1991, the industry experienced a major liberalization. Through the industrial liberalization in India, the government removed iron and steel sector from the list of industries reserved for the public sector and exempted it from the provisions of compulsory licensing under the Industries Act, 1951. For many years, the iron and steel industry was in the list of high priority industries for automatic approval for foreign equity investment up to 51%. In 1992, the government increased this limit to 100%. Pricing and distribution of steel also were deregulated in 1992.

Until 1992, the major steel products were priced by the Indian government and announced by the Joint Plant Committee (JPC). Though, not all steel items were under immediate control of JPC, but for many producers, about 50% to 80% of production was regulated by the JPC (Schumacher and Sathay, 1998). In 1992, the government has gradually decontrolled prices. The distribution of steel and production also freed from the government pricing scheme. In trade regime, import has undergone major liberalization moving gradually to freeing imports from licensing, canalization and lowering of import duty levels.

Through the major changes in the sector, India became the fifteenth largest steel producer in the world in 1998. It became the eighth largest crude steel producer in 2003 and now India is the fifth largest crude steel producer in the world and the world's largest producer of direct reduced iron or sponge iron.

Despite the major reforms in the Indian manufacturing sector, the Indian steel industry is trailing behind in several areas in technology and R&D which are reflected in poor techno-economic performance parameters. The Indian ministry of steel has emphasized the main problems of Iron and Steel Industry is technological obsolescence and lack of timely modernization/renovation as well as inferior quality of raw material and other inputs, and lack of R&D intervention.

In India similar to many developing countries, the government support are considered necessary for promoting innovation and research and development in the steel industry. Currently, In India the investment in R&D is about 0.15% to 0.25% of sales turnover which is way below the investment rate in the top steel makers in the world. The Indian government plans to increase the R&D investment to at least

1% of total turnover by 2015-16 and then to about 2% by 2020. To pursue the plan, in 2005, the government introduced the National Steel Policy (NSP) to speed up the development of the Iron and Steel sector. The long-term goal of the National Steel Policy is to attain production of over 100 million tonnes per year by 2020 (from 38 million tonnes in 2005 implying a compounded annual production growth rate of 7.3 percent).<sup>2</sup> To meet the target, the ministry of steel has taken three major initiatives in the form of (1) capacity expansion, (2) mergers, acquisitions and joint ventures, and (3) Research and development.

To ensure price stability of steel and steel-based products, the Indian government has introduced new fiscal measures as follow:

- Import Duty on all non-alloy steel, Zinc, Ferro-alloys and metcoke revised to 'Nil' from 5% w.e.f.<sup>3</sup>
- CVED on TMT bars and rounds modified to 'Nil' from 14% w.e.f.
- 15% export duty imposed on all flat products withdrawn
- 15% export duty imposed on Pig Iron, Sponge Iron, Scrap, Ingots and all categories of non-alloy semi finished steel.
- Export duty on long products such as bars, wire rods, angles etc. was revised to 15% w.e.f.

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<sup>2</sup> Crude steel production in India grew at 8% annually from 46.46 million tonnes in 2006 to 69.57 million tonnes in 2011.

<sup>3</sup> w.e.f: "with effect from"

- 15% ad-valorem export duty imposed on iron ore of all categories and grades w.e.f.
- Export duty on iron ore fines has been modified to 8% w.e.f.
- 5% import duty imposed on pig iron, semi-finished, flat and long category of products w.e.f.

The government also promoted capacity expansion projects in the industry through the support of large-capacity technologies and mergers and acquisitions initiatives. For example, since 2005, many integrated producers have signed memoranda of understanding (MoUs) with different states for planned capacity (mainly in the states of Orissa, Jharkhand, Chattisgarh, West Bengal, Karnataka, Gujarat and Maharashtra). The industry had already experienced 20 million tonnes of expansion in the finished steel manufacturing capacity during 2005-10.<sup>4</sup> The following table shows the 10 largest crude steel producers in 2012.

Table 2–1: Crude Steel Production, 1980-2012 (in thousand tonnes)

	1980	1985	1990	1995	2000	2005	2010	2012
China	37121	46794	66350	95360	128500	355790	638743	716542
Japan	111395	105279	110339	101640	106444	112471	109599	107232
United States	101455	80067	89726	95191	101824	94897	80495	88695
India	9514	11936	14963	22003	26924	45780	68976	77561
Russia				51589	59136	66146	66942	70426
South Korea	8558	13539	23125	36772	43107	47820	58914	69073
Germany	43838	40497	38434	42051	46376	44524	43830	42661
Turkey	2536	4832	9443	13183	14325	20965	29143	35885
Italy	26501	23898	25467	27766	26759	29350	25750	27257
Taiwan	3365	5186	9748	11605	16896	18942	19755	20664

<sup>4</sup> Reference: India's Ministry of Steel Annual Report.

### 2.3 Literature Review

Productivity growth of the India's manufacturing has been the subject of many empirical studies (Dougherty et al., 2011; Besley and Burgess, 2004). In a recent study, Bollard, Klenow, and Sharma (2013) used micro-level data to measure the aggregate manufacturing TFP and presents evidence of a substantial speedup in manufacturing TFP growth in India. Their estimate of the TFP growth rate was over 5 percentage points per year for 1993-2007 vs. 1980-1992. However, the overall results of their analysis did not provide conclusive evidence on whether the liberalization enhances productivity growth in the Indian manufacturing sector.

There are, however, only a few empirical investigations on the factors affecting productivity in the Indian Iron and Steel sector. The results of these empirical works are not conclusive and range from reporting improvements in measures of productivity to showing declines in the sector's productivity level. A study by Schumacher and Sathaye (1998) using industry-level data reports that the total factor productivity in India's Iron and Steel industry shows a downward trend of 1.71% per year from 1973-74 to 1993-94. They found that the decline was mainly because of price protective policies and the inefficiency of major public steel plants. In another study, Ray and Pal (2010) used industry-level data and conducted a productivity comparison of before and after liberalization in the period of 1980-92 and 1992-04. Their study shows evidence of improvement in partial productivity measures (labor and capital) after liberalization (1992-2004) but the results of overall productivity performance show declining TFP growth. They found that the significant output growth in India's

Iron and Steel industry was mainly input-driven rather than productivity-driven and that resource misallocation is the major obstacle to productivity growth.

The next section represents a growth accounting and productivity decomposition approach. I calculate the industry TFP and its components for the period of 1999 to 2008. The plant-level data from ASI are used to calculate aggregate industry TFP and productivity decomposition.

## 2.4 Framework

Following Basu and Fernald (2002) and Petrin and Levinsohn (2005), I used an index number approach to calculate TFP growth rates and then I decomposed it into a within-plant efficiency component and a reallocation component over 1999-2008, as well as both before and after the policy change in 2005. The index number approach is a straightforward method of calculating TFP and its components without any estimation (Biesebroeck, 2007).

The main advantage of the index number approach is that it enables researchers to handle multiple outputs and inputs cases while flexible and heterogeneous production technology is allowed. The other advantage of the index number approach is that there is no need to any estimation and all the measures are computed straightforward.

To start, consider the following production technology used by plant  $i$  at time  $t$ :

$$Q_{it} = H(A_{it}, X_{ijt}, E_{iet})$$

I denoted  $Q_{it}$  as the maximum quantity of gross output that can be produced by plant  $i$  at time  $t$  using primary and intermediate inputs. Primary inputs  $X$  indexed

by  $j$  include skilled labor  $L^s$ , unskilled labor  $L^u$ , and capital  $K$ . Intermediate inputs indexed by  $e$  include basic materials  $M$  and fuel  $F$ . The value-added function  $Y_{it}$  represents the maximum amount of current-price value-added that is produced by plant  $i$ , given a set of primary inputs, and its shadow prices  $P_x$ .  $A_{it}$  denotes plant level productivity parameter,  $w^u$  and  $w^s$  denote wage rate for unskilled and skilled labor, and  $R$  denotes interest rate.

$$Y_{it} = F(A_{it}, X_{ijt}) \quad (2.1)$$

Lets small letters represent natural logarithms. The aggregate TFP growth in the industry based on value-added is defined as,

$$da_t = dy_t - dx_t \quad (2.2)$$

where  $dy_t$  and  $dx_t$  are aggregate growth rates of value-added output and primary inputs.

The aggregate TFP growth can be decomposed into a within-plant efficiency growth component and a reallocation growth component of each primary input.

$$da_t = TE + RE_{L^u} + RE_{L^s} + RE_K \quad (2.3)$$

where,

$$\begin{aligned} TE &= \sum_i \frac{P_{it} Y_{it} da_{it}}{P_t Y_t} \\ RE_{L^u} &= \frac{\sum_i (w_{it}^u - w_t^u) L_{it}^u dL_{it}^u}{P_{xt} X_t} \\ RE_{L^s} &= \frac{\sum_i (w_{it}^s - w_t^s) L_{it}^s dL_{it}^s}{P_{xt} X_t} \end{aligned}$$



$$RE_K = \frac{\sum_i (r_{it} - r_t) K_{it} dK_{it}}{P_{xt} X_t}$$

and  $P_{xt} X_t$  stands for total input expenditures.

$$P_{xt} X_t = \sum_i w_{it}^u L_{it}^u + \sum_i w_{it}^s L_{it}^s + \sum_i r_{it} K_{it}$$

here  $Y_{it}$  denotes the nominal value-added of plant  $i$  and  $da_{it}$  denotes plant level TFP growth.  $TE$  is within-plant efficiency growth and is calculated as the weighted average of plant efficiency growth rates.  $\frac{P_{it} Y_{it}}{P_t Y_t}$  is share of firm  $i$  in the industry nominal value-added.  $RE$ 's reveal reallocation growth resulted from each primary input. The reallocation terms reflect reallocation of each primary input to plants that have a shadow price larger than the average industry input price. Since the plant-level input prices are not observable, I calculate the aggregate TFP growth rate and within-plant efficiency growth rate first. The residual difference between the two terms gives the overall reallocation component.

To calculate within-plant efficiency growth, first, I approximated the plant-level productivity growth  $da_{it}$  from:

$$da_{it} = dy_{it} - \alpha_{it}^{Lu} dL_{it}^u - \alpha_{it}^{Ls} dL_{it}^s - \alpha_{it}^K dK_{it} \quad (2.4)$$

In this equation,  $dy_{it}$  denotes the plant value-added growth rate which is calculated from the Divisia value-added growth formula and the Törnqvist Index as follows.<sup>5</sup>

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<sup>5</sup> The Törnqvist index is a discrete approximation to calculate growth rates. For a Törnqvist index, the growth rates are defined to be the difference in natural logarithms of successive observations of the plants. The weights are equal to the mean of the factor shares of the components in aggregate output.

$$dy_{it} = \frac{dq_{it} - \beta_{it}^m dM_{it} - \beta_{it}^f dF_{it}}{1 - \beta_{it}^m - \beta_{it}^f} \quad (2.5)$$

where,  $\alpha_{it}^j$  is the share of primary input  $j$  in the output of a plant  $i$  at time  $t$  and is given by,

$$\alpha_{it}^j = \frac{\alpha_{it}^j + \alpha_{it-1}^j}{2}, j \in \{l^u, l^s, k\}$$

and,  $\beta_{it}^e$  is share of intermediate input  $e$  in output of a plant  $i$  at time  $t$ , given by,

$$\beta_{it}^e = \frac{\beta_{it}^e + \beta_{it-1}^e}{2}, e \in \{m, f\}$$

All the growth rates are calculated as difference in natural logarithms. For example, for capital, the  $dK_{it}$  is given by,

$$dK_{it} = \ln(K_{it}) - \ln(K_{it-1})$$

## 2.5 Data

The Annual Survey of Industries (ASI) is the main source of industrial statistics in India. The ASI provides a variety of information on the value of output, assets (capital), employment and wages, value and types of materials and fuels at plant level. The ASI sampling frame includes all registered factories employing 10 or more workers using power, or factories with 20 or more workers without power. Production units in the survey are coded based on the National Industrial Classification (NIC). To extract the Iron and Steel sector from ASI, I use the NIC 1998 and NIC 2004. Under both industrial classification codes, basic metal products are classified under division 27, and group 271 which represents Iron and Steel products. With this, I can construct a sample of 1200 production units on average per year representing

Indian Iron and Steel sector. The details of Iron and Steel products under division 27 are provided in Appendix B.

Table 2–2: Average Number of Plants Per Year in Total Sample

	1999-2004	2005-2008	1999-2008
Number of Plants	950	1590	1200

The set of manufacturing units covered in every survey is called the “census” while rest of the units, which are chosen randomly, are treated as the “sample”. Census units for the period of 1999-04 include all manufacturing units with 200 employees or more, plus units with fewer than 200 employees but with significant contribution to the value of output, as well as all units in 12 industrially backward states. The definition of the census sample has been changed since 2005 and now covers units with 100 or more employees plus all the plants in the five industrial backward states (see Appendix C for more information on ASI sampling design). To have a reliable panel, this study uses both “census” and “sample” units between 1999 and 2008. The final sample includes 60% of sample units and 40% of census units. Figure 2.1 also shows the share of census units in the final sample.

The growth accounting undertaken in this study requires observations on individual production units every two consecutive years ( $t$  and  $t - 1$ ). In the ASI prior to 2005, plants were not assigned a unique identification number, so, it is not possible to link up directly the plant observations for every two years. So, I used a matching procedure following Bollard, Klenow, and Sharma (2013) to link production units across every two years from 1999 to 2005. I used information on several identification variables which are reported on a consistent basis every year. These include the year

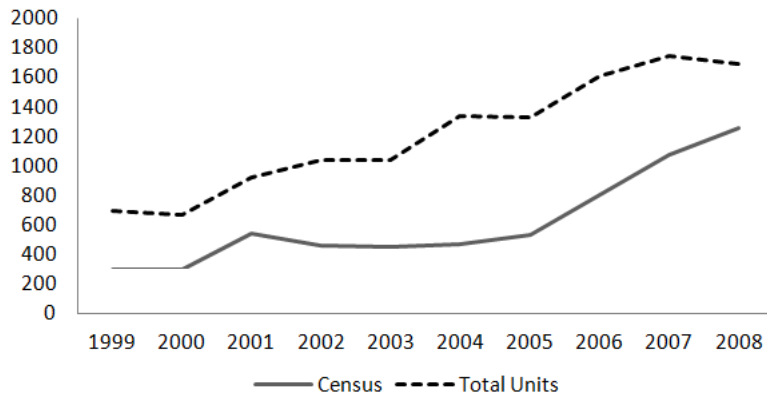


Figure 2–1: Number of Units in Census Sample vs. Total Sample

of initial production, state code, district code, sector code, type of organization, and type of ownership. The initial year of production and state code remain unchanged over time. I matched plants based on the initial year of production first. Dropping unmatched observations, I linked plants with the second identification variable (state code). This procedure was continued for the rest of the identification variables. To minimize possible errors, I ensured that for the plants in the final sample, the closing value of fixed assets was close to the opening value of the next year. The final sample contains plants that were matched based on at least 3 identification variables. To reduce the effect of spurious outliers, observations with extreme values were dropped from the sample. By the matching procedure, between 40-60% of units are matched on average in every two consecutive years.

At the aggregate and plant-level, I measure output as total value of output. I also use total mandays worked of workers to measure unskilled labor and total mandays worked of managers and supervisors to measure skilled labor. Capital is

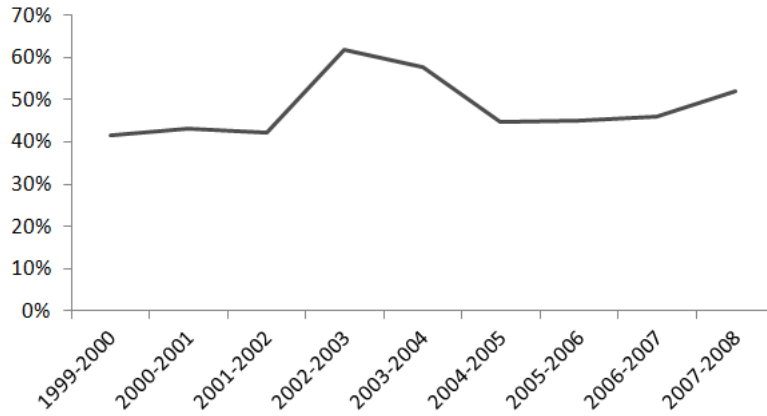


Figure 2–2: Percentage of Matched Plants to Previous Year Record

measured as the value of fixed assets. Materials and energy inputs are measured by total their expenditures.

All the values in the data are deflated based on the price indexes provided by the Handbook of Statistics on Indian Economy published by the “Reserve Bank of India”. In particular, the value of output was deflated with a price index for “basic materials and alloy industries”. The material was deflated by the price index of intermediate goods, and each fuel (coal, gas, electricity and hydrocarbons) was deflated by its own price index.

## 2.6 Productivity Growth Decomposition

Table 2.3 outlines the aggregate TFP growth rates and the share of reallocation growth in the growth rates. All the growth rates are reported as yearly average. The industry TFP grows averaged 1.72% over 1999-04, 3.61% over 2005-08 and 2.56% over the whole period of 1999-08. The within-plant efficiency was the main source of productivity gain in the industry both before and after the policy change and it

accounts for over 95% of the aggregate TFP growth in 1999-04. However, reallocation plays a higher role (15% of the aggregate TFP growth) after the policy change.

Table 2–3: TFP Growth Rates and Decomposition(%)

Period	1999-04	2005-08	1999-08
Aggregate Productivity	1.72	3.61	2.56
Share of within-plant efficiency	95.3	86.1	89.6
Share of Reallocation	4.7	13.9	10.4

What was the underlying cause of within-plant efficiency growth in India’s Iron and Steel industry? Given that the sector was highly technology-dependent, a natural candidate for the acceleration of within-plant efficiency growth is technological progress. In the ASI data, plants do not report the types of technology that they use in production, therefore, it is impossible to observe directly if there has been any change in technology use over time. However, Iron and Steel making processes are extremely intensive in material and energy usage. A wide range of Iron and Steel making technologies are characterized by the types of primary fuel input. Plant operators are forced to choose a technology that makes their production facilities energy-efficient. The answer to the question of which technology is appropriate lies in the cost and quality of fuel inputs as well as the capacity of the production unit. Knowing these requirements helps managers to decide, for instance, if a coal-based furnace should be used in production or an electric arc furnace.<sup>6</sup>

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<sup>6</sup> Fuel in some technologies constitutes up to 50% of the total production cost.

So, I used expenditures of primary fuel input as a proxy to infer the production technologies in the industry. Coal is a plentiful and cheap source of fuel in India and coal-based technologies are relatively less expensive but important to produce low-priced Iron and Steel products. Coal-based technologies are inefficient and outdated compared to alternative technologies that use an efficient fuel like gas, hydrocarbons, or electricity.<sup>7</sup> As a first pass, I calculated the share of each primary fuel input in total fuel expenditures and classified the plants that use coal as a primary input as standard plants and plants that use other fuels (natural gas, hydrocarbons, or electricity) as efficient plants. With this technology split, the standard technology becomes the less productive technology (less fuel-efficient) than the efficient technology but less expensive too.

This classification may not represent the entire technological features of the industry, but it is consistent with the Iron and Steel making process in India. For example, in the iron-making step, iron ore is reduced to either pig iron (low quality iron) or sponge iron (high quality iron). Pig iron production occurs in Blast Furnaces (BF) where coal is the primary fuel (this is classified as standard technology). “Direct Reduced” is an alternative technology that produces sponge iron using fossil fuels (this is classified as the efficient technology). The conversion of ore into pig iron is more energy-intensive and less efficient than conversion of iron ore to sponge iron.

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<sup>7</sup> For detailed information about steel production technologies, energy consumption and their efficiencies, see the Technology Road-map Research Program for the Steel Industry published by American Iron and Steel Institute in 2010 and available at [www.steel.org](http://www.steel.org).

The steel production step also involves two main technologies: Open Hearth Furnace (OHF) and Basic Oxygen Furnace (BOF). OHF is an old technology with high capital costs and fuel consumption. In an OHF process, over 90% of the fuel comes from coal, 3%-4% percent from gas and 1%-2% from liquid fuels (OHF is classified as the standard technology). In contrast, BOF is a newer technology with higher efficiency. The main energy input in BOF process is gas or combination of gas and other fuels (this is classified as the efficient technology). A typical technology change would be to switch from one technology to another. For example, in many steel producing units in India, Open Hearth Furnaces have been shutdown or replaced by the alternative technologies (e.g. Basic Oxygen Furnace) which leads to a decrease in the average share of crude steel production by OHF from 16.6% over 1990-04 to 2% over 2005-08 (see Appendix D for more information about iron and steel making technologies).

Next, I recalculated the TFPs and their components for plants with standard and efficiency technologies. The following table shows the results. Plants with the efficient technology grew significantly faster during 2005-08 with an average growth rate of 5.33% per year compared to 1.89% in 1999-04. While, producers with the standard technology experience a decline in average productivity growth rate from 1.16% per year in the first period to -0.61% over 2005-08. For the both types of plants, within-firm efficiency remains as the main source of productivity growth. However, for the standard producers, the share of reallocation has increased from 8.9% in 1999-04 to 33.9% during 2005-08 indicating a large reallocation of inputs across standard producers and between plants with different technologies.



Table 2–4: Technology-wise TFP Growth and Decomposition(%)

		1999-04	2005-08	1999-08
Standard Producers	Aggregate Productivity	1.16	-0.61	0.37
	Share of within-plant efficiency	91.1	66.1	90.7
	Share of Reallocation	8.9	33.9	9.3
Efficient Producers	Aggregate Productivity	1.89	5.33	3.42
	Share of within-plant efficiency	97.3	93.0	94.3
	Share of Reallocation	2.7	7.0	5.7

An important statistic that can be observed from the technology-wise growth accounting is the gap in the growth rates of plants with different technologies both before and after the policy change. While all the production units grew at slightly different rates before the policy change (1.16% vs. 1.89%), the acceleration of TFP growth of efficient plants along with declining TFP growth of standard plants, increased productivity growth gap between standard and efficient producers. This gap has increased from 0.73% in 1999-04 to 5.94% in 2005-08.

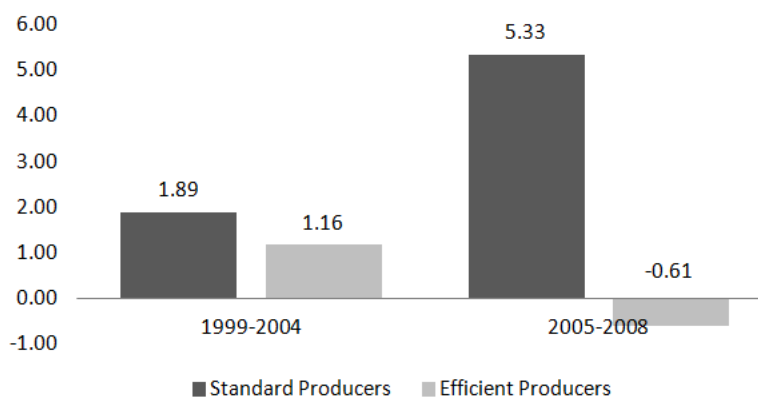


Figure 2–3: Gap in TFP Growth Rates of Standard and Efficient Plants

## 2.7 Conclusion

My quantitative analysis in this chapter provides supporting evidence that plants with more productive technologies have experienced a larger TFP growth after 2005 while there is also a large reallocation of resources across plants with less productive technologies. My results indicate that technological change might be a possible cause of the TFP growth in the sector after 2005 and the National Steel Policy introduced in 2005 and in particular its subsidy program could be the reason that encouraged plants to adopt more productive technologies. However, my results, cannot provide conclusive evidence if the subsidy program is an important contributor to the changes in TFP growth rates. In addition, it is important to examine if the policy generated distortions and led to misallocation effect that could potentially shave a part of productive growth through misallocation of resources across plants with different productivity. In the next chapter, I am going to quantitatively measure the misallocation effect and its potential negative impact on productivity. I will develop a empirical framework to assess if the subsidy policy has led to misallocation of resources across plants and if it is also quantitatively important in accounting for the changes in TFP growth rates and the gap between plants with different technologies.

## CHAPTER 3

### Innovation Subsidies: Misallocation and Technology Upgrade

#### 3.1 Introduction

It is well understood that total factor productivity (TFP) plays a major role in understanding the differences in income levels between rich and poor countries, as well as in accounting for growth miracles and growth disasters within countries. An important follow-up question is, what are the proximate sources of low or high aggregate TFP? Broadly speaking, macroeconomists have emphasized two types of explanations in accounting for aggregate TFP, both across countries and within individual countries over time: (a) how productivity is determined at the plant-level (e.g., Aghion and Howitt, 1992; Parente and Prescott (1994, 1999), and (b) how aggregate resources are allocated across plants of a given productivity (e.g., Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009). At a deeper level, we would like to understand what particular policies and frictions lead to changes in productivity at the plant-level or cause misallocation.

In recent years, there has been substantial progress in measuring the extent of misallocation and quantifying its importance for aggregate TFP, as well as in assessing the quantitative importance of specific factors leading to misallocation (see Restuccia and Rogerson, 2013 for an excellent survey of this literature). However, only a few studies exist on policies that cause misallocation but also induce changes in productivity at the plant-level. In this chapter, I ask what are the aggregate TFP

effects of a subsidy policy that generates misallocation across plants while at the same time induces certain plants to adopt more productive technologies? Answering this question requires the use of establishment-level data in an environment in which the policy change is directly observed. My focus in this chapter is on a particular policy in a specific industry, in which the link between observed policy and productivity outcomes is tight. I use plant-level data from the Annual Survey of Industries (ASI) to study the aggregate TFP effects of a subsidy program in India’s Iron and Steel sector.

Here, I examine whether the 2005 subsidy program was an important underlying contributor to the aggregate TFP changes in India’s Iron and Steel Industry, and if it was, through what channels did it manifest itself. In order to assess quantitatively how important the reform was in generating the industry TFP growth, I develop a simple general equilibrium model of firm heterogeneity with the possibility of technology upgrade at the establishment-level. In particular, I extended the Lucas (1978) span-of-control model to include a technology choice at the establishment-level along the lines of Adamopoulos and Restuccia (2014b). In this model, individuals draw their managerial ability from an invariant and known distribution, and choose whether to become entrepreneurs and operate plants or become employees working at the plants. When setting up an establishment, each entrepreneur has access to two technologies: a “standard” technology and an “efficient” technology. The efficient technology has higher TFP but requires a higher fixed cost of operation relative to the standard technology. Aggregate TFP is determined by the allocation of individuals across occupations (hired workers vs. entrepreneurs), the allocation

of resources across establishments, and the technology selection of entrepreneurs. In the absence of any distortions, individuals will optimally sort themselves across occupations and technologies, with the highest ability individuals operating efficient technology plants, intermediate ability individuals operating standard technology plants, and low ability individuals working as employees at both types of plants. The equilibrium is characterized by two cut-off levels of ability, where the lowest determines who becomes a worker vs. entrepreneur (occupational choice) and the second determines who operates the standard vs. efficient technology (technology choice). In other words, for a given distribution of managerial ability, the undistorted equilibrium implies an efficient distribution of plant sizes and technology usage. The efficient distribution of plant sizes and technologies can be observed from the ASI data which shows that the average number of workers in the efficient plants was 610 compared to the standard plants (268) before the policy change.

Introducing a non-uniform subsidy policy in this framework with endogenous technology choice will generate three direct effects. First, holding fixed the number of plants operating each technology, the subsidy introduces idiosyncrasy in the prices faced by individual producers, causing a reallocation of resources from non-subsidized to subsidized plants (misallocation effect). Second, the plants that receive the subsidies are motivated to switch to the efficient technology (technology upgrade effect). While the misallocation effect would tend to reduce aggregate industry TFP, the technology upgrade effect would tend to raise it. In addition, through general equilibrium effects, the division of individuals between workers and entrepreneurs also impacts aggregate industry TFP (selection effect). More specifically, the threshold

for occupational choice increases and the threshold for technology choice decreases in response to the subsidy policy. Which effect dominates is a quantitative question.

To quantify the effects of the subsidy policy, I calibrate the model to India's Iron and Steel industry prior to the policy change in 2005. Then, I introduce subsidy policy as being proportional to output. I assume that the subsidies are financed through a lump-sum tax on consumers. I chose the subsidy rates to match the government spending as a percentage of annual turnover of iron and steel producers in India. In the calibrated model, the size-dependent nature of the subsidies is captured by allowing only plants with labor input above an exogenously set level to receive the subsidies. In India's Iron and Steel sector, large plants with multi-unit production facilities were the main participants in the subsidy program. In line with this, I set the exogenous employment cut-off for the subsidized plants to the minimum employment size of multi-unit plants before the policy change.

The misallocation effect can be captured in the above framework if the technology choice of entrepreneurs is shutdown. If all plants use the standard technology, the size-dependent subsidies distort only the occupation decisions of individuals, implying a misallocation of resources across/between large and small production units (level-effect). In this environment, the model predicts that the size-dependent subsidies lead to a small decrease in aggregate TFP.

However, when individuals and plants are permitted to self-select, I show that the size-dependent subsidies distort both the occupation decision of individuals and the technology choice of entrepreneurs. The misallocation effect still generates aggregate TFP loss, however, the policy induces technology upgrading at plant level

which increases the marginal benefit of production and does so more for the high TFP/efficient technology producers than it does for the low TFP/standard producers. As a result, marginal plants that used to operate with the standard technology upgrade to the efficient technology. The positive impact of technology upgrading is high enough to increase the aggregate industry TFP. The calibrated model with technology choice predicts that the size-dependent subsidies increase the industry TFP growth rate by 0.63%-0.71% which explains 16%-21% of the aggregate TFP growth observed from data. The model also does well in predicting the gap in TFP growth rates of standard and efficient producers: the policy accounts for 44%-56% of the gap in TFP growth rates of plants with different technology. The source of the change in the industry TFP growth rate is accounted for by the misallocation effect (-2%), the technology upgrade effect (49%), and the selection effect (53%).

### **3.2 Literature Review**

The existence of large and persistent per capita income differences across rich and poor countries has attracted many theoretical and empirical studies. In the last two decades, establishment-level data have become available and economists have increasingly used it to better understand the sources of productivity differences across/within countries. The focus of the emerging literature using micro-level data has been to make inferences about aggregate economic performance through the lens of heterogeneity at the establishment-level.

Among many factors at establishment-level that might be important in accounting for the dispersion of aggregate TFPs, two factors are most prominent. A country

might be less productive because firms in that country use less productive technologies. Or, firms may have the frontier technologies, but without sufficient knowledge and skills, they are unable to operate the technologies efficiently. In this respect, the difference in the use of technology at the establishment-level is the source of low aggregate TFP (Aghion and Howitt, 1992; Parente and Prescott, 1994).

However, aggregate TFP depends not only on the dispersion of individual establishments, but also on how aggregate resources are allocated across them. The optimal resource allocation requires equalization of marginal products at the establishment-level. Idiosyncratic distortions can change relative prices faced by individual firms and alter the equalization of marginal returns to production factors at the establishment-level. This deviation leads to a sub-optimal resource allocation (or the so-called misallocation) which reduces the overall levels of output and aggregate productivity. Figure 3.1 illustrates misallocation effect generated from an inefficient allocation of labor across two firms. The unequal marginal products of labor across the two firms leads to an output loss. This view of the low aggregate productivity has received a great deal of attention recently by a large branch of the macroeconomics literature (e.g. see Restuccia and Rogerson, 2008, and, Hsieh and Klenow, 2009).

There are many underlying factors which are thought to be important causes of misallocation. For example, the cost of firing employees in large establishments, favorable loans to local firms, the political connections of state-owned corporations, financial frictions such as the extra borrowing costs for small firms, and size-dependent taxes or subsidies – all can potentially lead to misallocation.



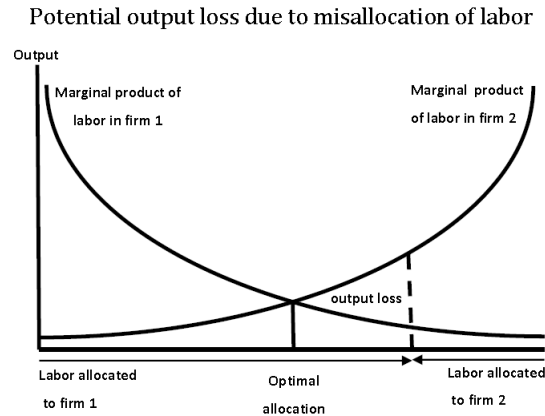


Figure 3–1: Labor Misallocation Effect

Restuccia and Rogerson (2013) provide an excellent survey of empirical studies on misallocation and identify two different types. The first set of empirical studies tries to understand the underlying factors that cause misallocation by considering one or more particular policies or institutions to examine the channel through which misallocation is generated, and then by quantifying the overall impact of misallocation on aggregate outcomes and firm performance. A study by Guner et al. (2008) considers policies that affect the size of establishments with a focus on the regulation of the retail sector in Japan and France, employment protection in Italy, and subsidies for small and medium size enterprises in Korea. Their study indicates that policies that reduce the average size of establishments by 20% lead to reductions in output and output per establishment up to 8.1% and 25.6% respectively, as well as a large increase in the number of establishments (23.5%).

Adamopoulos and Restuccia (2014a) looked at the 1988 Comprehensive Agrarian Reform Program (CARP) in the Philippines, that capped farm size at a legislated

ceiling and the 1976 Amendment to the West Pakistan Land Revenue Act which imposed a progressive tax on farm sizes. Their quantitative assessment reports that the land reform in the Philippines reduced average size and agricultural productivity by 7%, while the tax reform in Pakistan reduced size and productivity by 3%.

In a study on capital market imperfections, Gilchrist et al. (2012) measures the extent of misallocation through borrowing costs of firms in a sub-set of the U.S. manufacturing sector from interest rate spreads on their outstanding publicly-traded debt. Their findings show that the resource loss due to the financial market frictions leads to relatively a small TFP decline of 1.5 to 3.5 percent.

Given the wide array of policies and institutions that can generate misallocation, another set of papers focus on “wedges” rather than specific policies and institutions. In this case, the overall effect of misallocation is the object of interest. Within this literature the well-known paper by Hsieh and Klenow (2009) shows that resource misallocation has led to sizable gaps in marginal products of labor and capital across plants within narrowly-defined industries in China and India compared to the U.S. Their quantitative results report that moving to the U.S. efficiency increases TFP in China by 30-50% and TFP in India by 40-60%. Restuccia and Rogerson (2008) also examine policies that create heterogeneity in the prices faced by individual firms and then measure the potential extent of output loss due to misallocation. They find that such policies can result to 30% decreases in output and aggregate TFP.

Bello, et al. (2011) studied the link between misallocation and growth collapse in Venezuela after the late 1950s. Their study points out many policies and institutions that misallocated resources to unproductive establishments, and shows that

misallocation can explain most of the decrease in TFP and capital accumulation observed in Venezuela relative to the United States during the collapse period.

While in many studies, the impact of misallocation on aggregate output and TFP is measured holding the value of the establishment-level productivity fixed or exogenously given, a recent study by Gabler and Poschke (2013) evaluates distortions that not only generate misallocation but also impact the distribution of firm-level productivity. According to their framework, in absence of distortions, firms engage in costly experiments that can promote their productivity level. However, if high productivity firms are subject to distortions (tax), firms have no incentive to invest in purposeful experiments. In this case, the overall impact of misallocation on aggregate productivity is larger because the distortions not only misallocate resources across firms but also it discourage them from investing in experiments that could lead to an increase in the level of productivity.

In this chapter, I measure the quantitative impact of a policy that even though generates misallocation, it incentivizes technology upgrading at the establishment level. In particular, I consider the misallocation generated from the subsidy program in the Iron and Steel sector in India in 2005. In this sector, the subsidy program was the main source of financial support for innovation activities focused on the improvement of existing technologies, energy efficiency, and input upgrading. While in principle the allocation of subsidies was open to all firms, in practice the subsidies were effectively size-dependent, as they were only given to large Iron and Steel producers. The non-uniform distribution of subsidies creates heterogeneity in idiosyncratic prices faced by individual producers and led to misallocation. In contrast

to the study of Gabler and Poschke (2013), in which distortions discourage productivity improvements at the establishment-level, the subsidy program in Indian Iron and Steel sector provided incentives for technology upgrade activities at the establishment-level<sup>1</sup> .

### **3.3 National Steel Policy**

Successful transition to a modern and efficient steel industry requires technological progress. In terms of innovation and technological change, the iron and steel companies in India have a relatively small investment in R&D compared to the top steel producers in the world. For instance, China, as the world largest steel producer, invests in R&D more than all the investment made by rest of the world combined. To spur technological progress, the draft NSP initiated sustained budgetary support of various innovation and technology improvement activities in the industry.<sup>2</sup>

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<sup>1</sup> The literature has stressed several reasons for why small firms participate less frequently in support programs than large firms. The level of firms' participation in a subsidy program is determined by the government decision to distribute the funds and implicitly, by the firm's decision to apply for the funds. For example, Heijs and Herrera (2004) discuss that small firms suffer from limitations of human resource and they often do not have enough time to prepare application forms or to gather information about various kinds of financial aids from the public administration. A prime empirical example is the study by Hanel (2003) on the effect of innovation support programs by the Canadian government on manufacturing firms. Hanel shows that small firms participated in the R&D less frequently than large firms. In addition, a limited capacity of innovation management in small firms could have delayed the conversion of their innovation activities into well-organized projects with clear objectives which is necessary to apply for the funds.

<sup>2</sup> According to the World Steel Association, efficiency improvements could lead to reductions of up to 50 percent of energy required to produce a tonne of crude steel.

According to information provided by India’s Ministry of Steel, since 2005, the government has allocated around 20 to 40 million dollars per year to finance well-defined projects in various areas such as input upgrading, reduction in energy consumption, and technology progress. In addition to these direct funds, the ministry organized particular sessions and constituted a “Task Force” to review the existing institutional infrastructure available for research and development in steel producers. The task force was to determine the existing shortages and set up an advanced R&D center to utilize domestically available resources. For example, under this program, firms could receive a one-time grant of 10 million dollars during the first three years and the full establishment cost of a virtual center for R&D activities. In addition, the government approved a new scheme called the “Scheme for Promotion of R&D in Iron & Steel Sector” for which an additional amount of 25 million dollar has been allocated for the period of 2007-12.

Table 3–1: R&D investment (as % of turnover) in the Main Indian Steel Companies

	2005-06	2006-07	2007-08	2008-09	2009-10
SAIL	0.19	0.20	0.22	0.24	0.24
RINL	0.12	0.13	0.17	0.16	0.12
Tata Steel	0.21	0.24	0.21	0.20	0.21
JSPL	0.06	0.07	0.06	0.04	n.a.
Essar Steel	0.045	0.11	0.12	0.12	0.17
JSW Steel			0.13	0.09	0.067

An review of the R&D investment in Steel companies abroad shows that research and development activities in the top steel producers particularly in China, Japan and South Korea is quite different. Not only the companies are equipped with full-fledged in-house R&D laboratory, they also have visible tie-up with external

laboratories and Academic institutions with large outlay of funds earmarked for R&D. Naturally, annual R&D investment is very high and reportedly varies in the range of 1-2% of their turnover. The following table shows R&D investment as percentage of sales in the top steel producers in the world.

Table 3–2: R&D Expenditure of Global Steel Companies as percent of sales turnover(%)

Company Name	Country	2008-09	2009-10
Nippon Steel	Japan	0.9	1.0
JFE	Japan	1.1	1.1
POSCO	South Korea	1.2	1.3
Thyssen Krupp	Germany	0.6	0.7
KOBE Steel	Japan	1.4	1.4
Arcelor Mittal	Luxembourg	0.2	0.4
Sumitomo Metal	Japan	1.2	1.2
Boa Steel	China	1.2	1.7

The innovation subsidy policy has been used to promote iron and steel industry in China and Japan too. In Japan, in order to catch up with the advanced countries, in 1951 the government introduced the “First Iron and Steel Rationalization Plan” with focus on technological change and R&D. The “First Iron and Steel Rationalization Plan” was followed by the “Second Iron and Steel Rationalization Plan” in 1956. The focus of the second plan was the introduction of the basic oxygen furnace (BOF), which was a substitute for the open hearth furnace. A study by Ohashi (2005) shows that the subsidy policy had a significant impact on growth rate of the industry.

### 3.4 A Model of Plant Size and Technology Choice

I considered a standard version of the Lucas (1978) span-of-control industry model. Each individual in the economy is endowed with a set of skills to become

an entrepreneur. The skills can be considered as variety of someone's experience of different industries, companies, and technologies. The set of skills (or managerial talent) is fixed across time but varies across individuals. As in the standard span-of-control model, entrepreneurs tend to have more skills than employees. Occupation choice decision depends on an individual's level of skills and is determined by a comparison of benefits from being an entrepreneur (producer) versus a paid worker. Each individual that chooses to become entrepreneur will represent one production unit (plant) and in total they create an industry with heterogeneous producers. In this framework, the size of each establishment is endogenous and depends on the managerial ability of its entrepreneur.

To incorporate an endogenous technology change, I extend the Lucas span-of-control model to include a technology choice at the establishment-level along the lines of Adamopoulos and Restuccia (2014b). When an individual decides to become an entrepreneur, he/she has access to two technologies, a "standard" technology and an "efficient" technology. The two technologies differ in terms of TFP and fixed cost. In particular, the efficient technology is more productive but it requires a higher fixed cost relative to the standard technology. In this framework, the aggregate TFP is determined by the allocation of individuals across occupations, the allocation of resources across establishments, and the choice of technology use of entrepreneurs.

Without distortions, there is an optimal allocation of individuals across two occupations (working vs. entrepreneurship) and allocation of efficient and standard technology across plants. The equilibrium is characterized by two cut-off levels of

ability, where the lowest determines who becomes a worker vs. entrepreneur (occupational choice) and the upper threshold determines who operates the standard vs. the efficient technology (technology choice).

To start, consider an industry that has a given quantity of homogenous capital  $K$  and a given labor-force  $L_a = 1$ . The individual's level of skills  $s$  is drawn from an exogenous and time invariant distribution function represented by *cdf*  $G(s)$  and *pdf*  $g(s)$ .

The initial allocation of resources involves a division of labor-force into workers  $L$  and the rest to entrepreneurs  $L_p$ . To operate, a plant with productivity level  $s$  must choose either the standard technology with productivity parameter  $\kappa_n$  and technology-specific cost  $c_n$ , or, the efficient technology with productivity parameter  $\kappa_m$  and technology-specific cost  $c_m$  while  $\kappa_m > \kappa_n$  and  $c_m > c_n$ . Then, the establishment employs an efficient amount of capital  $k(s)$ , and labor  $l(s)$  and produces output according to a decreasing return to scale technology given by,

$$y_i(s) = (\kappa_i s)^{1-\gamma} (k_i(s)^\alpha l_i(s)^{1-\alpha})^\gamma, \quad i \in \{n, m\}, \quad \kappa_m > \kappa_n \quad (3.1)$$

where  $\gamma$  is the span-of-control,  $s$  is plant-level productivity parameter,  $\alpha$  is capital's share in output, and  $\kappa$  is the technology-specific parameter. A plant with productivity  $s$  and technology  $i$  maximizes profit with a given market wage rate  $w$  and rental rate of capital  $r$ .

$$\pi_i(s) = \max \{y_i - w l_i(s) - r k_i(s) - c_i\}$$



where  $c_i$  is the fixed cost of technology  $i$  and is measured in units of output. Plants are competitive in output and factor markets. Conditional on operating, the first order conditions give demands for labor and capital as,

$$k_i(s) = \left(\frac{\alpha}{r}\right)^{\frac{1-(1-\alpha)\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{1}{1-\gamma}} \kappa_i s \quad (3.2)$$

$$l_i(s) = \left(\frac{\alpha}{r}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{1-\alpha\gamma}{1-\gamma}} \gamma^{\frac{1}{1-\gamma}} \kappa_i s \quad (3.3)$$

All plants have the same capital-labor ratio which is independent of the plant productivity level  $s$ , and the technology-productivity parameter  $\kappa$ . This result is consistent with the data. Calculation of capital-labor ratio for the Iron and Steel Industry from ASI data also shows that the average capital-labor ratio before and after the policy change in 2005 are 0.1034 and 0.1049.

$$\frac{l}{k} = \left(\frac{1-\alpha}{\alpha}\right) \left(\frac{r}{w}\right) \quad (3.4)$$

Since the demands for labor and capital are linear in productivity parameter  $s$ , output and profit at plant level remain linear in  $s$  too. This implies that large establishments are operated by entrepreneurs with the higher level of managerial skills.

$$y_i(s) = \left(\frac{\alpha}{r}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{\gamma}{1-\gamma}} \kappa_i s \quad (3.5)$$

$$\pi_i(s) = (1-\gamma) y_i(s) - c_i$$

## Decisions

In a stationary environment, the efficient allocation of individuals between workers and entrepreneurs is determined by a comparison of the job market wage rate  $w$  and the profit earned under the standard production technology  $\pi_n(s_n)$ . The condition yields a threshold level of skills  $s_n$  at which, an individual becomes indifferent to whether they become a hired worker or an entrepreneur. This lower level of threshold is calculated,

$$\pi_n(s_n) = w \tag{3.6}$$

The second threshold of skills  $s_m$  is determined by a comparison of expected profits earned as a producer with the standard technology and a producer with the efficient technology.

$$\pi_n(s_n) = \pi_m(s_m) \tag{3.7}$$

Note that in equilibrium and in the absence of any distortions, individuals will optimally sort themselves across occupations and technologies. Individuals with the highest level of ability operate efficient technology plants, individuals with intermediate level of ability run the standard technology plants, and individuals with the lowest level of ability work as employees at the both types of plants. The undistorted equilibrium also implies an efficient distribution of plant sizes and technology usage.

## Subsidy Policy and Industry TFP

Let us assume that the government introduces a subsidy policy and each plant is subject to a subsidy to output  $\tau(s)$ . Since the policy aims to promote large units,

only plants with number of workers above a threshold can receive the subsidies. I define  $\bar{l}$  the cut-off employment threshold for subsidized plants.  $\bar{l}$  is exogenous and is determined by the government. Producers with standard or efficient technology can receive the subsidies as long as their employment size is above  $\bar{l}$ . The subsidy rate remains fixed as long as the plant is in operation.

$$\tau(s) = 0, \text{ if } l_i < \bar{l}$$

The policy changes the profit maximization problem of subsidized plants and their demands for capital and labor. Given the wage rate  $w$  and the rental price of capital  $r$ , the profit maximization problem of a firm  $s$  with technology  $i$  changes to,

$$\pi_i(s) = \max\{(1 + \tau(s)) y_i - w l_i(s) - r k_i(s) - c_i\}$$

The distortions generated from the size-dependent subsidies alter plant-level decisions and impact optimal allocation of resources across plants as well the optimal technology selections. It can be shown that the lower threshold of skills becomes,

$$s_n = \frac{w + c_n}{(1 + \tau(s)_n)^{\frac{1}{1-\gamma}} (1 - \gamma) \kappa_n} \left(\frac{\alpha}{r}\right)^{\frac{-\alpha\gamma}{1-\gamma}} \left(\frac{1 - \alpha}{w}\right)^{\frac{-(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{-\gamma}{1-\gamma}} \quad (3.8)$$

where  $\tau(s)_n$  is the subsidy rate to plants with productivity  $s$  and technology  $n$ . A lower wage rate or a higher subsidy rate increase expected profit of entrepreneurship and reduce the lower threshold of skills  $s_n$ . This motivates marginal workers with the highest level of ability to enter the industry and become entrepreneurs. A subsidy policy has no effect on the profit of standard plants with productivity below the kink point but increase the market wage rate. The policy leads to an increase in the lower threshold of skills such that the least productivity entrepreneurs leave the industry and become hired workers.

The upper threshold of skills also changes to,

$$s_m = \frac{c_m - c_n}{(1 - \gamma) \left( (1 + \tau(s)_m)^{\frac{1}{1-\gamma}} \kappa_m - (1 + \tau(s)_n)^{\frac{1}{1-\gamma}} \kappa_n \right)} \left( \frac{\alpha}{r} \right)^{\frac{-\alpha\gamma}{1-\gamma}} \left( \frac{1 - \alpha}{w} \right)^{\frac{-(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{-\gamma}{1-\gamma}} \quad (3.9)$$

where  $\tau(s)_m$  denotes the subsidy rate faced by producers  $s$  and technology  $m$ . A subsidy policy encourages marginal entrepreneurs with standard technology to switch to the efficient technology.

### Market Clearing Conditions

In equilibrium, there exist two types of establishments: high productivity entrepreneurs who operate larger plants using the efficient technology and entrepreneurs with lower level of productivity who run smaller plants using the standard technology. The aggregate demands for capital and labor are determined by wage rate  $w$ , rental rate of capital  $r$  and the productivity distribution condition on entry (conditional productivity distribution)  $g_c(s)$ . Setting the maximum level of skills at  $s_{max}$ , the sum of the capital employed by standard and efficient plants gives the aggregate capital in the industry.

$$K = K_n + K_m = \sum_{s_n}^{s_m} k_n(s) g_c(s) + \sum_{s_m}^{s_{max}} k_m(s) g_c(s) \quad (3.10)$$

The aggregate labor employed by standard and efficient plants are given by,

$$L = L_n + L_m = \sum_{s_n}^{s_m} l_n(s) g_c(s) + \sum_{s_m}^{s_{max}} l_m(s) g_c(s) \quad (3.11)$$

Then, the market clearing condition for labor becomes,

$$L_a = L + L_p = 1$$

I assume that the subsidies are financed by a lump-sum tax  $T$  on consumers which gives the government budget constraint as,

$$T = \sum_{s_{\bar{l}}}^{s_{max}} \tau(s) y(s)$$

where  $s_{\bar{l}}$  is productivity level of plant with minimum employment size  $\bar{l}$ . Then the economy resource constraint is given by  $C = Y$ , where  $C$  is aggregate consumption. Aggregate industry output equals sum of outputs produced by plants with different technologies.

$$Y = Y_n + Y_m = \sum_{s_n}^{s_m} y_n(s) g_c(s) + \sum_{s_m}^{s_{max}} y_m(s) g_c(s) \quad (3.12)$$

To find an expression for the industry TFP and TFP of plants with standard and efficiency technologies, I aggregated demands for capital and labor with subsidy over technology  $i$  and calculated total capital and labor employed by each group of producers.

$$K_i = \left(\frac{\alpha}{r}\right)^{\frac{1-(1-\alpha)\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{1}{1-\gamma}} \left( \kappa_i \sum_{s_i}^{s_{i+1}} s (1 + \tau(s)_i)^{\frac{1}{1-\gamma}} g_c(s) \right) \quad (3.13)$$

$$L_i = \left(\frac{\alpha}{r}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{1-\alpha\gamma}{1-\gamma}} \gamma^{\frac{1}{1-\gamma}} \left( \kappa_i \sum_{s_i}^{s_{i+1}} s (1 + \tau(s)_i)^{\frac{1}{1-\gamma}} g_c(s) \right) \quad (3.14)$$

where  $s_i$  and  $s_{i+1}$  are the lower and upper productivity thresholds of establishments with technology  $i$ .  $g_c(s)$  denotes the conditional productivity distribution on operating with technology  $i$ . Combining (3.13) and (3.14) gives,

$$(K_i^\alpha L_i^{1-\alpha})^\gamma = \left(\frac{\alpha}{r}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{\gamma}{1-\gamma}} \left(\kappa_i \sum_{s_i}^{s_{i+1}} s (1 + \tau(s)_i)^{\frac{1}{1-\gamma}} g_c(s)\right)^\gamma \quad (3.15)$$

Now, we can calculate the aggregate output of producers with technology  $i$  as,

$$Y_i = \left(\frac{\alpha}{r}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{\gamma}{1-\gamma}} \left(\kappa_i \sum_{s_i}^{s_{i+1}} s (1 + \tau(s)_i)^{\frac{\gamma}{1-\gamma}} g_c(s)\right) \quad (3.16)$$

substituting (3.15) in (3.16) yields,

$$Y_i = (TFP_i)^{1-\gamma} (K_i^\alpha L_i^{1-\alpha})^\gamma$$

where, the aggregate  $TFP$  for producers with standard and efficient technologies is given by,

$$TFP_n = \kappa_n \frac{\left(\sum_{s_n}^{s_m} s (1 + \tau(s)_n)^{\frac{\gamma}{1-\gamma}} g_c(s)\right)^{\frac{1}{1-\gamma}}}{\left(\sum_{s_n}^{s_m} s (1 + \tau(s)_n)^{\frac{1}{1-\gamma}} g_c(s)\right)^{\frac{\gamma}{1-\gamma}}} \quad (3.17)$$

$$TFP_m = \kappa_m \frac{\left(\sum_{s_m}^{s_{max}} s (1 + \tau(s)_m)^{\frac{\gamma}{1-\gamma}} g_c(s)\right)^{\frac{1}{1-\gamma}}}{\left(\sum_{s_m}^{s_{max}} s (1 + \tau(s)_m)^{\frac{1}{1-\gamma}} g_c(s)\right)^{\frac{\gamma}{1-\gamma}}} \quad (3.18)$$

Note that, without subsidies, or, if the subsidies are given to all plants in the industry, the aggregate TFP of standard and efficient producers become independent of the subsidy rate and becomes the weighted average of the plant level productivity indexes  $s$ .

$$TFP_i^* = \kappa_i \sum_{s_i}^{s_{i+1}} s g_c(s)$$

Now, to find an expression for the aggregate industry TFP, I calculated the aggregate capital ( $K = K_n + K_m$ ) and labor ( $L = L_n + L_m$ ) for the whole industry first. It can be shown that,

$$(K^\alpha L^{1-\alpha})^\gamma = \left(\frac{\alpha}{r}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{\gamma}{1-\gamma}} [V_n + V_m]^\gamma \quad (3.19)$$

where  $V_i$  is defined as;

$$V_n = \kappa_n \sum_{s_n}^{s_m} s (1 + \tau(s)_n)^{\frac{1}{1-\gamma}} g_c(s)$$

$$V_m = \kappa_m \sum_{s_m}^{s_{max}} s (1 + \tau(s)_m)^{\frac{1}{1-\gamma}} g_c(s)$$

Then, I define the aggregate output of the industry as the sum of outputs produced under each technology ( $Y_n + Y_m$ ),

$$Y = \left(\frac{\alpha}{r}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}} \gamma^{\frac{\gamma}{1-\gamma}} (W_n + W_m) \quad (3.20)$$

where  $W_i$  is defined as;

$$W_n = \kappa_n \sum_{s_n}^{s_m} s (1 + \tau(s)_n)^{\frac{\gamma}{1-\gamma}} g_c(s)$$

$$W_m = \kappa_m \sum_{s_m}^{s_{max}} s (1 + \tau(s)_m)^{\frac{\gamma}{1-\gamma}} g_c(s)$$

From (3.19) and (3.20), it is straightforward to derive an expression for the aggregate industry output in the form of Cobb-Douglas production technology as,

$$Y = (TFP)^{1-\gamma} (K^\alpha L^{1-\alpha})^\gamma \quad (3.21)$$

where the aggregate  $TFP$  is defined as,

$$TFP = \left( \frac{W_n + W_m}{(V_n + V_m)^\gamma} \right)^{\frac{1}{1-\gamma}}$$

substituting for  $W_i$  and  $V_i$ , gives the aggregate industry  $TFP$  in terms of subsidy rates and the conditional distribution of the plant level productivity indexes.

$$TFP = \left( \frac{\kappa_n \sum_{s_n}^{s_m} s(1 + \tau(s)_n)^{\frac{\gamma}{1-\gamma}} g_c(s) + \kappa_m \sum_{s_m}^{s_{max}} s(1 + \tau(s)_m)^{\frac{\gamma}{1-\gamma}} g_c(s)}{\left( \kappa_n \sum_{s_n}^{s_m} s(1 + \tau(s)_n)^{\frac{1}{1-\gamma}} g_c(s) + \kappa_m \sum_{s_m}^{s_{max}} s(1 + \tau(s)_m)^{\frac{1}{1-\gamma}} g_c(s) \right)^\gamma} \right)^{\frac{1}{1-\gamma}} \quad (3.22)$$

In this equation, the aggregate industry TFP is the weighted average of the plant-level productivity indexes of standard and efficient producers adjusted by the subsidy rate. Equation (3.17), (3.19), and (3.22) are the key equations for the quantitative experiments in the next section. An important feature of equation (3.22) lies on the link between subsidies and the industry TFP. Without subsidies,  $TFP_i = V_i$  and the industry TFP are simply the sum of TFPs of standard and efficient plants. If subsidies are given uniformly to all plants in the industry ( $\tau(s)_n = \tau(s)_m$ ), then the aggregate TFP becomes independent of the subsidy rates and it is simplified to (3.23). However, any idiosyncratic subsidy directly impacts the industry TFP and leads to a larger change in the measures of productivity.

$$TFP_{(\tau(s)_i=0)} = \kappa_n \sum_{s_n}^{s_m} s g_c(s) + \kappa_m \sum_{s_m}^{s_{max}} s g_c(s) \quad (3.23)$$

## Equilibrium

The model exhibits an equilibrium with a wage rate  $w$ , a rental rate of capital  $r$ , subsidy rates  $\tau_i$ , and distribution of productivity across plants  $g(s)$ , such that:

1. individuals make optimal decisions on occupation choice,



2. entrepreneurs optimally choose between standard and efficient technologies,
3. allocation of labor and capital across plants is efficient,
4. markets clear,

### Calibration

I calibrated the benchmark economy to India's Iron and Steel industry with no distortion ( $\tau_i(s) = 0$ ) prior to the National Steel Policy in 2005. The period was chosen to be one year and the population was normalized to one. I followed the standard procedure to choose parameters of the production technology. The span-of-control parameter  $\gamma$  is set to 0.7 and  $\alpha$  is set to 0.3. I split plants into standard and efficient producers as follows: I calculated the share of each primary input in total fuel expenditure. If a plant used coal as their primary input and if the coal expenditure accounted for at least 90% of the total fuel expenditure in that plant, I classified it as a standard plant. In contrast, If the plant used one of the other primary fuel inputs (gas, electricity, hydrocarbon), I classified it as an efficient producer. The productivity parameter of the standard and efficient technologies ( $\kappa_n$  and  $\kappa_m$ ) are chosen to match the relative labor productivity of standard and efficient producers over 1999-04. Normalizing  $\kappa_n$  to one, the productivity parameter of the efficient technology is calculated as 1.40. This indicates that on average, the labor productivity of the efficient technology is 40% higher than the standard technology.

In an economy with no distortions, there is a simple mapping between establishment-level productivity and the size of employment (Bello et al., 2011). I estimated the distribution of plant-level productivity to match the size distribution of employment in India's Iron and Steel sector over 1999-04. The distribution is approximated by

a log-normal distribution function. Since the demands for labor are linear in  $s$ , the relative productivity parameter of every two plants remains proportional to their employment sizes. I approximated the vector of plant-level productivity with a linearly spaced grid of 10000 points. Given that the average minimum and maximum number of employees in the industry are 10 and 4,000 workers, I set the minimum productivity level at  $s_{min}=0.01$  and pinned down the maximum level of productivity at  $s_{max} = 4$  using the following equation. Then, I approximated the mean and variance of the log-normal distribution function that corresponds to the plant-level productivity distribution. Figure 3.2 shows the plant-size distribution in data and its approximation by model.

$$\frac{l_{max}}{l_{min}} = \frac{s_{max}}{s_{min}}$$

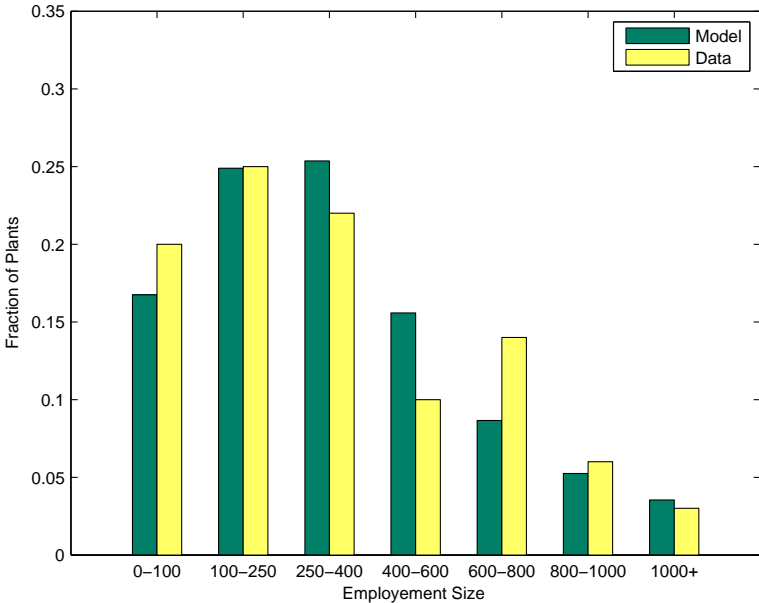


Figure 3–2: Distribution of Plant-level Productivity by Log-normal

To pin down the fixed technology-specific costs  $c_n$  and  $c_m$ , I set two targets: (1) the average share of managers and supervisory staff in total employees is 80%<sup>3</sup>, and (2) the share of efficient producers in total employment of the industry is 33%. These targets are used to locate the lower and upper productivity thresholds in the model. Now, using the mean and variance of the productivity distribution, the model can be solved in equilibrium for technology-specific fixed costs  $c_n$  and  $c_m$ , market wage rate  $w$ , and interest rate  $r$ . Table 3.3 provides a summary of the parameters and targets.

Table 3–3: Model Calibration with Technology Choice

Parameter	Value	Targets
share of workers	0.80	from data
Employment share of eff. plants	0.33	from data
Parameter of std. technology	$\kappa_n = 1$	normalization
Parameter of eff. technology	$\kappa_m = 1.40$	relative TFP of std. and eff. plants
span-of-control	$\gamma = 0.7$	from literature
capital income share	$\alpha = 0.3$	from literature
fixed cost of std. technology	$c_n = -0.0282$	share of workers=80%
fixed cost of eff. technology	$c_m = 0.1888$	employment share of eff. plants=33%
mean of distribution function	$\mu = -1.62$	to match employment distribution
variance of distribution function	$\sigma = 1.28$	to match employment distribution

To perform the quantitative experiments, the technology-specific costs and the mean and variance of the productivity distribution remain constant. To calibrate the subsidy policy, I constructed a subsidy vector. I computed the minimum employment size of plants with multiple production units over 1999-04. This gives the cut-off employment size of the subsidized producers at roughly  $\bar{l}=250$ . Any plant with

<sup>3</sup> This indicates that on average 80% of employees in each plant in data are managers and supervisors

minimum 250 employees receives subsidies to production. To construct the vector of plant-level subsidy, I calculated the plant-level productivity index that corresponds to 250 employees at 0.626 and define the subsidy vector as follows:

$$\begin{aligned}\tau_i(s) &= \tau \text{ if } s \geq 0.626 \\ \tau_i(s) &= 0 \text{ otherwise}\end{aligned}$$

I choose the size of subsidies as follows: The minimum and maximum disbursement of the government funds as a percentage of annual sales in Indian Iron and Steel sector between 2005 and 2008 were 0.12% and 0.16%.<sup>4</sup> Given that the subsidized plants produce around 70% of the aggregate output in the industry, the rates of subsidies are calculated between 0.17% (0.12/0.7) and 0.22% (0.16/0.7).<sup>5</sup>

### 3.5 Policy Impact

The calibrated model performs well in reproducing changes in TFP growth rates and the productivity gap between producers with different technologies. Table 3.4 reports the outcomes of subsidies to producers with a minimum 250 employees. The

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<sup>4</sup> Indian Ministry of Steel, Annual Report 2011-12.

<sup>5</sup> In India's Iron and Steel industry, subsidies are reported as a share in R&D investment and R&D investment is reported as a percentage of annual sales turnover. Annual turnover is the gross amount of sales received by plants. In contrast, the value of output represents the total value of turnover in an accounting period plus the value of other incomes including income from industrial, non-industrial services, variation in the stock of semi-finished goods, value of electricity generated and sold, value of own construction, net balance of goods sold in the same condition as purchased, and sale value of goods sold in the same condition as purchased. In my sample, the value of turnover and the value of output are roughly the same, so, to conduct the experiments, I consider subsidies as percentage of output.

policy increases the aggregate industry TFP and the the gap in TFP growth rates between plants with different technologies. The predicted changes in TFP growth rates and gap are consistent with the those directly observed from data. A subsidy of 0.17% - 0.22% to output increases the aggregate industry TFP growth by 0.57%-0.75% which contributes to 16% to 21% of the industry TFP growth reported by the data (around 1/5 of the observed aggregate TFP growth). The model also predicts that the policy would lead to a 1.50%-1.91% gap in TFP growth between standard and efficient producers which account to 44% to 56% of the actual productivity gap in the industry calculated from data.

Table 3–4: Average Annual TFP Growth Rates and Gap; (%)

	Industry	TFP growth gap between standard and efficient plants
$\tau_{min} = 0.17\%$	0.57	1.50
$\tau_{max} = 0.22\%$	0.75	1.91

## Output Change

Table 3.5 reports the impact of the size-dependent subsidies on aggregate industry output and output of plants with standard and efficient technologies. The idiosyncratic policy leads to 0.23%-0.29% increase in the aggregate industry output per year. The policy also increase output of efficient producers by 1.72%-2.20% and reduce output of standard producers by 2.037%-3.05% (average per year).

Table 3–5: Average Annual Output Growth Rates; (%)

Subsidy Rate	Industry	Standard Producers	Efficient Producers
$\tau_m = 0.17\%$	0.23	-2.37	1.72
$\tau_m = 0.22\%$	0.29	-3.05	2.20

I identify three direct effects through which the size-dependent subsidies impact the aggregate TFP growth and the gap in growth rate of plants with standard and efficient technologies. (1) misallocation effect: the subsidy introduces idiosyncrasy in the prices faced by individual producers, causing a reallocation of resources from non-subsidized to subsidized plants, (2) technology upgrade effect: the plants that receive the subsidies switch from the standard to the efficient technology, (3) selection effect: through general equilibrium effects, who becomes worker and entrepreneur and what technology each entrepreneur decides to use also impacts the aggregate industry TFP.

### **Misallocation Effect**

In the standard literature, the misallocation effect is expected to reduce aggregate TFP. To measure the quantitative significance of misallocation in my framework, I shutdown the endogenous technology choice. I re-calibrate the model to a new environment in which only one technology was available for production. The only decision for individuals is to choose between being a hired worker or an entrepreneur. For simplicity, the technology specific parameter  $\kappa$  is normalized to one. In the above environment, there is only one threshold of skills that determines allocation of individuals between workers and entrepreneurs. The rest of the calibrated parameters and the approximation of the productivity distribution remain unchanged. Table 3.6 shows parameter of the model in the environment with one production technology.

The policy is still to subsidize plants with a minimum of 250 employees. Therefore, the subsidy vector remains the same too. Since, the subsidies are given to

Table 3–6: Model Calibration Without Technology Choice

Parameter	Value	Targets
share of workers	0.80	from data
technology-specific parameter	$\kappa= 1$	normalization
span-of-control	$\gamma= 0.7$	from literature
capital income share	$\alpha= 0.3$	from literature
fixed cost of stnd. technology	$c= 0.0243$	share of workers=80%
mean of distribution function	$\mu= -1.62$	to match employment distribution
variance of distribution function	$\sigma=1.28$	to match employment distribution

the large plants, the profit of plants with a productivity index closed to the threshold of skills remains unchanged. The following equation is used to calculate the aggregate TFP. To control for the general equilibrium effect, I hold the total number of entrepreneurs fixed. The policy leads to a reallocation of resources from non-subsidized plants to subsidized plants (larger units) causing misallocation. The impact of 0.17%-0.22% subsidies to output on aggregate TFP is reported in Table 3.7. The misallocation effect should cause a 2% decline in the observed aggregate TFP growth in the industry.

$$TFP = \left( \frac{\sum_{s_{min}^{ax}}^{s_{max}^{ax}} s(1+\tau(s)_n)^{\frac{\gamma}{1-\gamma}} g_c(s)}{\left( \sum_{s_{min}^{ax}}^{s_{max}^{ax}} s(1+\tau(s)_n)^{\frac{1}{1-\gamma}} g_c(s) \right)^\gamma} \right)^{\frac{1}{1-\gamma}}$$

The proportional increase in the output of subsidized plants is less than the proportion increased in the inputs employed by those plants. The policy leads to a small decrease in the aggregate TFP as the subsidies are given to more productive producers in the industry (there is a negative correlation between the misallocation effect and productivity levels of plants that are hit by distortions).

Table 3-7: Misallocation Effect; (%)

	Industry TFP
$\tau_m = 0.17\%$	-0.01
$\tau_m = 0.22\%$	-0.04

### Technology Upgrade Effect

A part of the productivity growth is attributed to the technology upgrading at plant level. The technology selection is determined by the level of plant productivity as well as the technology-specific costs. The subsidies incentivize plants to adopt the efficient technology that is more productive. To measure the technology upgrade effect, I held the total number of plants unchanged and calculated the productivity gain generated from the technology switch only. The model predicts that the technology upgrading effect contributes to 49% of the aggregate TFP growth calculated from data.

There is strong supporting evidence of technological change in India's Iron and Steel industry over the last decade. Iron and steel making processes are extremely intensive in the use of material and energy. The Iron and Steel producers were faced with a wide range of technologies that were fundamentally characterized by energy usage. For example, an Open Hearth Furnace (OHF) is an inefficient technology introduced in 1850's in India. Most OHFs have been closed due to their fuel inefficiency and are being replaced by other technologies such as the Basic Oxygen Furnace (BOF). According to India's Iron and Steel industry Annual Report, technology replacement reduced the average share of the OHF in the total steel production in India from 16.6% over 1999-2004 to less than 2% in 2005-08 (Table 3.8).



In addition, in recent years, a number of smaller units equipped with the Electric Arc Furnace (ERF) have invested in capacity expansion projects and increased their level of production.<sup>6</sup>

Table 3–8: Share of Technologies in Crude Steel Production, %

	1999-2004	2005-2008
Efficient technology (BOF)	50.8	41.4
Efficient technology (EAF)	32.6	56.6
Standard technology (OHF)	16.6	2.0

The evidence of technological change can also be observed from fuel expenditures in the industry. The technological change would be expected to reduce consumption of coal as an inefficient input in the industry. Table 3.9 reports the share of coal, electricity, and other fuels as the main primary inputs in total fuel expenditures from 1999-04 to 2005-08 using the ASI data. The share of coal in total fuels expenditures decreased from 24.3% to 21% while share of other fuels increased from 14% to 17% during the same period.

Table 3–9: Share of Primary Fuel Inputs in Total Fuel Expenditures, %

	1999-2004	2005-2008
Efficient Fuels (gas, electricity, hydrocarbon)	75.7	79.0
Inefficient Fuel (coal)	24.3	21.0

<sup>6</sup> Source: Statistics Archive, World Steel Association.

## **Selection Effect**

The choice of occupation for individuals and choice of technology for entrepreneurs were directly influenced by the industry wage rate and the expected profit of entrepreneurship with a given technology. A higher wage rate makes the labor market more attractive than entrepreneurship. On the other hand, the expected profits in the industry depend directly on establishment-level productivity and the size of subsidies. Since the subsidies were given only to large producers, the expected profit earned by small plants remained unchanged while the wage rate went up. The entrepreneurs with the lowest managerial ability changed their occupation and become hired workers. This increased the average plant size and market share of the surviving plants. In addition, the subsidies changed the upper threshold level of skills and increased the size of efficient plants throughout the industry. The overall general equilibrium effect is such that the aggregate industry TFP increased. The model predicts that the selection effect would contribute to 53% of the aggregate TFP growth in the industry.

Table 3.10 reports changes to the average plant size in India's Iron and Steel industry as observed from the ASI data and predicted by the model before and after the policy change in 2005. The subsidy policy explains about 15% of the increase in the average number of workers per plant in the whole industry, and 40% and 27% of the decrease/increase in the average number of workers in standard and efficient plants respectively.

Overall, the share of each channel in the aggregate TFP growth is summarized in Table 3.11.

Table 3–10: Change in Average Number of Workers in Each Plant; Model vs. Data

	Data	Model
Total Industry	11%	1.7%
Standard Producers	-8%	-3.4%
Efficient Producers	17%	4.6%

Table 3–11: Sources of TFP Growth (%)

	Model
Misallocation Effect	-2.0
Technology Upgrade Effect	49.0
Selection Effect	53.0

### 3.6 Conclusion

In overall, the results of this chapter show that an endogenous improvement in the establishment-level productivity induced by size-dependent subsidies can dominate the misallocation effect and lead to an increase in aggregate TFP.

In this chapter, I examined the impact of distortions generated by size-dependent subsidies that lead to misallocation but encouraged technology adoption at establishment-level. I focused on subsidies that were given under the National Steel Policy initiated in 2005 in India’s Iron and Steel sector. The policy was size-dependent in practice and only large Iron and Steel plants received the subsidies. My growth accounting in chapter two shows that India’s Iron and Steel industry experienced a high TFP growth during 1999-08 and especially after the policy change in 2005. The average growth rate of TFP increased from 1.72% over 1999-04 to 3.61% over 2005-08. The main source of the TFP growth was within-plant efficiency rather than reallocation. I identified technology change as a possible source of the within-plant efficiency

growth. The technology-wise growth accounting showed that only plants with efficient technology grew faster after the policy change and that the TFP of standard producers actually declined over 2005-08.

I extended the Lucas (1978) span-of-control model to include a technology choice at the establishment-level along the lines of Adamopoulos and Restuccia (2014b) and calibrated it to the plant-level data prior to the policy change in 2005. Without the technology change, the model produces misallocation effect through a small TFP loss. However, when the technology upgrade is allowed, the model predicts that subsidies to plants with minimum 250 employees can increase industry TFP growth by 0.63%-0.71% which explains about 16%-21% of the observed TFP growth from data (calculated in chapter two). While, the misallocation effect had a negative impact on the aggregate TFP growth, the technological upgrade effect is dominant and increases TFP growth in the industry.

The findings of this chapter contribute to a deeper understanding of policy distortions that generate misallocation effect but impact establishment-level productivity at the same time. My findings are similar to the existing empirical works on misallocation if the technology upgrade channel is shutdown. However, because distortions induce a technology upgrade at establishment-level, then an increased establishment-level productivity can enhance TFP at the aggregate level.

My empirical analysis in this chapter did not take into account the other sources of TFP growth in the industry. The Indian manufacturing sector has experienced major liberalization policies in the last two decades that could potentially have impacted measures of productivity too.

## CHAPTER 4

### The Impact of Labor Market Regulations on Plant-Level Productivity

#### 4.1 Introduction

The Indian industry has witnessed a remarkable transformation to a market based economy over the past two decades. Over this period, there has been a major shift in economic policies towards opening markets to foreign trade, international and private investments and reduction in government influences over the economic decisions. Along with the output market, labor market outcomes have also improved in India during the economic reforms. However, in the labor markets the observed gains have arisen primarily in the unorganized and informal sectors,<sup>1</sup> where productivity and wages are generally much lower than in the formal organized sector (OECD, 2007). One of the main reasons why formal labor markets in India did not benefit from the reforms is that the labor markets are inflexible and are subject to many regulations.

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<sup>1</sup> In India, the first official definition of the unorganized sector was given by Central Statistical Organization (CSO). According to CSO (1980), the unorganized sector refers to those operating units whose activity is not regulated under any statutory Act or legal provision and/or which do not maintain any regular accounts.

According to the OECD indicator of Employment Protection Legislation (EPL)<sup>2</sup>, India has one of the highest employment protection legislation indexes among OECD countries and the labor market in India is among the most stringent in the world. Despite the remarkable output growth in the last four decades, the labor market regulations in India have been blamed for the poor productivity performance especially for the large-scale labor-intensive manufacturing sector (Dougherty et al., 2011). The lack of job creation particularly in larger firms operating in the organized sector is also attributed to the restrictive legislation governing regular employment in large firms. Rigid labor legislation makes it extremely difficult for large firms to make necessary adjustments in labor demands and even making a change in job descriptions can be problematic for large firms. Consequently, firms in India are moving toward less labor-intensive activities or use of more capital-intensive technologies in the production process.

The India's employment protection legislation index (EPL) captures the stringency of labor regulations, for both regular employment and temporary or fixed-term employment. For regular employment, India's labor laws are stricter than all OECD countries except Portugal and Indonesia (Figure 4.1). This stringency in the regular

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<sup>2</sup> The OECD indicators of Employment Protection Legislation measure the procedures and costs involved in dismissing individuals or groups of workers and the procedures involved in hiring workers on fixed-term or temporary work agency contracts. It is important to note that employment protection refers to only one dimension of the complex set of factors that influence labor market flexibility.

employment status is mainly attributed to the existing difficulties of obtaining government permission to lay-off workers for plants with more than 100 workers (based on the Industrial Disputes Act (IDA)).<sup>3</sup>

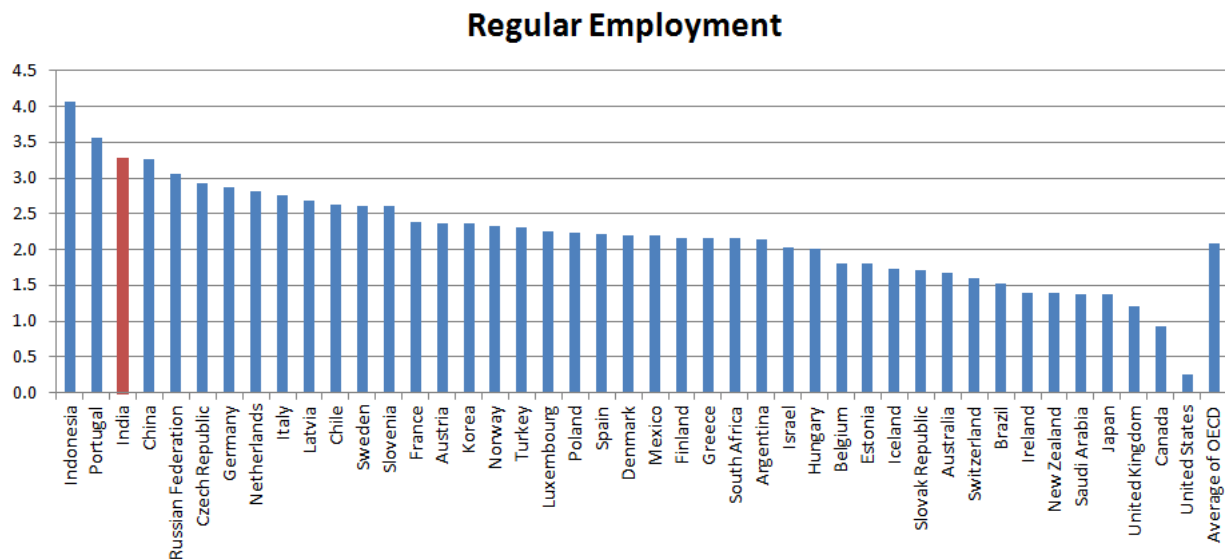


Figure 4–1: Strictness of EPL: Regular Employment (Source: OECD)

The position of India’s EPL regime is more relaxed only for temporary and fixed-term contracts. The EPL score for the temporary employment status in India is around the mean score among the OECD countries (Figure 4.2). The moderate

<sup>3</sup> Firms are required to give workers written notice of dismissal. For retrenchments, the relevant government authority must also be notified (art. 25F, Industrial disputes act, 1947). For establishments with 100 or more workers, the employer must also obtain permission from the relevant government authority before retrenchment can take place. Retrenchment is defined as termination for whatsoever reason, except in the case of disciplinary action (see e.g. State Bank of India v. N Sundara Money [1976] 3 SCR 160).

score of India for temporary contracts implies that India has experienced partial labor reforms in recent years, which allow employers to hire workers on temporary contracts basis using job contract agencies. Standard fixed-term contracts are also allowed for white-collar workers in India.

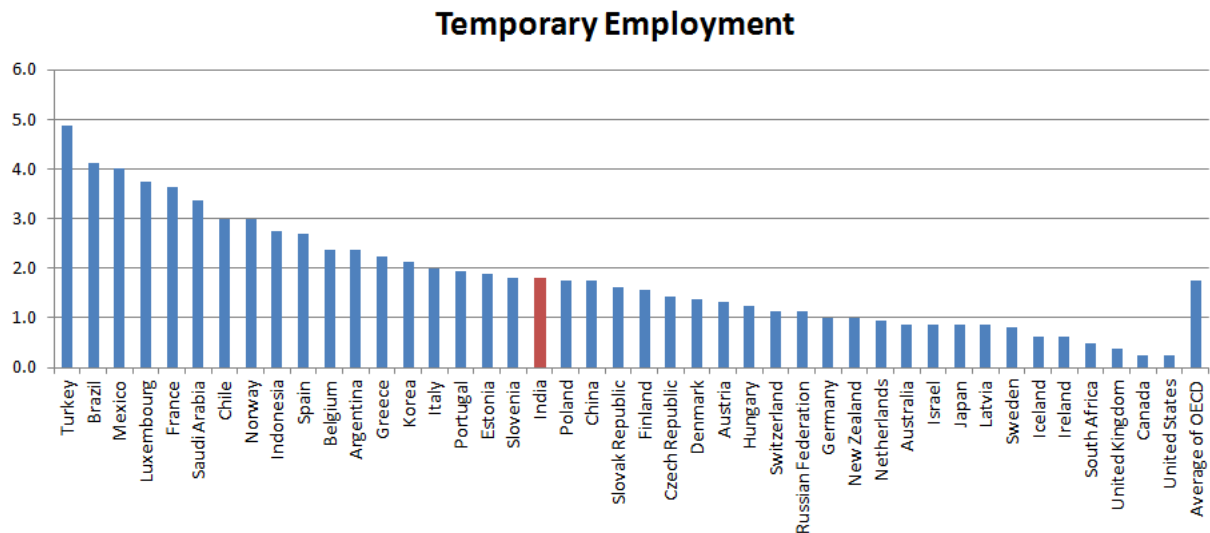


Figure 4–2: Strictness of EPL: Temporary Employment (source: OECD)

Despite the stringency in the labor regulations in India, the implementation of the labor market regulations varies across the states which allows firms to alter their behavior to reduce the impact of the regulations. India’s constitution gives direct responsibility for a number of areas of economic policy to the state governments as well as shared responsibility with central government in a number of other areas. The state governments have also been given the right on how to implement the laws in certain areas, or amend central legislation prior to the implementation. Moreover, the state governments usually formulate and administer the rules and procedures through which all laws are enforced. As a result, differing economic views across



state governments on the role of the public sector have led to a considerable variation in the business environment across states in India including labor markets.

For a better understanding of how state-level reforms and amendments to the laws may have influenced the labor market outcomes in India, the OECD developed a customized survey instrument to identify the areas in which Indian states have made specific changes to the implementation and administration of labor laws and regulations.

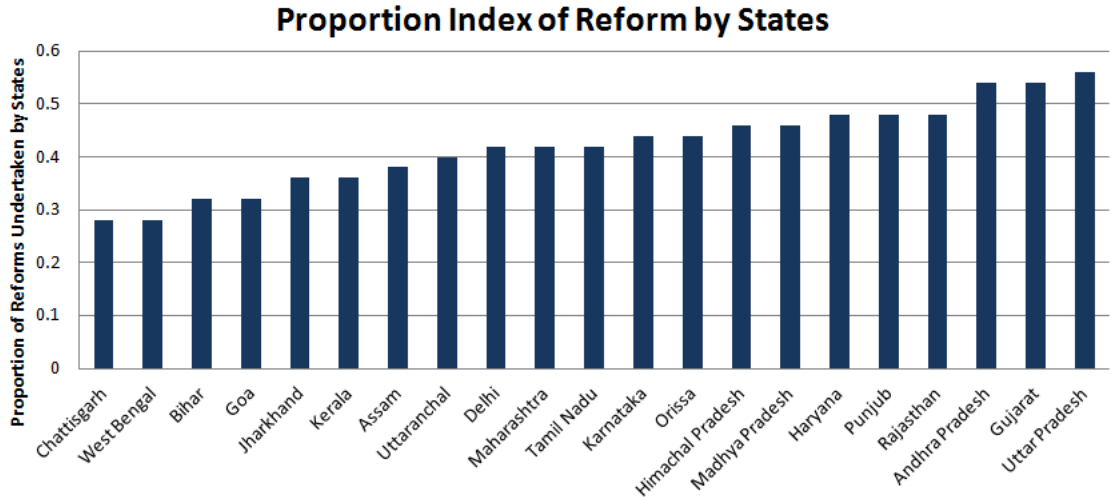


Figure 4-3: Index of State-level Labor Reforms in India (source: OECD)

Figure 4.3 represents the normalized proportion of the labor market reforms undertaken by the states in India. The index provides a quantitative measure of the extent to which states have made changes in their implementation of labor laws and regulations. The index was constructed based on eight major labor legal areas, identifying 50 specific subjects of possible reforms. For example, an index of over 0.5 for Uttar Pradesh indicates that this state has made over 50% formal amendments on

implementation of the eight major labor laws to improve its labor market outcomes. As the figure shows, there is a large variation in the extent of reforms across the states. The state of Chhattisgarh, Goa and Bihar are ranked among the lowest in terms of the proportion of reforms while Uttar Pradesh, Gujarat and Andhra Pradesh with over 50% amendments are ranked among the highest in terms of labor market reforms.

In this study, I propose to investigate the impact of labor market regulations on plant-level productivity in manufacturing sector in India. I use plant-level data for the whole manufacturing sector from the India Annual Survey of Industries (ASI) and construct a balanced panel of establishments over 1999-2008. I calculate TFP at the plant-level first. Then, I use the state-level labor reform index (Dougherty2008) that captures cross-state variation in labor market reforms and examine how the state-level reforms may have affected plant-level productivity in the manufacturing sector. A positive association between plant-level productivity and the measure of labor market reform will indicate that amendments to the labor laws reduce the scope of regulations and increases plant-level productivity.

The results of this chapter imply that the state-level labor reforms in India have a positive impact on TFP and labor productivity. The impact of labor market reforms on productivity is larger in industries where plants rely more on labor than in industries in which labor is relatively less important.

## 4.2 Literature Review

A broad literature exists on the economic impacts of labor market regulations. A primary question in this literature is how an increase in the layoff costs (or firing/dismissal costs) impacts employment level or other measures of performance. The labor market theory suggests that firing costs may have an ambiguous impact on employment levels. Regulations that increase cost of labor adjustment operate as a tax on firing and increase the cost of layoffs. While, the employment protection seems to enhance employment by preventing labor dismissals, it may also affect incentive of firms to hire new workers which in turn reduces employment in the long-term. Given that the protection legislation generates distortions at the firm-level, some producers may find it optimal not to hire workers whose short-term marginal product exceeds their market wage and stay with unproductive workers (Blanchard and Portugal, 2001). The distorted input choice reduces worker flows and firms are more likely to substitute capital for labor and move to more capital-intensive activities.

The impact of labor market regulations on measures of productivity has also attracted considerable attention in the literature. The net effect of labor market regulations on productivity is ambiguous too. A study by Crafts (2006) provides strong evidence consistent with the endogenous growth models that regulations which inhibit entry to product markets, have an adverse effect on TFP growth in OECD countries. Scarpetta and Tressel (2002) also provide evidence that strict employment protection legislation can raise the cost of hiring and impact the labor adjustment process. Regulations make the labor adjustment more difficult and can reduce

firm's incentives to innovation, which further slow-downs productivity growth at the firm-level. Auer et. al (2005) assessed the impact of employment tenure on firms' productivity in 13 European countries between 1992 and 2002. The study shows that both extensive tenure and short-tenure have possible adverse affects on productivity.

On the other hand, there are empirical studies showing that labor market regulations may actually enhance productivity growth. For example, Storm and Naastepad (2007) examined the impact of labor market regulations on labor productivity growth of 20 OECD countries between 1984 and 1997 and showed that relatively rigid labor markets can promote long-run labor productivity.

Most of the empirical studies on the impacts of labor market regulations in India have used the OECD's indicator of Product Market Regulation (PMR), the Employment Protection Legislation (EPL) Index, and the BB Index constructed by Besley and Burgess (2004). The last two indexes were calculated at the state-level based on the amendments made to the labor market regulations. The amendments to the acts and regulations are normally made by the state's legal authorities in order to reduce transaction costs through limiting the scope of the regulations. In calculating the labor market indexes, particular attention is often given to amendments made to the Chapter V-B in the IDA-1947, which required firms employing 100 or more workers to obtain government permission for layoffs, retrenchments and closures. The Chapter V-B in the IDA-1947 is important because the permission to lay-off workers is normally difficult to obtain and employers might be reluctant to hire workers because later they cannot lay-off workers without permission. The legislation could also harm economic performance since it provides protection for workers only in

the organized sector and prevent the expansion of industrial employment that could benefit the mass of workers outside. In addition, the restriction could discourage firms from expanding their production scale, thereby reducing the level of manufacturing productivity.

A study by Besley and Burgess (2004) focused on the effect of the Industrial Disputes Act 1947 on the pattern of manufacturing growth over the period of 1958-1992. They reviewed the state amendments to the Industrial Disputes Act of 1947 and classified the amendments to pro-worker (if workers benefited from the amendment to the act), pro-employer (if employer benefited from the amendment to the act), and neutral (if the amendment had no impact on either group). This index is known as the BB index. Besley and Burgess (2004) show that the pro-worker labor legislation is associated with an increase in urban poverty. Pro-worker labor regulation also results in lower output, employment, investment and productivity in the formal manufacturing sector while the output in informal manufacturing sector will increase.

In another study, Bassanini and Venn (2008) investigated the impact of labor market policies on labor productivity and multi-factor productivity with industry-level data across OECD countries. Their study shows that the employment protection legislation, minimum wage, parental leave and unemployment benefits influence productivity through multiple channels, over and above their impact on employment levels. They found that stringent EPL has a small negative impact on long-run productivity growth, most likely by restricting the movement of labor into emerging, high-productivity activities. Dougherty et al. (2011) also used plant-level data to

assess the impact of labor reforms on total factor productivity (TFP) and labor productivity in India. Their findings indicate that labor reforms have a positive impact on establishment-level productivity and firms in the labor-intensive industries benefited the most from labor reforms.<sup>4</sup> Conway and Herd (2009) assess the extent to which India's regulatory environment promotes or inhibits competition in markets where technology and market conditions make competition viable. Their study using the OECD's indicators of Product Market Regulation (PMR)<sup>5</sup> considers a number of channels through which the regulatory environment can influence productivity at the state-level and found that states with relatively liberal regulatory settings could attract more foreign direct investment, have better infrastructure, and a larger share of employment in the organized sector relative to more restrictive states.

Despite the wide use of the labor reform index and the BB index, they have been criticized by Bhattacharjea (2006 and 2009) in terms of research methodology. Bhattacharjea states that in calculating the labor reform index and BB index too

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<sup>4</sup> My study differs from Dougherty et al. (2011) in terms of data and analysis. I constructed a balanced panel of continues firms over 1999-2008 without accounting for entry and exit. The variables used in my regression model also differ in terms of control variables and measurements. In addition, I used the LP approach to estimate TFP at the plant-level. The LP approach uses material as the proxy variable as oppose to investment as the proxy for the unobservable shocks in the OP approach. As it was shown by Levinsohn and Petrin (2003), using investment as a proxy may not smoothly respond to the productivity shock since many plants in the ASI survey report zero investment.

<sup>5</sup> PMR index also has been used extensively over the last decade to benchmark regulatory frameworks in OECD countries

much attention has been given to the Chapter V-B in the IDA-1947 while other areas of improvement in the India labor market performance were ignored. His study showed that there is no conclusive evidence of a link between the labor market reforms and firms' performance in India.

### **4.3 Data**

In this chapter, I use the ASI data in the entire manufacturing sector over 1999-2008. The ASI is the principal source of industrial statistics in India, which provides information on performance, composition and structure of organized manufacturing sector. The ASI was initially launched in 1960 with 1959 as the reference year and is continuing since then except for 1972. The ASI extends to the whole of India and covers all factories registered under Sections 2m(i) and 2m(ii) of the Factories Act, 1948 i.e. those factories employing 10 or more workers using power; and those employing 20 or more workers without using power.

The ASI frame is based on the lists of registered factory/units maintained by the Chief Inspector of Factories (CIF) in each state in India. All the factories in the ASI frame are classified under the National Industrial Classification (NIC) in their appropriate industry groups based on the principal product manufactured. The data used in this study are based on the NIC-1998 covering ASI 1998-99 to ASI 2003-04. Then, for ASI 2004-05 to ASI 2007-08, I use the revised NIC introduced in 2004.

Since, the OECD survey of labor market regulations in India and the state-level labor reform index covered only 21 states in India (Appendix E provides more information about the OECD Indicators of Employment Protection Index), I also use plant-level data on the same 21 states for the analysis. This gives an unbalanced

panel of 1,306,106 plants over 1999-2008. Table 4.1 shows the number of plants per year in the unbalanced panel varies from 123,957 in 2003 to 141,599 in 2008.

Table 4-1: Number of plants per year in unbalanced panel

year	Number of plants
1999	128439
2000	127952
2001	127438
2002	124524
2003	123957
2004	125011
2005	131760
2006	135497
2007	139929
2008	141599
Total	1306106

The size of organized sector as well as the number of registered establishments varies across states. Table 4.2 shows the average number of registered plants in each state in India reported by the ASI. The average number of plants in each state in the panel is 130,000. Goa has the lowest number of registered establishments with 512 plants over 1999-2008 while Tamil Nadu has the highest number of registered establishments with an average of 20704 over 1999-2008.

Table 4.3 shows the capital-labor ratio, labor productivity and average plant size in each state over 1999-08. The capital-labor ratio is calculated as the ratio of fixed assets to total number of workers over 1999-08. Labor productivity is measured as the ratio of value of gross output to total number of workers over 1999-08. Plants size is calculated as ratio of total workers to total number of plants over 1999-08.



Table 4–2: Number of plants per state (averaged over 1999-08)

State	Number of plants
Himachal Pradesh	645
Punjab	7748
Uttaranchal	844
Haryana	4343
Delhi	3370
Rajasthan	5523
Uttar Pradesh	9931
Bihar	1570
Assam	1643
West Bengal	6066
Jharkhand	1508
Orissa	1720
Chattisgarh	1419
Madhya Pradesh	3092
Gujarat	14127
Maharashtra	18436
Andhra Pradesh	14831
Karnataka	7412
Goa	512
Kerala	5167
Tamil Nadu	20704
Total	130611

As the table shows, on average, plants in Jharkhand have the largest size with 109.4 workers per plant compared to the other states in India.

The capital-labor ratio also shows a large variation across the states. While Himachal Pradesh, Orissa, and Gujarat have higher capital-labor ratios, Kerala, Delhi, and Andhra Pradesh are mostly labor-intensive states and have lower capital-labor ratios (Figure 4.4).

Figure 4.5 provides the index of labor productivity for the Indian states over 1999-2008. As the figure shows there are large variations in the labor productivity

Table 4–3: State-level performance in 1999-2008 (unbalanced panel)

State	Capital-Labor Ratio	Labor Productivity	Plant Size
Himachal Pradesh	0.057	0.103	74.4
Punjab	0.014	0.062	50.6
Uttaranchal	0.026	0.076	67.5
Haryana	0.023	0.088	82.2
Delhi	0.009	0.072	37.1
Rajasthan	0.030	0.076	48.0
Uttar Pradesh	0.031	0.077	60.7
Bihar	0.018	0.079	40.6
Assam	0.022	0.063	73.0
West Bengal	0.020	0.053	90.8
Jharkhand	0.050	0.094	109.4
Orissa	0.056	0.070	81.3
Chattisgarh	0.049	0.097	77.0
Madhya Pradesh	0.034	0.095	76.8
Gujarat	0.054	0.125	58.5
Maharashtra	0.033	0.108	67.2
Andhra Pradesh	0.018	0.047	63.6
Karnataka	0.032	0.073	75.7
Goa	0.047	0.155	68.8
Kerala	0.011	0.051	61.0
Tamil Nadu	0.018	0.053	61.5

index across states over 1999-08. The states of Goa, Gujarat, and Maharashtra had the highest labor productivity index while Kerala, Andhra Pradesh, and Tamil Nadu had the lowest labor productivity index over the period 1999-08.

Because there is no plant identifier in the ASI data before 2004-05, I can not use the unbalanced panel directly for data analysis which needs observations at the plant-level and over time. Therefore, I applied a matching procedure to construct a balanced panel over 1999-2008. As explained in chapter two, to link-up the observations over years, I use the information on several identification which are reported on

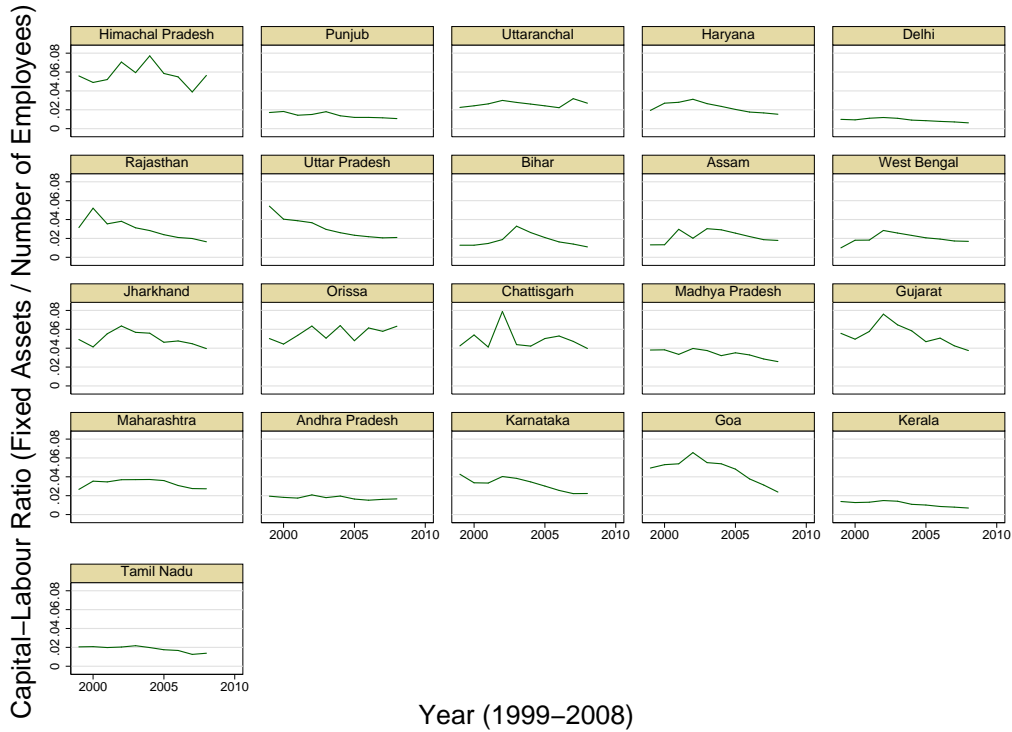


Figure 4-4: Capital-Labor Ratio by State, (Unbalanced Panel)

a consistent basis. These variables are reported every year and include “year of initial production”, “state code”, “district code”, “sector code”, “type of organization”, and “type of ownership”. I match plants in every two consecutive years based on each identification variable separately first and I keep only plants that match for at least three identification variables. To minimize the errors, I check the closing value of fixed assets with the opening value of fixed assets next year. The balanced panel must then include plants that are matched based on at least 3 identification variables and plants must also have the same or very similar closing values and opening values of fixed assets next year. To reduce the influence of outliers in the analysis,

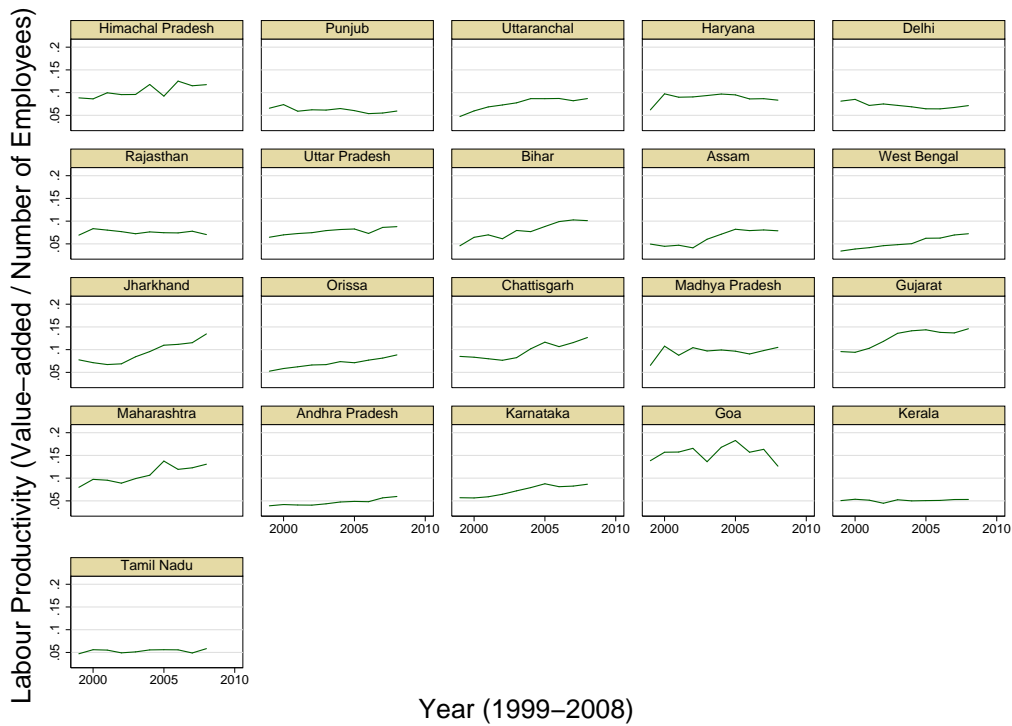


Figure 4-5: State-level labor productivity, (Unbalanced Panel)

following Bollard et al. (2010), I winsorize the data. To winsorize the data, I replace data in the top 1% tail and bottom 1% tail of all variables with their value of the 99th and 1st percentiles. All the values are deflated by price indexes provided by the Handbook of Statistics on Indian Economy published by the “Reserve Bank of India”.

The constructed balanced panel includes around 1750 plants per year or in total 17,500 observations. Because the balanced panel only includes plants that have been in operation during 1999-2008 and entry of new plants or exit are not reported, its size reduces dramatically compared to the unbalanced panel. In addition, the

matching procedure has resulted in drop of many plants for either lack of identifiers or missing information.

The index of state-level labor reform comes from the OECD (2007) which summarizes state-level indicators of procedural changes to the implementation of labor laws. The indicators measure the strictness of federal EPL settings in India, and provide a quantitative indication of the extent to which states have or have not made changes in their implementation of labor laws and regulations. To construct the index, the OECD used a customized survey instrument to identify the areas in which Indian states have made specific discrete changes to the implementation and administration of labor laws. This state-level survey covered eight major labor legal areas, identifying 50 specific subjects of possible reforms, many of which could be implemented by administrative procedures rather than through formal amendments to the laws. The survey only 21 states in which the amendments to the law have been systematically documented. The reforms covered in the index concern eight specific areas of “The Industrial Disputes Act (IDA)”, “Factories Act”, “State Shops and Commercial Establishments Acts”, “Contract Labor Act”, “the Role of Inspectors”, “the Maintenance of Registers”, “the Filing of Returns” and “Union Representation.” A list of the subjects and summary scores are provided in Appendix F.

To incorporate the state-level labor reform index in the data analysis, I follow the approach of Dougherty et al. (2011) and classify Indian states into having flexible and inflexible labor markets based on their state-level labor reform scores. In particular, a state has a flexible labor market if it has labor reform score above the median and inflexible otherwise. This classification exhibits the degree of labor regulation

reforms in each state in India. I will use this indicator later as a dummy variable in the regression analysis.

Figure 4.6 shows the mean score of labor reforms across the Indian states reported in 2007. The figure illustrates that the largest number of reforms that were identified concern the Industrial Disputes Act (IDA) and the Contract Labor Act. In contrast, the smallest amount of reforms has been on the Role of Inspectors and Registers which indicate the rules concerning the role of unions in the Indian labor markets.

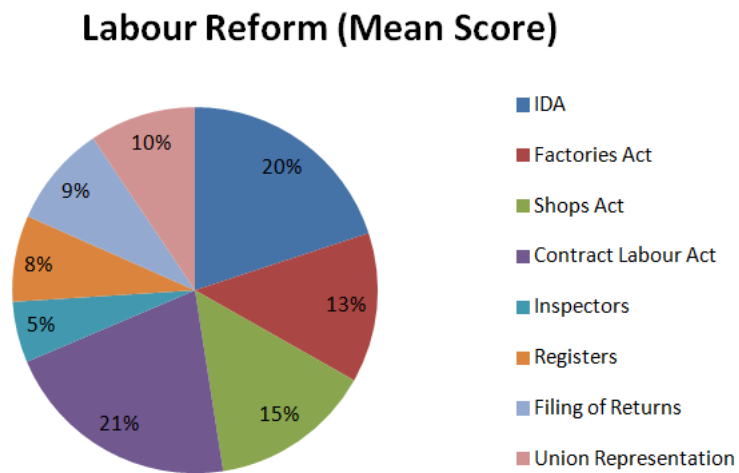


Figure 4-6: Areas of state-level labor law reform

The index of labor market reform is consistent with the state-wise unemployment data in India. Table 4.4 shows the unemployment rate for Rural and Urban areas in the Indian states with flexible and inflexible labor markets collected from Ministry of Labour & Employment of India. As the table illustrates, the states that introduced more amendments to the labor regulations (states with flexible labor markets) have

relatively lower unemployment rates than the states with inflexible labor markets. For example, the average unemployment rate in the states with flexible labor market is 5.0% while the average unemployment rate in the states with inflexible labor market is 9.6% per year.

Table 4–4: Unemployment Rate in States with Flexible and Inflexible Labor Markets

States	Rural	Urban	Rural+Urban
Andhra Pradesh	5.4	7.9	5.9
Delhi	6.9	6.3	6.4
Gujarat	1.6	1.6	1.6
Haryana	6.7	5.3	6.3
Himachal Pradesh	4.7	5.7	4.8
Karnataka	4.4	3.5	4.2
Madhya Pradesh	3.9	6.3	4.4
Maharashtra	4.2	5.3	4.6
Orissa	6.6	5.4	6.5
Punjab	4.3	4.4	4.3
Rajasthan	3.8	3.8	3.8
Tamil Nadu	6.6	5.8	6.3
Uttar Pradesh	5.6	4.4	5.4
Average Flexible States	5.0	5.1	5.0
Assam	7.4	9.7	7.7
Bihar	11.2	5.8	10.8
Chhattisgarh	5.4	5.6	5.4
Goa	16.1	7.0	12.1
Jharkhand	9.6	8.2	9.4
Kerala	13.2	17.2	14.3
Uttarakhand	7.6	5.8	7.2
West Bengal	8.8	13.8	9.9
Average Inflexible States	9.9	9.1	9.6
India	6.3	6.3	6.3

Figure 4.7 and 4.8 plot the density distribution of plant-level productivity and plant-level capital-labor ratio for states with flexible and inflexible labor markets. Labor productivity was measured as the ratio of value of output to total man-days

worked in each plant. The capital-labor ratio was measured as the value of fixed assets divided by total man-days worked. Figure 4.7 suggests that labor productivity in the states with flexible labor markets is relatively higher than in states with more stringent labor market regulations. In addition, states with flexible labor markets are relatively more capital-intensive than the states with inflexible labor markets. As the figure shows, states with lower labor intensity (larger capital intensity) experience a greater improvement in their labor productivity distribution from the relaxation of labor laws' enforcement when compared to more labor-intensive states. Figures 4.7 and 4.8 exhibit a modest positive relationship between labor productivity/capital-labor ratio and labor market reforms in the Indian states.

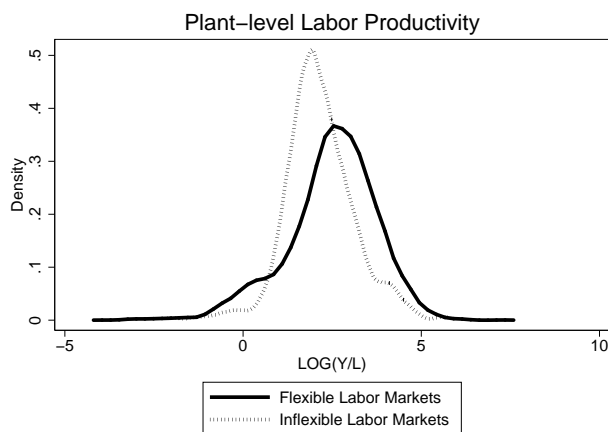


Figure 4-7: Labor productivity

### Plant-level TFP

To examine the impact of labor market regulations on measures of productivity, in this section I will estimate TFP at the plant-level. To estimate TFP, I use the balanced panel of establishments in the 21 states over 1999-2008. I use the TFP



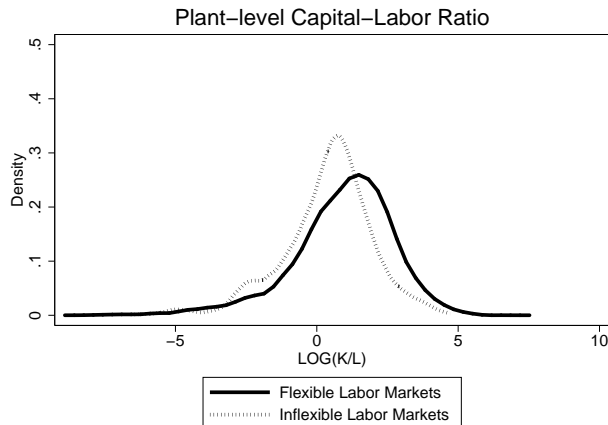


Figure 4–8: Capital-labor ratio

estimation methodology (LP) developed by Petrin et al. (2004). The main advantage of the LP estimator is that it accounts for the correlation between unobservable productivity shocks and input levels in micro-level data sets. For example, a positive productivity shock may encourage plants to expand output which in turn increases demand for the inputs too. This correlation between the demand for inputs and productivity shocks makes the OLS estimator biased and by implication, it leads to biased estimates of plant-level productivity. The LP estimator use intermediate input as proxies to solve the possible endogeneity in estimations<sup>6</sup>.

Following Levinsohn and Petrin (2003), I consider a CobbDouglas production technology given by,

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<sup>6</sup> Olley and Pakes (1996) (OP) also developed an estimator that uses investment, as a proxy for these unobservable shocks. Levinsohn and Petrin (2003) showed that using investment as a proxy may not smoothly respond to the productivity shock and is only valid for plants reporting nonzero investment.

$$y_t = \alpha_0 + \alpha_l l_t + \alpha_k k_t + \alpha_m m_t + \omega_t + \eta_t \quad (4.1)$$

where  $y_t$  represents logarithm of output.  $l_t$  denotes logarithm of labor,  $k_t$  denotes logarithm of capital, and  $m_t$  denotes logarithm of materials.  $\omega$  indexes the productivity component and  $\eta$  denotes the error term. Here the labor and material inputs are considered as the freely variable inputs and capital is the state variable. Levinsohn and Petrin (2003) show that the error term  $\eta$  is uncorrelated with input choices. The productivity component  $\omega$  is a state variable which influences the decision rules of individual plants. Since  $\omega$  is not observable, it can affect the choices of inputs, leading to an endogeneity problem in the estimation of the production function.

To account for the possible endogeneity, Levinsohn and Petrin (2003) assumed that the demand for the intermediate inputs depends on capital  $k$  and productivity shock  $\omega$  where the demand function is monotonically increasing in  $\omega_t$ . The LP approach also uses the fact that the previous period's level of material usage  $m_t$  is uncorrelated with this period's error term.

$$m_t = m_t(k_t, \omega_t) \quad (4.2)$$

These assumptions allow the unobservable productivity term to be expressed as a function of the two observed inputs of capital and materials.

$$\omega_t = \omega_t(k_t, m_t) \quad (4.3)$$

The last assumption in the LP estimation is that the productivity parameter  $\omega$  follows a first-order Markov process given by,

$$\omega_t = E[\omega_t|\omega_{t-1}] + \xi_t \quad (4.4)$$

where  $\xi_t$  is considered a possible source of the endogeneity and is defined as an innovation to productivity that is uncorrelated with  $k_t$ , but not necessarily with  $l_t$ .

Now define  $\phi_t$  as,

$$\phi_t(k_t, m_t) = \alpha_0 + \alpha_k k_t + \alpha_m m_t + \omega_t(k_t + m_t) \quad (4.5)$$

subsisting (4.5) back into the production function gives,

$$y_t = \alpha_l l_t + \phi_t(k_t, m_t) + \eta_t \quad (4.6)$$

In equation (4.6),  $\alpha_l$  can be estimated using OLS with a third-order polynomial approximation in  $k_t$  and  $m_t$  in place of  $\phi_t(k_t, m_t)$  and then with the given assumptions, the production function (4.1) and plant-level productivity can be estimated using micro-level data.

In my estimation of the plant-level TFP, output is measured as the value of gross output, labor is measured as total man-days worked, capital is measured as the value of fixed assets, and materials are measured as the total value of materials and fuels. All the variables are measured in constant prices.

Figure 4.9 plots the distribution of plant-level TFP in the states with flexible and inflexible labor markets. The plant-level TFP estimates are obtained from the LP

estimator explained above which yields unbiased estimates of the production function coefficients. The figure shows that plants in states with less restrictive labor market regulations gain a larger improvement in their TFP distribution than plants in states with inflexible labor markets.

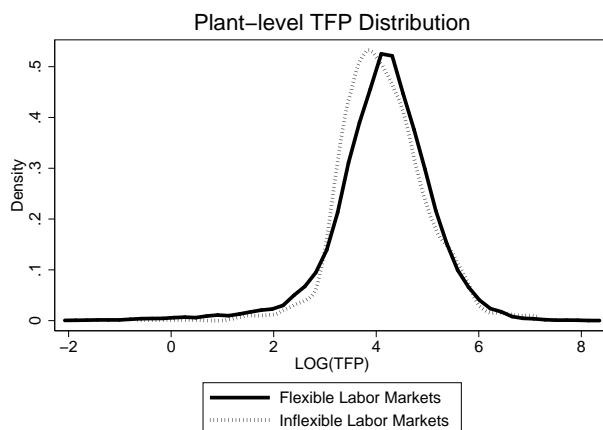


Figure 4-9: Plant-Level TFP Density

#### 4.4 Regression Analysis

The main purpose of this study is to explore the link between labor market regulations (or labor market reforms) and measures of productivity. I exploit the employment protection legislation data, which reflect the state-level variation in labor laws in India. While most of the regulations were passed at the central level, the state governments have the right to amend and enforce the regulations under the Indian Constitution. Therefore, the cross-state variation in the data on the labor market legislation comes from the amendments made to the labor acts and regulations. The main objective of my empirical investigation is to provide evidence that

plants operating in states with protected labor markets are more likely to have lower productivity levels than plants operating in states with flexible labor markets.

A number of empirical works have found that regulatory environments in input and output markets can encourage competition and have a positive impact on measures of productivity. In the context of labor markets, even in relatively less productive economies, labor market reforms could also encourage competition among establishments. For example, stringent regulations may reduce productivity by making it more difficult for resources to flow from low productivity establishments to high productivity ones. To examine the impact of state-level labor reform on productivity, I consider a panel regression of the form:

$$\text{Log}(Pro_{jst}) = \beta_0 + \beta_1 Dinx_s + \beta_2 Downer_j + \beta_3 KL_j + \beta_4 Dnic_{it} + \beta_5 inx_i \times Dnic + \lambda_t + \epsilon_{jst} \quad (4.7)$$

where  $Pro_{jst}$  denotes productivity of plant  $j$  operating in state  $s$  and industry  $i$  and at year  $t$ . TFP and labor productivity are used as the measures of productivity for the dependent variable.  $Dinx_s$  is a dummy variable showing state-level labor market reform index. States with labor market reform index above the median are considered as having flexible labor market and states with score below the median are considered as having inflexible labor market. Then, the dummy variable is defined as  $Dinx_s = 1$  ; if the state has a flexible labor market and  $Dinx_s = 0$  ; if the state has a inflexible labor market.

I also control for plant ownership ( $Downer_j$ ), plant capital-labor ratio ( $KL_j$ ), and industry-level labor intensity ( $Dnic_{it}$ ).  $Downer_j$  represents ownership type of

plant  $j$ . I assign  $Downer_s = 1$  ; if a plant is privately owned, and  $Downer_s = 0$  otherwise.  $Dnic_{it}$  is the measure of labor-intensity in industry  $i$  at year  $t$ . It is measured as the total number of workers in the industry to the industry-level value of fixed assets. The last terms in the equation captures the interaction of state-level labor market reform score ( $inx_s$ ) and industry-level labor intensity ( $Dnic_{it}$ ). I added this variable to see if plants in more labor-intensive industries benefit more from labor market reforms. The industry-level labor intensity is calculated from industry-wise ASI sample with total plants as the ratio of fixed assets to total number of workers. In the Indian industry, the manufacturing of “Tobacco and Related Products” (NIC. 16) and manufacturing of “Wearing Apparel, Dressing and Dyeing of Fur” (NIC. 18) have the highest labor intensity, while, manufacturing of “Coke, Petroleum Products and Nuclear Fuel” (NIC. 23) and manufacturing of “Basic Metals” (NIC. 15) have the lowest average labor intensity. To control for year fixed effects, I add a plant-specific trend to each regression model.

#### 4.5 Results

The regression model 4.7 is estimated using the balanced panel first. Then, since the labor market laws are more likely to affect larger establishments, I estimate the model with the balanced panel but with plant-size restrictions. In particular, I use a balanced panel of establishments with less than 100 workers and then a sample of plants with more than 100 workers to examine if small and large plants are affected differently by the regulations. Table 4.5 provides results of the first two regressions with the unrestricted balanced panel.

Table 4–5: Impact of Labor Market Reforms

Variable	Log (TFP)	Log (Y/L)
State-level labor reform score (dummy variable)	0.148 (0.392)	0.657 (0.457)
Plant ownership (dummy variable)	0.103 (0.074)	0.013 (0.086)
Plant capital-labor ratio	-0.002 (0.000)	0.013** (0.000)
Industry labor intensity	0.038 (0.101)	0.054 (0.117)
Interaction of labor reform score and industry labor intensity	0.005 (0.004)	-0.022 (0.005)
Constant	3.421** (0.284)	1.348** (0.331)
Number of obs	17410	17410
Prob > F	0.0000	0.0000
R-squared	0.2769	0.4217
Adj R-squared	0.1959	0.357
Plant trend	Yes	Yes
Year fixed effect	Yes	Yes
Standard errors in parentheses.		
* $p < 0.01$ , ** $p < 0.05$		

In the first two regressions with unrestricted plants, I estimated the impact of labor market reforms on plant labor productivity and TFP. The state-level employment protection legislation and its interaction with the industry-level labor intensity show no significant impact on total factor productivity or labor productivity. I restrict the sample and include plants with minimum 100 employees to capture the impact of labor market reforms on larger establishments. Table 4.6 provides the results.

Table 4–6: Impact of Labor Market Reforms (panel of large plants)

Variable	Log (TFP)	Log (Y/L)
State-level labor reform score (dummy variable)	1.227* (0.630)	1.493* (0.732)
Plant ownership (dummy variable)	0.113 (0.071)	0.025 (0.082)
Plant capital-labor ratio	0.002 (0.000)	0.019** (0.000)
Industry labor intensity	-0.108** (0.107)	-0.297* (0.125)
Interaction of labor reform score and industry labor intensity	0.011** (0.005)	-0.012 (0.005)
Constant	3.393** (12.680)	1.300** (4.180)
Number of obs	15035	15035
Prob > F	0.000	0.000
R-squared	0.3173	0.4909
Adj R-squared	0.2273	0.4238
Plant trend	Yes	Yes
Year fixed effect	Yes	Yes
Standard errors in parentheses.		
* $p < 0.01$ , ** $p < 0.05$		

By controlling for the size of establishments, the regression models provide different outcomes. The state-level labor reform has a moderate positive impact on productivity in both TFP and labor productivity. The interaction of state-level labor reform score and industry-level labor intensity also shows a positive impact on TFP. This result implies that the impact of reforms on productivity is larger in industries where plants rely more on labor than in industries in which labor is



relatively less important than capital in the production process. In addition, in industries with more frequent labor adjustment, regulations are more likely to hurt productivity because firms will have a harder time adjusting the labor input usage. My point estimates show that reforms in the states with inflexible labor market that increase their labor reform score to the median, will increase  $\log(\text{TFP})$  by 1.23 and  $\log(Y/L)$  by 1.49. The results also imply that one unit increase in the interaction of state-level labor reform score and industry labor-intensity causes to 0.011 unit increase in  $\log(\text{TFP})$  of plants with at least 100 employees.

Finally, I estimate the model to examine the potential impact of labor market regulations on productivity of establishments with less than 100 employees (Table 4.7).

As the table shows, there is no significant association between state-level labor reforms and measures of productivity in plants with less than 100 employees. The interaction of state-level labor reform score and industry-level labor intensity also does not show any significant relationship with the plant-level TFP or labor productivity. This result is consistent with the study of Dougherty (2008) who shows that for small firms in India with 100 or fewer workers, job creation rates were more than double job destruction rates for this group of firms, causing employment in small firms to increase by more than 20% a year during 1998-2004. He also found that despite the absence of restrictive dismissal laws for smaller firms, the job destruction rate in small plants was actually less than that in larger ones. In contrast, for firms having a minimum 100 employees, the impact of labor reforms is higher than its impact on smaller firms and job creation rate for those firms was low and well below

Table 4–7: Impact of Labor Market Reforms (panel of small plants)

Variable	Log (TFP)	Log (Y/L)
State-level labor reform score (dummy variable)	1.729 (1.676)	1.840 (1.869)
Plant ownership (dummy variable)	0.303 (0.714)	0.243 (0.796)
Plant capital-labor ratio	-0.001 (0.001)	0.005** (0.001)
Industry labor intensity	1.212* (0.501)	1.962** (0.559)
Interaction of labor reform score and industry labor intensity	-0.046 (0.022)	-0.092 (0.025)
Constant	1.799 (1.308)	0.525 (1.459)
Number of obs	2375	2375
Prob > F	0.000	0.000
R-squared	0.6287	0.6591
Adj R-squared	0.3167	0.3726
Plant trend	Yes	Yes
Year fixed effect	Yes	Yes
Standard errors in parentheses.		
* $p < 0.01$ , ** $p < 0.05$		

the job destruction rate. For larger firms the net employment of fell by more than 5% per year in the period 1998 to 2004 while job creation for contract workers in large firms was twice the rate for large firms' regular workers.

#### 4.6 Conclusions

Employment protection legislation raises the cost of employment for firms and has a detrimental impact on labor adjustment process that is vital to economic growth and technological progress. Labor market regulations also limit job turnover

in industries that need frequent adjustment of workers for technological reasons or competition.

In this chapter, I examined the impact of state-level labor reforms on plant-level measures of productivity in India. I assessed how labor reform strategies across the Indian states could affect plant-level TFP and labor productivity. The main finding of this study implies that plants with at least 100 employees, operating in labor-intensive industries are more likely to benefit from labor market reforms in terms of an improvement in TFP and labor productivity. I also showed that an improvement in the degree of labor market reform will have a positive impact on TFP and labor productivity and these effects remain even after controlling for some state-level variables. The state-level labor reforms could increase job turnover or flexibility in the labor markets while a lack of such reforms limits labor turnover and negatively impacts the labor adjustment process particularly in labor-intensive industries. This study found that the state-level labor reform does not seem to have any important effect on small plants.

Despite the fact that this study exploits the variation in state-level labor reform scores, the lack of time series information on labor market reforms may influence the results. Time series data on labor reforms across the states could allow future studies to measure changes in productivity over time. In addition, my study used a balanced panel of plants without accounting for entry and exit effects, which might also have a significant impact on industry performance.

## REFERENCES

- [1] Tasso Adamopoulos and Diego Restuccia (a). The Size Distribution of Farms and International Productivity Differences. *American Economic Review*, 104(6):1667–97, June 2014.
- [2] Tasso Adamopoulos and Diego Restuccia (b). Land Reform and Productivity: A Quantitative Analysis with Micro Data. unpublished manuscript, University of Toronto, 2014.
- [3] Philippe Aghion, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt. Competition and innovation: An inverted-u relationship. *The Quarterly Journal of Economics*, 120(2):701–728, May 2005.
- [4] Philippe Aghion and Peter Howitt. A model of growth through creative destruction. *Econometrica*, 60(2):323–51, March 1992.
- [5] Ahmad Ahsan and Carmen Pags. Are all labor regulations equal? Evidence from Indian manufacturing. *Journal of Comparative Economics*, 37(1):62–75, March 2009.
- [6] Werner Antweiler, Brian R. Copeland, and M. Scott Taylor. Is free trade good for the environment? NBER Working Papers 6707, National Bureau of Economic Research, Inc, August 1998.
- [7] Shuhei Aoki, Julen Esteban-Pretel, Tetsuji Okazaki, and Yasuyuki Sawada. The Role of the Government in Facilitating TFP Growth during Japan’s Rapid Growth Era. CIRJE F-Series CIRJE-F-622, CIRJE, Faculty of Economics, University of Tokyo, June 2009.
- [8] Elias Asproudis and Maria Jose Gil-Molto. Technological choice under environmentalists participation in emissions trading systems. Discussion Papers in Economics 09/9, Department of Economics, University of Leicester, 2009.

- [9] Andrew Atkeson and Ariel T. Burstein. Aggregate implications of innovation policy. Working Paper 17493, National Bureau of Economic Research, October 2011.
- [10] Peter Auer, Janine Berg, and Ibrahim Coulibaly. Is a stable workforce good for productivity? *International Labour Review*, 144(3):319–343, 2005.
- [11] Claustre Bajona and Luis Locay. Entrepreneurship and productivity: The slow growth of the planned economies. *Review of Economic Dynamics*, 12(3):505–522, July 2009.
- [12] Richard Baldwin. Heterogeneous firms and trade: Testable and untestable properties of the melitz model. NBER Working Papers 11471, National Bureau of Economic Research, Inc, July 2005.
- [13] Andrea Bassanini and Danielle Venn. The Impact of Labour Market Policies on Productivity in OECD Countries. *International Productivity Monitor*, 17:3–15, Fall 2008.
- [14] Susanto Basu and John G. Fernald. Aggregate productivity and aggregate technology. *European Economic Review*, 46(6):963–991, June 2002.
- [15] Yoram Bauman, Myunghun Lee, and Karl Seeley. Does technological innovation really reduce marginal abatement costs? some theory, algebraic evidence, and policy implications. *Environmental & Resource Economics*, 40(4):507–527, August 2008.
- [16] Omar D Bello, Juan S Blyde, and Diego Restuccia. Venezuela’s growth experience. Working Papers tecipa-431, University of Toronto, Department of Economics, June 2011.
- [17] Paul R. Bergin and Robert C. Feenstra. Staggered price setting, translog preferences, and endogenous persistence. *Journal of Monetary Economics*, 45(3):657–680, June 2000.
- [18] Paul R. Bergin and Robert C. Feenstra. Pricing-to-market, staggered contracts, and real exchange rate persistence. *Journal of International Economics*, 54(2):333–359, August 2001.
- [19] Andrew Bernard, Stephen Redding, and Peter Schott. Products and productivity. Working Papers 08-22, Center for Economic Studies, U.S. Census Bureau, August 2008.

- [20] Timothy Besley and Robin Burgess. Can Labor Regulation Hinder Economic Performance? Evidence from India. *The Quarterly Journal of Economics*, 119(1):91–134, February 2004.
- [21] Aditya Bhattacharjea. Labour Market Regulation and Industrial Performance in India—A Critical Review of the Empirical Evidence. Working papers 141, Centre for Development Economics, Delhi School of Economics, June 2006.
- [22] Aditya Bhattacharjea. The Effects of Employment Protection Legislation on Indian Manufacturing. Technical Report 22, Economic & Political Weekly, May 2009.
- [23] Dhritiman Bhattacharya, Nezh Guner, and Gustavo Ventura. Distortions, endogenous managerial skills and productivity differences. IZA Discussion Papers 5963, Institute for the Study of Labor (IZA), September 2011.
- [24] Johannes Van Biesebroeck. Robustness of productivity estimates. *Journal of Industrial Economics*, 55(3):529–569, 09 2007.
- [25] J. Vicente Blanes and Isabel Busom. Who participates in R&D subsidy program?. the case of spanish manufacturing firms. Working Papers wpdea0407, Department of Applied Economics at Universitat Autònoma de Barcelona, August 2004.
- [26] Albert Bollard, Peter Klenow, and Gunjam Sharma. India’s mysterious manufacturing miracle. *Review of Economic Dynamics*, 16(1):59–85, January 2013.
- [27] Lee Branstetter and Jong-Rong Chen. The impact of technology transfer and R&D on productivity growth in taiwanese industry: Microeconomic analysis using plant and firm-level data. *Journal of the Japanese and International Economies*, 20(2):177–192, June 2006.
- [28] Francisco J. Buera and Yongseok Shin. Productivity growth and capital flows: The dynamics of reforms. NBER Working Papers 15268, National Bureau of Economic Research, Inc, August 2009.
- [29] Paul Conway and Richard Herd. How competitive is product market regulation in india? *OECD Journal: Economic Studies*, 2009(1), 2010.
- [30] Brian R Copeland and M Scott Taylor. Trade and transboundary pollution. *American Economic Review*, 85(4):716–37, September 1995.

- [31] Nicholas Crafts. Regulation and productivity performance. *Oxford Review of Economic Policy*, 22(2):186–202, 2006.
- [32] Dirk Czarnitzki, Petr Hanel, and Julio Miguel Rosa. Evaluating the impact of R&D tax credits on innovation: A microeconomic study on canadian firms. *Research Policy*, 40(2):217–229, March 2011.
- [33] Avinash K Dixit and Joseph E Stiglitz. Monopolistic competition and optimum product diversity. The Warwick Economics Research Paper Series (TWERPS) 64, University of Warwick, Department of Economics, 1975.
- [34] Sean Dougherty. Labour Regulation and Employment Dynamics at the State Level in India. OECD Economics Department Working Papers 624, OECD Publishing, August 2008.
- [35] Sean Dougherty, Vernica C. Frisancho Robles, and Kala Krishna. Employment protection legislation and plant-level productivity in india. Working Paper 17693, National Bureau of Economic Research, December 2011.
- [36] Robert Feenstra and Hiau Looi Kee. Export variety and country productivity: Estimating the monopolistic competition model with endogenous productivity. *Journal of International Economics*, 74(2):500–518, March 2008.
- [37] Don Fullerton and Seung-Rae Kim. Environmental investment and policy with distortionary taxes and endogenous growth. NBER Working Papers 12070, National Bureau of Economic Research, Inc, March 2006.
- [38] Don Fullerton and Gilbert E. Metcalf. Environmental taxes and the double-dividend hypothesis: Did you really expect something for nothing? NBER Working Papers 6199, National Bureau of Economic Research, Inc, September 1997.
- [39] Don Fullerton and Gilbert E. Metcalf. Cap and trade policies in the presence of monopoly and distortionary taxation. Discussion Papers Series, Department of Economics, Tufts University 0015, Department of Economics, Tufts University, 2000.
- [40] Alain Gabler and Markus Poschke. Experimentation by firms, distortions, and aggregate productivity. *Review of Economic Dynamics*, 16(1):26–38, January 2013.

- [41] Simon Gilchrist, Jae W. Sim, and Egon Zakrajsek. Misallocation and financial market frictions: Some direct evidence from the dispersion in borrowing costs. *Review of Economic Dynamics*, 16(1):159–176, January 2013.
- [42] Douglas Gollin. Nobody’s business but my own: Self employment and small enterprise in economic development. Center for Development Economics 172, Department of Economics, Williams College, May 2001.
- [43] Douglas Gollin. Nobody’s business but my own: Self-employment and small enterprise in economic development. *Journal of Monetary Economics*, 55(2):219–233, March 2008.
- [44] Xulia Gonzalez, Jordi Jaumandreu, and Consuelo Pazo. Barriers to innovation and subsidy effectiveness. *RAND Journal of Economics*, 36(4):930–949, Winter 2005.
- [45] Xulia Gonzlez and Consuelo Paz. Do public subsidies stimulate private R&D spending? *Research Policy*, 37(3):371–389, April 2008.
- [46] Gene M. Grossman and Elhanan Helpman. *Innovation and Growth in the Global Economy*, volume 1 of *MIT Press Books*. The MIT Press, 1993.
- [47] Nezhil Guner, Gustavo Ventura, and Xu Yi. Macroeconomic implications of size-dependent policies. *Review of Economic Dynamics*, 11(4):721–744, October 2008.
- [48] Angel Gurra. Economic survey of india. Development of economics, OECD, April 2007.
- [49] Sato Hajime. The iron and steel industry in asia: Development and restructuring. IDE Discussion Papers 210, Institute of Developing Economies-Japan External Trade Organization, August 2009.
- [50] Bronwyn H. Hall. The financing of research and development. NBER Working Papers 8773, National Bureau of Economic Research, Inc, February 2002.
- [51] Joost Heijs and Liliana Herrera. The distribution of R&D subsidies and its effect on the final outcome of innovation policy. Working Papers 46, Instituto de Analisis Industrial y Financiero, 2004.



- [52] Berthold Herrendorf and Yan Bai. What is the relationship between competition and productivity. 2009 Meeting Papers 1142, Society for Economic Dynamics, 2009.
- [53] Liliana Herrera and Edna R. Bravo Ibarra. Distribution and effect of R&D subsidies: A comparative analysis according to firm size. *Intangible Capital*, 6(2):272–299, September 2010.
- [54] Almas Heshmati and Hans Loof. The impact of public funds on private R&D investment: New evidence from a firm level innovation study. Discussion Papers 11862, MTT Agrifood Research Finland, 2005.
- [55] Thomas J. Holmes and Jr. James A. Schmitz. Competition and productivity: a review of evidence. Staff Report 439, Federal Reserve Bank of Minneapolis, 2010.
- [56] Hugo Hopenhayn and Richard Rogerson. Job turnover and policy evaluation: A general equilibrium analysis. *Journal of Political Economy*, 101(5):915–38, October 1993.
- [57] Chang-Tai Hsieh and Peter J. Klenow. Misallocation and manufacturing tfp in china and india. *The Quarterly Journal of Economics*, 124(4):1403–1448, November 2009.
- [58] Douglas A. Irwin and Peter J. Klenow. High-tech R&D subsidies estimating the effects of sematech. *Journal of International Economics*, 40(3-4):323–344, May 1996.
- [59] Adam B. Jaffe and Karen Palmer. Environmental Regulation And Innovation: A Panel Data Study. *The Review of Economics and Statistics*, 79(4):610–619, November 1997.
- [60] Robert E. Lucas Jr. On the size distribution of business firms. *Bell Journal of Economics*, 9(2):508–523, Autumn 1978.
- [61] Robert E. Lucas Jr. On the Size Distribution of Business Firms. *Bell Journal of Economics*, 9(2):508–523, Autumn 1978.
- [62] T.J. Klette, J. Moen, and Z. Griliches. Do subsidies to commercial R&D reduce market failures? microeconomic evaluation studies. Papers 16/99, Norwegian School of Economics and Business Administration-, 1999.

- [63] Paul Krugman. Scale economies, product differentiation, and the pattern of trade. *American Economic Review*, 70(5):950–59, December 1980.
- [64] A. P. Lerner. The concept of monopoly and the measurement of monopoly power. *Review of Economic Studies*, 1(3):157–175, 1934.
- [65] Arik Levinson and M. Scott Taylor. Unmasking the pollution haven effect. NBER Working Papers 10629, National Bureau of Economic Research, Inc, July 2004.
- [66] Zhe Li. Productivity dispersion across plants, emission abatement, and environmental policy. MPRA Paper 9564, University Library of Munich, Germany, September 2008.
- [67] Jan De Loecker and Frederic Warzynski. Markups and firm-level export status. Working Paper 15198, National Bureau of Economic Research, July 2009.
- [68] Marc J. Melitz and Giancarlo I. P. Ottaviano. Market size, trade, and productivity. *Review of Economic Studies*, 75(1):295–316, 01 2008.
- [69] Mark J. Melitz. The impact of trade on intra-industry reallocations and aggregate industry productivity. Working Paper 8881, National Bureau of Economic Research, April 2002.
- [70] Veronica Mies. Adoption technology targets and knowledge dynamics: Consequences for long-run prospects. Documentos de Trabajo 385, Instituto de Economía. Pontificia Universidad Católica de Chile., 2010.
- [71] Robert D. Mohr. Technical change, external economies, and the porter hypothesis. *Journal of Environmental Economics and Management*, 43(1):158–168, January 2002.
- [72] Hiroshi Ohashi. Learning by doing, export subsidies, and industry growth: Japanese steel in the 1950s and 1960s. *Journal of International Economics*, 66(2):297–323, July 2005.
- [73] Peter F. Orazem and Milan Vodopivec. Do market pressures induce economic efficiency? the case of slovenian manufacturing, 19942001. *Southern Economic Journal*, 76(2):553–576, October 2009.

- [74] Gianmarco Iero Paolo Ottaviano and Jacques-Francois Thisse. Agglomeration and trade revisited. CEPR Discussion Papers 1903, C.E.P.R. Discussion Papers, June 1998.
- [75] Karen Palmer, Wallace E. Oates, and Paul R. Portney. Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm? *Journal of Economic Perspectives*, 9(4):119–132, Fall 1995.
- [76] Stephen L Parente and Edward C Prescott. Barriers to Technology Adoption and Development. *Journal of Political Economy*, 102(2):298–321, April 1994.
- [77] Michael Peters. Heterogeneous Mark-Ups and Endogenous Misallocation. 2011 Meeting Papers 78, Society for Economic Dynamics, 2011.
- [78] Amil Petrin and James Levinsohn. Measuring aggregate productivity growth using plant-level data. NBER Working Papers 11887, National Bureau of Economic Research, Inc, December 2005.
- [79] Michael E Porter. *America's Green Strategy*. Scientific American 264, no. 4, 1991.
- [80] Michael E Porter and Claas van der Linde. Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, 9(4):97–118, Fall 1995.
- [81] Edward C. Prescott and Stephen L. Parente. Monopoly Rights: A Barrier to Riches. *American Economic Review*, 89(5):1216–1233, December 1999.
- [82] Copeland Brian R. International trade and the environment: Policy reform in a polluted small open economy. *Journal of Environmental Economics and Management*, 26(1):44–65, January 1994.
- [83] Sarbapriya Ray and Mihir Kumar Pal. Trend in total factor productivity growth in indian iron and steel industries under a liberalized trade regime: An empirical analysis with adjustment for capacity utilization. *Journal of Applied Business and Economics*, 11(3), 2010.
- [84] Diego Restuccia and Richard Rogerson. Policy distortions and aggregate productivity with heterogeneous plants. *Review of Economic Dynamics*, 11(4):707–720, October 2008.

- [85] Diego Restuccia and Richard Rogerson. Misallocation and productivity. *Review of Economic Dynamics*, 16(1):1–10, January 2013.
- [86] Paul M Romer. Endogenous technological change. *Journal of Political Economy*, 98(5):S71–102, October 1990.
- [87] Katja Schumacher and Jayant Sathaye. Indias cement industry: Productivity, energy efficiency and carbon emissions. Working Papers 41842, LBNL, July 1998.
- [88] Aminata Sissoko. R&D subsidies and firm-level productivity: Evidence from france. Discussion Papers (IRES - Institut de Recherches Economiques et Sociales) 2011002, Universit catholique de Louvain, Institut de Recherches Economiques et Sociales (IRES), January 2011.
- [89] Servaas Storm and C.W.M. Naastepad. Why labour market regulation may pay off: Worker motivation, co-ordination and productivity growth. Development of economics, Delft University of Technology, The Netherlands, April 2007.
- [90] Gordon Tullock. Excess benefit. *Water Resources Research*, 3:643–644, 1967.
- [91] Alistair Ulph. Environmental policy and international trade when governments and producers act strategically. *Journal of Environmental Economics and Management*, 30(3):265–281, May 1996.
- [92] Clara Villegas and Jessica Coria. Taxes, permits and the adoption of abatement technology under imperfect compliance. Working Papers in Economics 368, Gteborg University, Department of Economics, June 2009.
- [93] Scott J. Wallsten. The effects of government-industry R&D programs on private R&D: The case of the small business innovation research program. *RAND Journal of Economics*, 31(1):82–100, Spring 2000.
- [94] Anastasios Xepapadeas and Aart de Zeeuw. Environmental policy and competitiveness: The porter hypothesis and the composition of capital. *Journal of Environmental Economics and Management*, 37(2):165–182, March 1999.
- [95] Hide-Fumi Yokoo. Heterogeneous firms, the porter hypothesis and trade. Technical report, Kyoto Sustainability Initiative, Kyoto University, 2009.

**APPENDIX A**  
**Indirect Utility Function**

To find the indirect utility function, note that by definition,

$$\bar{x} = \frac{1}{N} \int x_i^c di \text{ and } var(x) = \frac{1}{N} \int (x_i - \bar{x})^2 di$$

substitution into consumer preferences yields,

$$U = x_0^c + \beta N \bar{x} - \frac{N}{2\gamma} var(p) - \frac{N}{2} \bar{x}^2 (\gamma + \eta N)$$

where  $var(p) = \gamma^2 var(x)$  From demand function  $p_i = \beta - \gamma x_i^c - \eta X$ , we can show that  $\bar{x} = \frac{\beta - \bar{p}}{\gamma + \eta N}$  then, the consumer's preferences becomes,

$$U = x_0^c + \beta N \bar{x} - \frac{N}{2\gamma} var(p) - \frac{N}{2} \bar{x} (\beta - \bar{p})$$

The consumer's budget constraint is denoted by  $I^c$  and is defined by,

$$I^c = x_0^c + \int p_i x_i^c di$$

From  $p_i = \beta - \gamma x_i^c - \eta X$ , and  $X = N \bar{x}$ , we can show that,

$$\int p_i x_i di = N \bar{x} \bar{p} - \frac{N}{\gamma} var(p)$$

Then, total consumer's budget constraint becomes,

$$I^c = x_0^c + N \bar{x} \bar{p} - \frac{N}{\gamma} var(p)$$

Substituting  $I^c$  in  $U$ , yields the indirect utility function as,

$$U = I^c + \frac{N}{2\gamma} var(p) + \frac{1}{2} N \bar{x} (\beta - \bar{p})$$

In order to evaluate the indirect utility function, by definition we have  $\bar{\varphi} = \frac{k+1}{k} \varphi^*$ ,

and we can calculate,

$$var\left(\frac{1}{\varphi}\right) = \frac{k}{(k+1)^2(k+2)} (\varphi^*)^{-2}$$

Then, from (19),

$$\text{var}(p) = (1/b^*)^2 \frac{k}{(k+1)^2(k+2)} (\varphi^*)^{-2}$$

This equation along with (18), (28), and (29) gives equation (32) in the text.

$$U = I^c + \frac{N}{2\gamma} \left( \frac{\beta}{k+1} (\varphi_f^*)^{-1} (1/b^*)^{\frac{k}{k+2}} - \frac{2}{k+2} (\varphi_f^*)^{-2} (1/b^*)^{\frac{2k}{k+2}} \right)$$

**APPENDIX B**  
**National Industrial Classification(NIC)**

The first National Industrial Classification in India adopted in 1959. With effect from ASI 1973-74, the National Industrial Classification (NIC) 1970 developed based on UNISIC 1968. NIC has been revised several times due to the industrial development in India and other administration issues. The following table outlines National Industrial Classification (NIC) and its coverage since ASI 1973. The 5-digit

Table B-1: India National Industrial Classification (NIC)

National Industrial Classification	Coverage
NIC 1970	ASI 1973-1974 to ASI 1988-1989
NIC 1987	ASI 1989-1990 to ASI 1997-1998
NIC 1998	ASI 1998-1999 to ASI 2003-2004
NIC 2004	ASI 2004-2005 to ASI 2009-2010

National Industry Classification (NIC) codes of Iron and Steel Industry is outlined in the following table.

Table B-2: Basic Metals, National Industry Classification (NIC), 5-Digit Codes

Description
27110 ferro alloys.
27120 Direct Reduced Iron (DRI)/ Sponge Iron
27130 Pig Iron
27141 semi -finished non ally steel of these shapes
27142 semi -finished alloy steel of these shapes
27143 semi -finished stainless steel of these shapes
27151 alloy-steel of these shapes
27152 non-alloy steel of these shapes
27153 stainless steel of these shapes
27161 non-alloy steel hot rolled flat products
27162 alloy steel hot rolled flat products
27163 stainless steel hot rolled flat products
27164 non-alloy steel cold rolled flat products
27165 alloy steel cold rolled flat products
27171 GP/GC/Zn-Al. coated sheets/ Color coated
27172 Tinplate
27173 Tin Free Steel
27181 non-alloy steel wires
27182 alloy steel wires
27183 stainless steel wires
27184 wires coated with zinc or other materials
27190 other basic iron and steel n.e.c.



## **APPENDIX C**

### **Annual Survey of Industries (ASI)**

The Annual Survey of Industries (ASI) is the principal source of industrial statistics in India. It provides statistical information to assess and evaluate, objectively and realistically, the changes in the growth, composition and structure of organized manufacturing sector comprising activities related to manufacturing processes, repair services, gas and water supply and cold storage. The Survey is conducted annually under the statutory provisions of the Collection of Statistics Act 1953. The definition of census and sample have been changed several times after the first ASI in 1986. The first coverage of the survey under census sector was all units with 50 or more workers operating with power, and units having 100 or more workers operating without power. The procedure continued until ASI 1986-87 by which time the total number of factories in India grew enormously. Accordingly, the definition of the census sector was changed from ASI 1987-88 to the units having 100 or more workers irrespective of their operation with or without power. This design continued until ASI 1996-97. In 1998, to maintain the budget limit a new sampling design was adopted in ASI 1997-98. The census sector was redefined to include units having 200 or more workers and significant industrial units having less than 200 workers. This approach significantly reduced the sample size in ASI 1997-98 compared to that of ASI 1996-97 while maintaining a fair level of degree of precision for the estimates up to the state level. In 2005, following the decision taken in the Standing Committee

on Industrial Statistics (SCIS), the sampling design for ASI 2004-05 to ASI 2008-09 changed again and covered units with 100 or more workers as census sector and the rest of the units as sample sector, without any change in the existing criteria.

Table C-1: Sampling Design of Census Sample Criteria

Coverage	Criteria
	100 or more workers
ASI 1980-81 to ASI 1986-87	50 or more workers with power All plants in 12 industrially backward states
ASI 1987-88 to ASI 1996-97	100 or more workers (with or without power) All plants in (same) 12 industrially backward states
ASI 1997-98 to ASI 2003-04	200 or more workers Selected “Significant Units” with fewer than 200 workers which “contributed significantly to the Value of Output” in ASI data between 1993-94 and 1995-96 All plants in (same) 12 industrially backward states All public sector undertakings
ASI 2004-05 to ASI 2008-09	100 or more workers All plants in 5 industrially backward states

## APPENDIX D Iron and Steel Making Technologies

The Indian Iron and Steel industry has experienced a remarkable growth since 1990s. India was the fifteenth largest steel producer in the world in 1998. In 2013, India has become the 4th largest crude steel producer and the world's largest producer of direct reduced iron. The following graph shows share of India in the world production of crude steel. The Iron and Steel industry heavily depends on the production

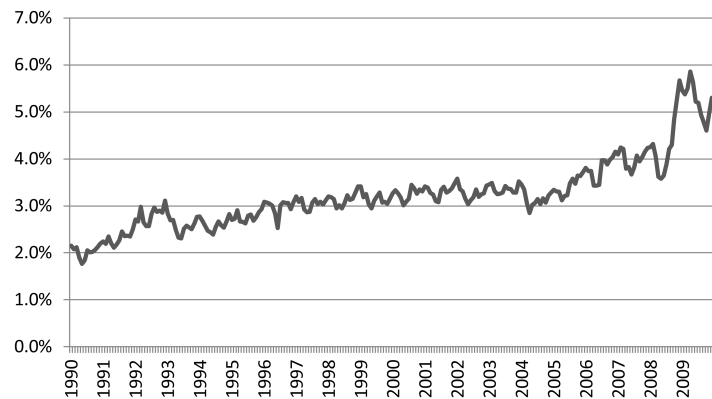


Figure D-1: Share of India in the World Production of Crude Steel (%)

technology and process. Around 70% of total steel production in the world is through Basic Oxygen Furnace (BOF), 28.8% by Electric Steel Making (EAF&EIF) and the balance 1.2% through the Open Hearth Furnace (OHF). The open hearth route is an inefficient technology and almost extinct in most of steel producing countries. In terms of production units, there are two types of steel producers: (1) primary or

integrated producers and (2) secondary producers. In the integrated units, Pig Iron and Sponge Iron are produced from iron ore first and then they are converted to crude steel. Crude steel is used further for rolling, casting, blooming, slabbing, or coating products. Integrated producers in India use Blast Furnace (BF) and Direct Reduced (DR) technologies to produce iron and Open Hearth Furnace (OHF) and Basic Oxygen Furnace (BOF) to produce steel. In the terms of energy inputs, coal and gas are the main inputs in the primary Iron and Steel making process. In particular, coal is the main energy for blast furnace and open hearth furnace while liquid hydrocarbons are used in direct reduced and Basic Oxygen Furnaces. Secondary units produce steel from sponge iron or steel scrape using electric arc furnace (EAF) or electric induction furnace (EIF). Electricity is the main energy in these production root. Basic Oxygen Furnace is the main large scale technology to produce steel.

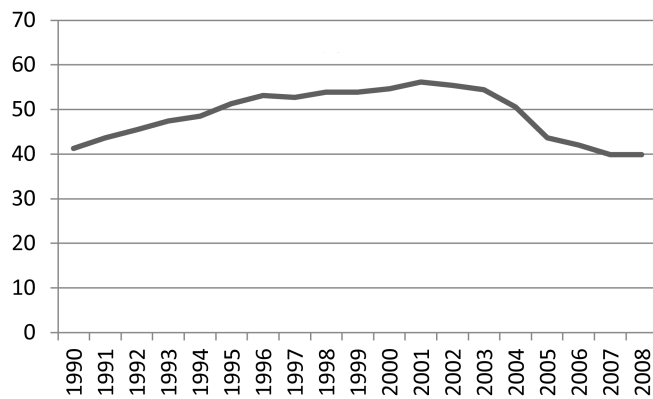


Figure D-2: Share of Basic Oxygen Furnace in Steel Production in India (%)

The average share of Basic Oxygen Furnace in production of crude steel in India has decreased from 50.8% in 1990-04 to 41.4% in 2005-08. Open-Hearth Furnace is characterized by low efficiency and quality of output. In many steel producing

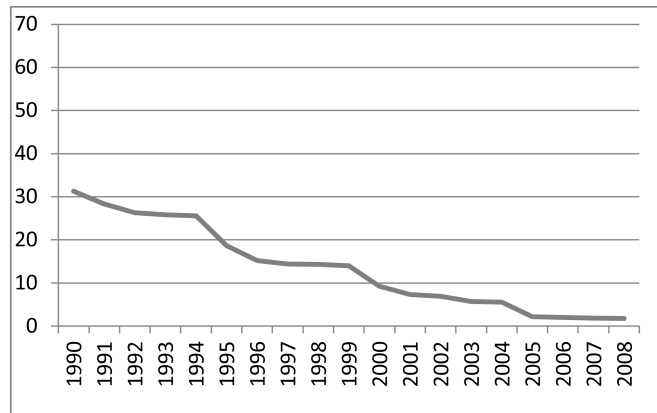


Figure D-3: Share of Open-Hearth Furnace in Steel Production in India (%)

units in India, Open-Hearth Furnaces are shutdown or replaced by newer technologies. The average share of crude steel production by OHF in India has decreased from 16.6% in 1990-04 to 2% in 2005-08. Electric Arc Furnaces range in size from

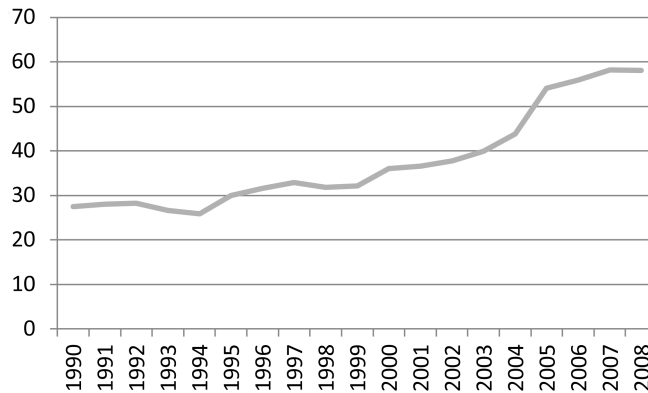


Figure D-4: Share of Electric Furnace in Steel Production in India (%)

small to large units and are used for secondary steel-making. The average share of this technology has increased from 32.6% in 1990-04 to 56.6% in 2005-08. Steel is

produced through a complicated processes involving many stages and yielding thousands of by-products. Steel is produced from either steel scrap or iron ore. On the basis of production technology, Iron and steel producers are classified to two types of producers: integrated producers and secondary producers. Integrated producers are large units with advanced technologies that operate ore and coke mines. They produces iron ore in the iron-making process and then use iron ore to produce steel. Integrated steel units traditionally have captive plants for iron ore and coke, which are the main inputs to these units.<sup>1</sup> In contrast, the secondary producers are mini-steel plants. They make steel by melting scrap or sponge iron or a mixture of the two. The secondary steel producers use less complicated technologies and electricity is the main input. For the both producers, material and the process substantially affect quality of steel and the total energy consumed during production. In the iron-making step, ore is reduced to either pig iron or sponge iron. Pig iron production occurs in blast furnaces where coke is the primary fuel. Sponge iron is produced by direct reduction (DR) processes using fossil fuels and coal. The conversion of ore into pig iron is the most energy-intensive stage of steel making. In a conventional integrated steel plant, pig iron is produced in a blast furnace, using coke in combination with injected coal, oil, or gas. Blast furnaces are operated at various scales, ranging from mini-blast furnaces to large furnaces. Sponge iron, produced by direct

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<sup>1</sup> Currently there are three main integrated producers in India namely Steel Authority of India Limited (SAIL), Tata Iron and Steel Co Ltd (TISCO)and Rashtriya Ispat Nigam Ltd (RINL)

reduction (DR) processes, has different properties from pig iron. In the DR process, iron is produced by reducing the ores using syngas from different fossil fuels (mainly oil or natural gas; in India coal or gas based) in small-scale plants. DR iron (or sponge iron) serves as high quality alternative for scrap in secondary steel-making. Steel-making is the reduction of the amount of carbon in the hot iron metal to a level below 1.9 percent through the oxidation of carbon and silicon.

### **Primary Steel Producers**

Most primary steel is produced by two processes: open hearth furnace (OHF) and basic oxygen furnace (BOF). While OHF is an older technology and uses more energy, this process can also use more scrap than the BOF process. However, BOF process is rapidly replacing OHF worldwide because of its greater productivity and lower capital costs. In addition, this process needs no net input of energy and can even be a net energy exporter in the form of BOF-gas and steam. The process operates through the injection of oxygen, oxidizing the carbon in the hot metal. Several configurations exist depending on the way the oxygen is injected. The steel quality can be improved further by ladle refining processes used in the steel mill.

### **Secondary Steel Producers**

Secondary steel is produced in an electric arc furnace (EAF) using scrap. In secondary steel production, the scrap is melted and refined, using a strong electric current. Steel making based on external scrap (scrap from outside the steel sector) requires less than half as much primary energy as steel made from ore. In a continuous steel casting process, liquid steel is directly cast into semi-finished products. The semi-finished steel is fed in to re-rolling mills to get finished steel products. Finished

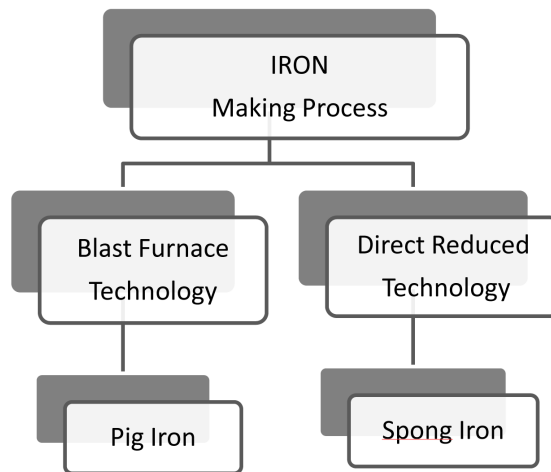


Figure D-5: Iron Making Technologies

steel products are classified in to two types of finished carbon steel or finished alloy steel. Long products are bars, rods, channels, angles and other structural materials are finished carbon steel. Finished steel products are used in the construction and engineering industry and, to some extent, in the manufacturing sector. Flat products also another type of carbon steel consist of sheets, coils and plates. Alloy steels can be further classified into two categories of stainless steel and alloy steels.



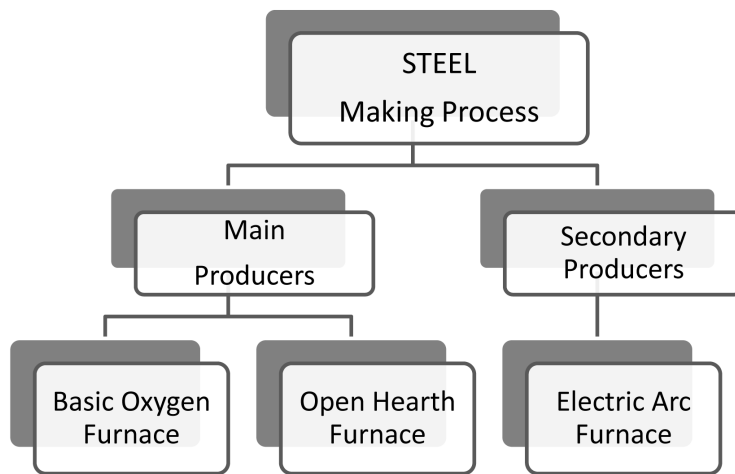


Figure D-6: Steel Making Technologies

## APPENDIX E

### OECD Indicators of Employment Protection

#### Methodology

The OECD employment protection indicators are compiled from 21 items covering different aspects of employment protection regulations as they were in force on January 1st of each year:

- Individual dismissal of workers with regular contracts, incorporating three aspects of dismissal protection: (i) procedural inconveniences that employers face when starting the dismissal process, such as notification and consultation requirements; (ii) notice periods and severance pay, which typically vary by tenure of the employee; and (iii) difficulty of dismissal, as determined by the circumstances in which it is possible to dismiss workers, as well as the repercussions for the employer if a dismissal is found to be unfair (such as compensation and reinstatement).
- Additional costs for collective dismissals. Most countries impose additional delays, costs or notification procedures when an employer dismisses a large number of workers at one time. The indicator measuring these costs includes only additional costs which go beyond those applicable for individual dismissal. It does not reflect the overall strictness of regulation of collective dismissals, which is the sum of costs for individual dismissals and any additional cost of collective dismissals.

- Regulation of temporary contracts, including regulation of fixed-term and temporary work agency contracts with respect to the types of work for which these contracts are allowed and their duration, as well as regulation governing the establishment and operation of temporary work agencies and requirements for agency workers to receive the same pay and/or conditions as equivalent workers in the user firm, which can increase the cost of using temporary agency workers relative to hiring workers on permanent contracts.

## APPENDIX F

### State Labor Reform Questionnaire Summary Responses

Question	Andhra Pradesh	Assam	Bihar	Chhattisgarh	Delhi	Goa	Gujarat	Haryana	Himachal Pradesh	Jharkhand	Karnataka	Kerala	Madhya Pradesh	Maharashtra	Orissa	Punjab	Rajasthan	Tamil Nadu	Uttar Pradesh	Uttarakhand	West Bengal	Overall	
<b>Transaction cost-reducing actions</b>																							
<b>A. IDA</b>																							
more than 21 days notice req'd under 9A	1.1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19	
exemption given for some items	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
additions to public utility list	2	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16	
amendments made to chapter VB (+/-1)	3	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21	
complete cessation is excluded	4	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	5	
there is a time limit for raising disputes	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	3	
threshold for disputes not 100 (+/-1)	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	22	
<b>B. Factories Act</b>																							
amendments to increase work hours	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	
export units have exemptions	8	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	1	0	6	
three shift working is allowed	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21	
women are allowed in shift working	10	1	0	0	0	0	1	0	1	0	0	1	0	0	1	1	0	1	1	1	1	9	
deemed approval is allowed	11	1	1	1	1	1	0	1	1	0	1	1	0	1	1	0	0	1	1	1	0	15	
license renewal longer than one year	12	1	0	0	0	0	1	1	0	0	0	1	0	0	1	1	1	1	0	1	0	7	
<b>C. Shops Act</b>																							
provisions for shift working (under act)	13	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	7	
more than 8 cont' hours per day allowed	14	0	1	1	1	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	9	
more than 48 hours allowed per week	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
more than 5 hours of overtime allowed	16	0	0	1	1	0	0	1	0	0	1	1	0	1	1	0	0	0	0	0	0	8	
nightshift work is allowed for women	17	1	0	0	0	0	0	1	1	0	1	0	0	0	0	1	1	0	1	0	0	7	
ambiguous answers to question	18																						
number of inspectors greater than one	19	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	15	
captured in question 21	20																						
no provisions similar to 5A of IDA	21	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	18	
<b>D. Contract Labour Act</b>																							
moves made to facilitate contract labour	22	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
licensing at local level	23	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	
deemed approval is allowed	24	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	3	
not req'd to amend reg if empl contractor changes	25	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	3	
contract labour allowed in non-core activities	26	1	1	1	1	1	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	17	
freely allowed in EP Zs and SEZs	27	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	0	14	
provision for fixed term contracts	28	0	1	0	0	1	0	1	0	1	1	0	1	1	0	1	1	0	1	0	0	11	
core and non-core clearly defined	29	1	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	5	
contract employment allowed in IT/BPO	30	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	19	
<b>E. Inspectors</b>																							
single annual inspection	31	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2	
authorization is required for surprise inspections	32	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	6	
authorization is required for specific complaints	33	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	6	
other moves to lessen inspection regime	34	1	0	0	0	0	1	1	0	1	0	0	1	0	1	1	1	0	1	0	1	10	
<b>F. Registers</b>																							
common attendance register for different acts	35	1	1	0	0	0	1	1	1	1	0	1	0	0	0	0	0	1	0	0	0	9	
common accident register for different acts	36	1	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	0	0	1	8	
single inspection book	37	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	0	4	
computerized records are accepted	38	0	1	1	0	0	1	1	1	0	0	1	1	0	1	1	1	1	0	0	1	13	
<b>G. Filing of Returns</b>																							
ambiguous answers to question	39																						
filing on a consolidated form is allowed	40	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	1	1	1	0	8	
single format of various returns allowed	41	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	6	
self-certification provision exists	42	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	4	
measures to simplify returns taken	43	1	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	1	1	1	0	8	
single window procedure exists	44	1	0	1	0	1	0	0	1	1	0	1	0	1	0	1	1	1	1	1	1	12	
<b>H. Union Representation</b>																							
minimum number of workers greater than 7	45	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	6
provision to restrict unions in enterprise	46	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	
provision to recognize union as bargaining agent	47.1	1	0	0	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	8	
ambiguous answers to question	47.2																						
minimum number of workers to support strike	48	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	
additional restrictions beyond IDA to declare strike	49	1	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	6	
code of conduct between unions and employer	50	1	1	0	1	1	0	1	1	0	1	0	1	1	0	1	1	1	1	1	1	16	

Figure F-1: Source: Dougherty, 2009