THE ROLE OF TRANSPORT COSTS AND POLLUTION TAXES IN DETERMINING THE LOCATION OF PRODUCTION: A THEORETICAL APPROACH

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DECLARATION

I declare that the dissertation entitled "**The Role of Transport Costs and Pollution Taxes in determining the Location of Production: A Theoretical Approach**" submitted by me for the award of the degree of Master of Philosophy of Jawaharlal Nehru University is my own work. The dissertation has not been submitted for any other degree of this University or any other university.

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CERTIFICATE

We recommend that this dissertation be placed before the examiners for evaluation.

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Gaurav Bhattacharya

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Acronyms

EMS	Environmental Management Systems
ESI	Environmental Sustainability Index
FDI	Foreign Direct Investment
GSDP	Gross State Domestic Product
INR	Indian National Rupees
ISO	International Organisation for Standardisation
MC	Marginal Cost
MI	Material Index
NCT	National Capital Territory
NIMBY	Not in my backyard
PIL	Public Interest Litigation
R&D	Research and Development
UK	United Kingdom
UP	Uttar Pradesh
US	United States

Chapter 1

Introduction

1.1 Background

In this study, we make an attempt to examine how transportation costs and pollution taxes both jointly determine the location of production in a spatial framework. Our approach will be at variance with the standard location theory which deals with only the role of transportation costs in determining the location of economic activities. In contrast, we examine how pollution taxes along with the transportation costs jointly determine the spatial allocation of economic activities. The two distinct types of location problems that the standard location theory deals with are (1) location of vertical stages of production and (2) location of an industry or firm in a multi-market framework. Let us discuss each of the two cases in more detail.

Taking the first case of the location of vertically integrated stages of production in a spatial framework, let us consider a simplified location problem where the raw material used in the production of a finished good is located at a particular point in space which is separated by distance from the market for the finished good. Then the standard problem of location becomes whether production should be located at the site of raw materials or it should be located at the point of market. If production takes place at the point of raw materials, then the firm has to transport the finished goods to the market which is located elsewhere. The transport costs associated with the finished good are called the 'distribution costs'. If, on the other hand, the firm decides to locate the production in the place of market, then the firm needs to procure raw materials from the site of the raw materials. The transportation cost associated with the procurement of raw materials is called 'procurement cost'. If we assume that processing costs are same at both the places of location, then the relative transportability of the good determines where the location should take place. Alfred Weber (1909) had suggested that in such a situation the minimisation of transport cost determines the location of economic activity. For instance, if the raw materials lose weight in the process of production then production should normally take place at the site of the raw materials. Examples of such activities are sugar processing industry, iron manufacturing, etc. In contrast, when the commodity gains weight in the process of production like canning of aerated drinks, production of such goods normally takes place at the site of the market. This simplified case may be generalised by introducing more than one raw material or more than one market for the final good.

In contrast, the second case relates to a situation whether the production of a final consumer good should take place in a single market or in more than one market. If we could imagine a simplified case of consumers being located in a straight line then the location problem becomes whether to serve the consumers from a single point of location or from multiple points of location. In other words, whether there should be a single market or multiple points of markets. High transport costs may induce firms to set up production plants in more than one market from where they serve the consumers. This type of location problem may be termed as 'horizontal location problem' since it concerns with a finished consumer good. It is important to note that we do not make any distinction between raw materials and finished goods in this kind of location problem. Harold Hotelling (1929), for example, argued that in such a situation the optimum market size is determined by the twin effects of the economies of scale and the transportation costs.

With the advent of Industrial Revolution and unprecedented growth in industrial production there was a growing concern about the harmful impacts of industrial pollution on the environment. Industrial production generates negative externalities in form of emissions, solid wastes, effluent discharge, etc. The extent of environmental damage is huge if we consider sectors like iron and steel, hazardous chemicals, paper and pulp, petrochemicals and so on. Till the late nineteenth century, this issue had attracted inadequate attention. Absence of proper regulatory bodies and stricter liability laws had aggravated the pollution problem. The Bhopal Disaster (1984) is a prominent example. In the meanwhile, during 1970s, increased concerns in the developed world had led to the formation of Environmental Protection Agency and the Department of Environment in the US and the UK respectively. Such agencies, functioning as regulatory bodies, imposed several regulations on manufacturing industries (e.g. the US Clean Air Act, 1963). Hence, manufacturing units were compelled to limit the negative externalities resulting from production activities since these regulations had an impact on the costs of production (in form of taxes, standards, adoption of cleaner technology, purchase of permits, etc.). Apparently, environmental policy became a potential factor influencing industrial location.[1]

The analysis of the significance of environmental regulations as a factor inducing location of production is predominantly based on horizontal production structure. Empirical studies on this aspect provide mixed results.[2] Stafford (1985) found no evidence that relocation decisions by polluting industries are driven by environmental regulations. On the contrary, some studies establish the fact that stricter environmental regulations lead to delocation of polluting industries (McConnell, 1990; Helburn, 1997; Stafford, 2000). There has been a sufficient amount of work within the ambit of industrial flight (Pollution Haven Hypothesis) from developed to developing countries owing to differences in environmental regulations (Xing and Kolstad, 2002; Levinson and Taylor, 2008).

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[1] Chapman, Keith & Walker, David F (1991). *Industrial location : principles and policies* (2nd ed). Blackwell, Oxford, Ox., UK ; Cambridge, Mass., USA

[2] Leonard, H. J. (1988). *Pollution and the struggle for the world product: Multinational corporations, environment, and international comparative advantage.* Cambridge University Press.

1.2 Motivation and Rationale for study

The standard location theory establishes the fact that transport costs play a predominant role in plant location decision (Launhardt, 1882; Weber, 1929; Venables, 1996). Several studies have also identified plant location factors like nearness to raw materials, access to markets, availability of skilled and/or cheap labour, availability of power, degree of industrial unrest, tax and duty exemptions, entrepreneur's personal preferences, etc. (Ross, 1896; Helburn, 1943; Papola, 1981). Furthermore, growing concerns about environmental damage on account of industrial activities have necessitated the need for environmental regulations on pollution intensive industries. Such regulatory policies influence location decisions of polluting firms since they raise their cost of production. However, most studies do not incorporate the impact of both transport costs (a predominant factor) and pollution taxes (measuring environmental regulation) in determining industrial location.

Therefore, in our study, we try to extend the standard location theory by taking into account pollution taxes along with transportation costs. Thus, in the case of the vertically integrated stages of production, we make an attempt to determine the impact of both pollution taxes and transport costs on the location of production. On the other hand, in the case of horizontal location problem, we try to show how governments may play a role by imposing differential pollution tax rates to affect the location of firms. Finally, we try finding some examples of industries in India for each of the two cases of location as discussed above. It must be further noted that our focus will be on a manufacturing firm throughout the study.

The motivation for such study is two-fold. One, it aims to analyse the interplay of transport costs and pollution taxes in determining the optimal location of production plants. Two, the study identifies how location of plants, driven by public policies, can have an impact on the environment.

1.3 Chapter Scheme

We have organised the study in the following chapters:

Chapter two comprises of a detailed review of the existing literature on location theory from the viewpoint of transport costs and environmental regulations. Both theoretical and empirical studies have been included in order to develop a deeper insight into the problem. The existing literature has also been classified into vertical as well as horizontal production structure in order to address the two distinct cases separately. Finally, it identifies the lacuna and makes an attempt to add value to the existing literature.

In *Chapter three*, we present a theoretical model of transport cost and pollution tax which determine the location of a firm with a vertical production structure where processing of raw materials results in weight loss/gain. The model, presented here, assumes that the firm produces a dirty good and its production causes pollution which is subject to a pollution tax. Conclusions about the ideal location are drawn based on pollution taxes and transport costs.

Chapter four presents a model of transport cost and pollution tax which determines the location of a firm with a horizontal production structure. A firm, producing a dirty good, has to decide whether it should set up plants in both regions or serve both regions from a single plant depending on transportation cost and pollution tax. Regional governments set pollution taxes which influence location decisions of the firm.

Several case studies related to industrial location in various regions in India have been included in *Chapter five.* These case studies demonstrate the current scenario of location of industries in different regions in India and make an effort to find evidences of regional location of industries driven by differences in transport costs and environmental regulations, if any.

Key findings of the analysis have been included in *Chapter six* which concludes our study.

Chapter 2

Critical Review of the Literature

2.1 Introduction

Our study is primarily concerned with the analysis of how transportation costs and pollution taxes jointly determine the location of production. In order to understand the problem of location of industries better, we provide below a review of the existing literature from the view point of the present study. Several studies have identified a number of factors which influence the location of industries, namely, transportation costs, availability of raw materials, cheap labour, environmental regulations, etc.

For the sake of convenience, the chapter has been divided into two major sections- one, a detailed study of the theoretical background of the issue; two, a review of the empirical literature. The theoretical background has been further classified based on the type of production structure, viz. vertical and horizontal. It must be noted that most studies do not incorporate environmental regulations as a factor while analysing the significance of the aforementioned factors. Hence, a separate section has been included which discusses studies related to environmental regulations as a factor of location of production. This is followed by a section that reviews the empirical literature. The last section of this chapter identifies the gap in the literature.

2.2 Review of Theoretical Literature

A review of the standard theory of location of a firm seems pertinent as it will enable us to understand the basic framework of the location problem. The literature on two types of location problem, namely, vertical and horizontal, has been analysed separately. It is apparent that studies on the location of firms with vertical production structure have emphasised on transport cost as a primary factor influencing location decisions. On the contrary, the literature on horizontal production structure suggests both transport costs and environmental regulations as location factors. However, most studies do not incorporate both the factors while analysing firm location decisions.

2.2.1 Transportation cost: A location factor for vertically integrated production structure

When production stages are vertically integrated, a firm has to decide whether to locate at the place of raw materials or at the site of the market. Much of the received analyses of location of vertically integrated stages of production focus mainly on the transportation cost as a major determinant of location of production. For instance, Launhardt (1882) emphasised on transportation links as a primary determinant of whether production should take place at the place of raw materials or market. Factors like differences in land prices, the opportunity costs of energy, the difference in labour costs are secondary for such problem because such factors in his view come to play a role only after the optimal location has been determined based on transportation cost. However, Alfred Weber (1909) had provided a more general theory of location of industries based on minimisation of transport cost. He had categorised the nature of materials as (1) ubiquitous materials which are available everywhere at the same cost, e.g., water, electricity in developed countries, etc.; (2) localised materials which are found at specific locations. These localised materials may be pure, i.e., their entire weight enters into the final product, or gross, when processing results in weight loss.[1] His theory was based on the assumption that the location of raw materials and the market are fixed. In a perfectly competitive world, an industry would be material oriented or market oriented, depending on what Weber had called the value of the 'material index'. The material index as defined by Weber was given by the following factor:

$$Material\ index(MI) = \frac{Weight\ of\ localised\ material}{Weight\ of\ finished\ product} \tag{1}$$

Thus, industries with material index greater than one are attracted towards the site of raw materials. In this case, processing of raw materials results in weight loss. Hence, it is more profitable to process them at the site of raw materials and then distribute the finished product to the market, which is of lower weight, e.g.,

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[1] Chapman, Keith & Walker, David F (1991). *Industrial location : principles and policies* (2nd ed). Blackwell, Oxford, Ox., UK ; Cambridge, Mass., USA

iron and steel industry, sugar producing industry. On the contrary, if the product gains weight with successive stages of processing, the material index being less than one, then it is more profitable to locate at the market, e.g., mineral water packaging industry, canning of soft drinks, etc. In case, the material index takes the value one, a manufacturer would be indifferent between the two sites. The entire analysis is based on the fact that transport cost is an increasing function of the number of units of materials or goods transported. In contrast to Weber's argument, M.J. Webber (1985) suggested that over time industries would be more attracted to markets and less dependent on raw material sites. This was essentially due to falling average material index on account of technological progress in the material processing activity of manufacturing firms.[2]

However, orientation of factories towards raw material sites or markets may also take place due to differences in procurement costs and distribution costs, given the fact that the relative weights of materials and products are roughly the same. A manufacturer, whose objective is to minimise costs, would compare the costs associated with procurement and distribution prior to setting up a plant at any point in space. These costs are directly associated with the weight of raw materials and finished goods. If procurement costs exceed distribution costs, industries will be material oriented. Market orientation would take place if distribution costs are higher than procurement costs. The nature of products in terms of value, physical characteristics,

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[2] Webber, M. J. (1985). *Industrial location. Regional Research Institute, West Virginia University Book Chapters.*

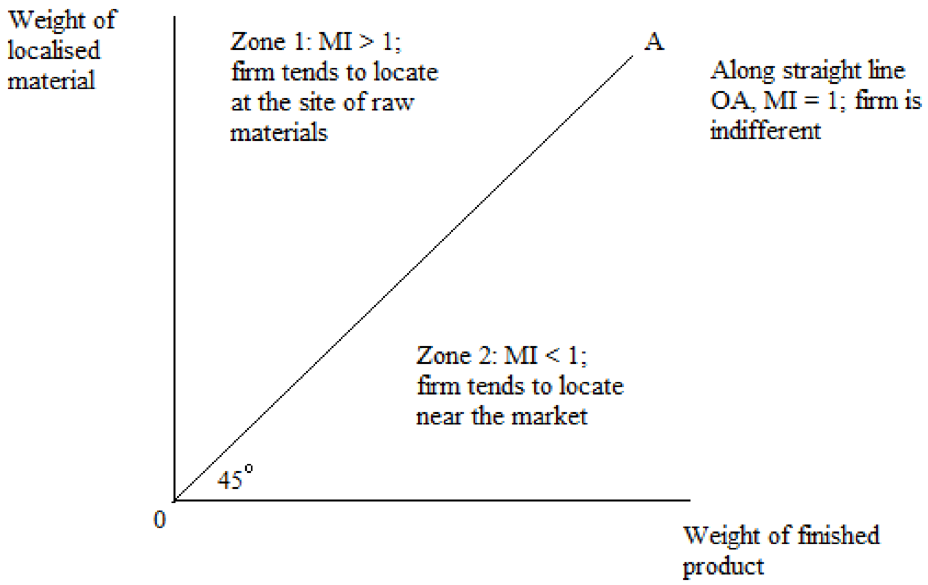

Figure 2-1: Material index and spatial orientation of a firm

perishability also determines the orientation. Industries where the finished products are fragile or perishable are generally market oriented. Certain finished products like glass, refined oil, marbles, etc., require special attention while shipment due to their high insurance rates. Thus, the tendency to locate near markets is higher for such industries (Chapman and Walker, 1991).

Transportation cost is also an important location factor in case of Weberian triangle space where we have two sites of raw materials and a single market (Weber, 1929). A firm locates production within the triangle depending on minimum transport costs. There may be cases where we have only one raw material site which supplies output to two markets.

In case of industries which are vertically linked, both demand and cost linkages determine location of production (Venables, 1996). The output of the upstream industry forms the input of the downstream industry and the upstream industry would locate near the downstream industry as it provides a market for its output. In contrast, the downstream industry locates near the upstream industry in order to save on transport costs. This would result in concentration of industries at a single location (centripetal force). However, immobility of the factors of production would work in the opposite direction causing dispersal of production activities to the sites where the factors of production are available (centrifugal force).

Apart from transportation costs, nearness to sources of raw or auxiliary materials which further depends on weight gaining or losing characteristics of materials after processing, nature of commodities in terms of perishability (e.g., salmon canneries clinging to the bank of the Columbia) are important factors determining location of production (Ross, 1896). Besides, some studies have found that the impact of transport costs on business location is small (Swanson et al., 2006).

Recent studies have emphasised on the role of economies of scale in transport technologies in location choice of a firm (Xu, 2013). It has been shown that a firm tends to build its plant within the interior of the Weberian triangle. The plant is located further away from the market with a rise in transport economies of scale.

So far, the existing literature on vertical production structure has primarily focused on transportation cost as the factor influencing location decisions of firms. Apparently, even the Weberian framework has not been extended in order to incorporate environmental factors. This attracts attention since pollution is also associated with production stages which are vertically integrated. For instance, the sugar processing industry, which is vertically integrated, causes pollution in form of solid as well as liquid wastes.[3] The units including mill house, process house, power house, boiler house, alcohol producing unit and distillery stages generate pollution in form of waste water, fly ash, filter cake, particulate matter from combustion of bagasse, lime sludge and press mud. Consequently, such manufacturing firms are subject to environmental regulations which may have an impact on their location.

2.2.2 Transportation cost: A location factor for horizontal production structure

Firms with horizontal production structure face the problem of locating in one or more markets depending on economies of scale and transport costs. The earlier work on this sort of issue was due to Hotelling (1929), who had considered a linear approach to firm location based on transportation costs. Reiterating Hotelling's proposition, a linear city model of location was developed by Lederer et al. (1986), who studied the location problem in the presence of two markets with non-uniform distribution of consumers. They found that firms practising price discrimination never locate coincidentally if they incur identical transport costs. Some studies suggest that imperfectly competitive firms engaged in international trade have to decide whether to operate

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[3] Sanjay, K. S. (2005). Environmental pollution and sugar industry in India its management in: An appraisal. *Sugar Tech,* 7(1), 77-81.

from a single plant in the home market or set up multiple plants in the foreign market (Haaland et al., 1998, Haufler et al., 1999, Ferrett et al., 2010). In such cases, firms compare trade costs vis-à-vis plant set up costs. As transport costs rise relative to plant set up costs, firms have a tendency to build multiple plants in foreign markets. These studies also state that antidumping policies, corporate profit taxes, etc., undertaken by respective governments influence location decisions of firms.

A recent study by Usategui et al. (2000) suggests that relative differences in transport costs have been a driving force in determining location of firm/firms. It is ideal for a firm to set up its plant at a region where transport costs are higher. This would enable the firm to save on the high transport cost if it had to supply its output from some other region where it sets up the plant. Furthermore, improvements in transport infrastructure through public policy intervention may also alter location decisions of firms (Andaluz et al., 2002; Riou, 2003). If countries share common boundaries and engage in trade, transportation costs incurred by firms in each country are influenced by trade policies and this has an impact on location of firms. The adjacent countries, characterised by different levels of development, lie on non-homogeneous space and have unequal transport costs. With barriers to trade, a firm producing a product that is imported by the more developed country, would locate on the common frontier while the other firm locates at the far extreme, away from its rival. On the contrary, economic integration, which results in homogeneous transport costs across countries, drives each firm to locate at the non-neighbouring extreme points of the respective nations. Andaluz et al. explained this phenomenon using models of imperfect competition. Similar analysis was undertaken by Riou, who suggested that public policies in form of investments in transport infrastructure can relocate firms to poorer regions and reduce regional inequalities. He had studied the interaction of both centripetal and centrifugal forces that determine location of firms in the presence of imperfect knowledge spillovers and public investment in improvement in inter-regional transport infrastructure. Sometimes, government regulations which are aimed to linearise transportation costs of multi-market firms have an impact on their expected profits and hence location decisions (Dalal et al., 2003). Matsumura et al. (2005) have emphasised on the potential importance of transportation cost and the associated functional form (linear/non-linear) it takes in determining profits of firms.

Apparently, recent studies have challenged the role of transportation costs in location decisions (Jovanovi, 2003). Technological advancements have reduced transport costs as well as their importance as a factor influencing location decisions. According to Jovanovi, firms producing similar and related commodities are more influenced to form clusters. Such clusters attract similar industries so that they can reap economies of scale and linkage effects.

2.2.3 Environmental regulations: A location factor for horizontal production structure

So far we have ignored the importance of environmental regulations on the location of economic activities. Since production leads to emission of pollution which is a public bad, the State therefore needs to intervene to regulate pollution levels. Such regulation of environmental pollution may take place through imposition of taxes, standards, purchase or sale of tradable permits, etc. The government's objective lies in reducing pollution levels either by motivating firms to abate pollution levels or by compelling them to shift location of production activity to other sites where such regulations are less stringent.

There have been few studies which focus on environmental regulations as a factor of firm location. Helburn (1943) addressed the issue of waste disposal faced by a manufacturer who locates in a region with legal restrictions imposed by the government. Spatial differences in environmental policies are counted as location factors only to industries which are pollution intensive (Chapman, 1980). The literature on 'Pollution Haven' provides an insight into relocation of dirty industries from countries with stringent environmental laws to countries with higher laxity in environmental regulations (Levinson and Taylor, 2008). Chapman (1980) states that historical experience of Third World countries have been such that the number of heavy industries was inherently low. This provides an incentive to dirty industries to set up plants in such regions since the assimilative capacity of the physical environment is relatively higher.

Markusen et al. (1995) presented a model where the government tries to regulate a polluting firm's decision to set up plants in both regions, serve both regions from a single plant or shut down completely, with the primary objective of the government being maximisation of consumers' surplus. A similar study (Morey et al., 1993) incorporating two polluting firms in a two region model preceded the Morey et al. 1995 study, which impressed on environmental policies as crucial factors governing location decisions of firms. Both these studies incorporate plant set up costs as a function of location decisions. Interestingly, stricter environmental regulations in a region may not induce firms to relocate to other regions if plant set up costs are very high (Bhattacharya and Pal, 2010).

Markussen et al. contributed to the literature by incorporating both pollution tax and transport cost in their study. However, the assumption of identical marginal disutility from pollution to consumers in each region was unrealistic and Pfluger (2001) addressed this issue. Other aspects like the determination of optimal pollution taxes ignoring the strategic nature of tax competition between regions and welfare analysis based on consumers' surplus only, were criticised. Pfluger studied the possibilities of 'ecological dumping' and 'not in my backyard' (NIMBY) policies depending on the relative share of emissions in production. If the importance of emissions in production is small relative to transport costs and the mark up, regional governments compete by undercutting emission taxes to attract firms to their region (ecological dumping). NIMBY possibility arises when emissions have a significant share in production. However, it has been observed that environmental tax competition results in lower environmental quality (Kim et al., 1997; Upmann, 1998; Riuz and Garzon, 2003; Kunce and Shogren, 2005) as governments tend to undercut pollution taxes to attract polluting firms (a Race to the Bottom Hypothesis). In contrast to these studies, Marsiliani et al. (2004) and Withagen (2013) have shown that such possibilities are rare when capital is endogenous and inter-regional spillovers are small. Undercutting capital taxes results in lower capital tax which encourages savings and consequently raises the capital stock. The wealth effect of a higher stock of capital induces governments to value the environment more, which is a normal good. Hence, environmental regulations are stricter than under cooperation. In fact, regional governments have no incentives to misuse environmental policies to attract firms if they have other policy instruments at hand like corporate taxes. A race to the bottom tendency does not exist even in case of direct regulation of output which is a dirty good (Dijkstra, 2003). Regional governments have no incentives to pull firms to their regions since they do not earn any tax revenue. The region where the firm locates has to bear the environmental damage instead. As a result, regional policies would cause 'NIMBY' taxes or a 'chicken game [4]' between players. It was Rauscher (1995), who had emphasised on the level of environmental damage as a determinant of regional

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[4] This term has been used by Rauscher. It is a situation in which a region benefits from investment but prefers the plant to be established elsewhere. This is due to the fact that the environmental damage caused by production is high. The term 'chicken' refers to the player who finally hosts the plant but levies a considerably high rate of emission tax which maximises the regional welfare.

policy, viz. a race to the bottom, chicken game and NIMBY taxes.

Further developments in the realm of environmental regulations and location took place with the incorporation of market imperfections like imperfect competition and asymmetric information. Carrera and Rivas (2003) showed that the degree of product differentiation across firms plays a significant role in determining firm location. Strategic pollution tax policies of regional governments are governed by the degree of product differentiation which is higher if goods are substitutes and lower for complements. Sometimes, regulators do not have complete information about the type of technology used by firms. As a result, taxation policies differ as compared to the case of symmetric information (Antelo et al., 2009). Due to informational effect, regulators have a tendency to impose higher taxes since they are unable to distinguish between clean and dirty firms. Celic and Orbay (2011) construct a game theoretic model and show that a developing economy would benefit from FDI if and only if the marginal damage from pollution is sufficiently low.

2.3 Empirical Overview

The empirical literature focuses on both transportation costs and environmental regulations as factors determining location choice. These studies address location choice of specific industries. For instance, in the case of the iron and steel industry in North America and Europe, Hartshorne (1928) observed that availability of water resource, which is extremely important in such industries, was an important location factor.

Factors like land, labour, capital and taxes play minor roles in location. The significance of raw materials or factor endowments has also been suggested by Crafts et al. (2006). Their study on Britain's manufacturing industries at the two-digit level shows that falling transport costs had a relatively weaker effect on industrial location than proximity to natural resources.

The Weberian theory of location being a general theory, Hoover (1933) made efforts to relate the distribution of shoe industry in the United States to Weber's theory. Hoover identified a residue of 'chance' factors which are not completely explained by Weber's theory. Apart from the weight of materials processed, labour costs and skills, history plays a significant role in location of the shoe industries in the US. It was apparent that new industries had a tendency to cluster around regions where industries are already established. Hoover's analysis points out certain industry specific factors which are not explained by the general theory. Factors like speed of delivery, contact with leather markets, shoe buyers and style sources are more significant than freight rates.

The literature on public policies, namely environmental regulations as a factor influencing location decisions for manufacturing industries provides mixed results. Stafford (1985) found that despite the implementation of National Environmental Policy Act, traditional factors like market, labour and materials were predominant in determining location of 162 new manufacturing branch plants of large US corporations. A recent study on French firms by Raspiller et al. (2008) revealed similar results. Environmental regulations were neither statistically significant nor economically significant. The reason being the share of environmental compliance costs was low relative to differences in factor costs. Different results were obtained by Henderson (1997), who empirically studied the impact of National Air Quality Standards imposed on five 3-digit manufacturing industries (industrial organic chemicals, miscellaneous plastics, plastic materials and synthetics, blast furnace and primary steel and petroleum refining) which are major emitters of Volatile Organic Compounds across counties in the US. Results suggested that new plants were more likely to locate in attainment counties than in non-attainment counties. This is primarily due to stringent standard enforcement norms in non-attainment counties compared to their attainment counterparts. Though such relocations help improve air quality in non-attainment counties, it worsens air quality in attainment areas.

Another empirical study of the motor vehicle industry for 50 new branch plants during 1973-82 across randomly selected counties in the US showed similar results (McConnell, 1990). Stafford (2000) found similar results for hazardous waste management industry for the period 1976-1993 in the US.

2.4 Concluding Remarks

The literature studied so far has dealt with a number of factors determining location decisions of firms. These include transportation costs, environmental regulations, nearness to raw materials and markets, access to energy and power, nature of product produced, etc. However, there have been very few studies which focus on the impact of both transport costs and pollution taxes on location decisions of firms. The lacuna lies in the fact that these studies do not incorporate transportation costs as a locating factor while studying environmental regulations.

The literature on location decisions in case of vertically integrated production structure has hardly incorporated the impact of pollution tax along with transport costs. Thus, we intend to predict the optimal location of a firm when it faces both transport costs and pollution taxes, in a Weberian framework.

The literature on horizontal production structure focuses on models of inter-governmental tax competition. Studies provide mixed results regarding evidences of 'race to the bottom' phenomenon and 'NIMBY' taxes. However, most studies have ignored the existence of transportation costs while analysing location decisions of firms. Hence, this has obviated the possibility of a case where the firm sets up plants in more than one region. Markussen et al.'s (1995) study should be considered as an improvement in this regard.

At this juncture, it would be interesting to incorporate both transport costs and environmental costs to determine the location of economic activities since these factors were individually addressed in previous studies. The scope of the study will be confined to theoretical analysis to extend the basic Weberian hypothesis of location in vertically integrated stages of production and also to study the horizontal location problem incorporating both the factors. We also provide some examples from the

Indian structure of location of industries to reaffirm our theoretical predictions.

Chapter 3

Vertical Location of Production

3.1 Background

Manufacturing activities are often characterised by several different yet integrated stages of production. For instance, a firm manufacturing iron rods has to procure iron from the site of raw materials, process the iron in its factory and distribute the finished good to the market. In such a situation, each activity is linked vertically to the other. The location problem associated with such production structures is termed as the problem of vertical location of production. Suppose, the raw material used in the production of a finished good is located at a particular point in space which is separated by distance from the market for the finished good. The manufacturer has to decide whether to produce at the site of raw materials or at the point of market. If production takes place at the site of raw materials, the firm has to bear distribution costs associated with transportation of finished goods to the market from the production site. On the other hand, the manufacturer has to bear procurement costs if manufacturing activity is undertaken at the place of market, since he has to procure raw materials from the site of raw materials to the market. If processing costs are same at both places of location, the manufacturer would undertake production at a location which is associated with minimum transportation cost. In other words, it is the relative transportation cost that determines optimum location.

Earlier studies on vertical location of production put much emphasis on transportation links as a primary factor influencing location decisions. Other factors like differences in land prices, the opportunity costs of energy, the difference in labour costs are secondary for such problem because such factors come to play a role only after the optimal location has been determined based on transportation cost (Launhardt, 1882). Furthermore, transportation costs are positively related to the weight of raw materials/finished good. If processing results in weight loss like in case of sugar processing, production takes place at the site of raw materials. On the contrary, canning of aerated drinks takes place in the market since processing causes weight gain. Hence, optimum location is based on minimisation of transportation costs (Weber, 1909; Weber, 1929). The ratio of weight of raw materials to the weight of finished good, termed as Weber's material index, gives a measure of orientation of industries. However, there are instances when relative weights of materials and finished product are the same. Under such circumstances, it is the difference in procurement cost and distribution cost that determines optimum location (Chapman and Walker, 1991). Unlike market oriented industries, material oriented industries face higher procurement costs relative to distribution costs. Although recent studies undermine the role of transportation costs on account of technological progress and development of transport networks (Webber, 1985; Swanson et al., 2006; Xu, 2013), their impact cannot be undermined in case of less developed countries where infrastructural bottlenecks are still prevalent.

Since our focus is on manufacturing industries, the problem of environmental pollution owing to production assumes special significance. Growing concern over the negative externalities emanating from production in the form of emissions, hazardous wastes, particulate matter, etc. has induced regulatory bodies like the State to impose environmental regulations on manufacturing industries (e.g. the US Clean Air Act, 1963). These regulations have a direct or indirect impact on costs of production of industrial units (in form of taxes, standards, adoption of cleaner technology, purchase of permits, etc.). Hence, relative differences in environmental regulations across regions would have an impact on location decisions of firms. So far, most studies on vertical location of production attribute transportation cost as the predominant factor determining location of a firm.

The present model is an extension of the Weberian location problem in a sense that it incorporates pollution tax as a measure of environmental regulation in the standard theory which considers only transportation cost as a determinant of location choice of a firm.

3.2 The Model

We assume that the production structure is vertically integrated with two possible location choices where processing can take place, viz. the site of raw materials, R and the market, M. Multiple points of processing along the chain of integrated stages have not been considered in the present analysis. We have assumed the simple case of only one input that goes to produce a single output. Procurement costs have to be incurred if production takes place at M and distribution costs have to be borne if production takes place at R. Though processing costs are invariant of location choice, procurement cost, t_p and distribution cost , t_d vary with respect to the nature of processing. In order to understand the difference between weight losing and weight gaining production processes, we express weight of the final output as

$$Weight\ of\ final\ output = g.Weight\ of\ raw\ materials \tag{1}$$

where g denotes the parameter determining weight of the final output.

In case of processing that results in weight loss, $g \epsilon (0,1)$ and $g > 1$ for processing that causes weight gain. Hence, the weight of final output is lower than the weight of raw materials when $g \epsilon (0,1)$ and the reverse is true when $g > 1$. If the firm has to compare transportation costs at R and M, it has to consider the weight of the raw materials/final output. It is evident that procurement costs are associated with transportation of the raw materials and distribution costs are transportation costs associated with the distribution of the finished good. Given that transportation costs are positively related to the weight of raw materials/final output, distribution costs will be lower in case of weight losing production process than that of weight gaining production process. In other words, procurement costs will be higher in case of weight losing production process.

As a result, if processing results in weight loss, we have, $t_p > t_d$, and in case of processing that results in weight gain, we have, $t_p < t_d$.

Production causes emissions which pollute the local environment and regulators in each region impose a pollution tax on the level of emissions. The site of raw materials is assumed to possess a greater assimilative capacity than the market. Furthermore, a market is generally centrally located with a greater proximity to the consumers, unlike a raw material site which is at the periphery. As a result, the environmental damage will be higher at the market than at the raw material site. Hence, pollution taxes are higher at the market, although the emission level is invariant of the location of production. Therefore,

$$e_R < e_M \tag{2}$$

where e_R and e_M denote the pollution tax rates in region R and M respectively.

The emission function is given as

$$E(x) = x^2 \tag{3}$$

and $E'(x) \geq 0$; $E''(x) \geq 0$ and $E(0) = 0$.

(3) shows that emissions rise at a non-decreasing rate with the level of output.

The cost functions associated with production in regions R and M, respectively, are given as

$$\begin{aligned} C_R\,(x) &= e_R\,E(x) + t_d\,x \\ &= e_R x^2 + t_d\,x \end{aligned} \tag{4a}$$

$$\begin{aligned} C_M\,(x) &= e_M\,E(x) + t_p\,x \\ &= e_M\,x^2 + t_p\,x \end{aligned} \tag{4b}$$

The marginal costs in regions R and M, respectively, are given as

$$\begin{aligned} MC_R\,(x) &= \tfrac{\partial C_R\,(x)}{\partial x} \\ &= 2e_R\,x + t_d \end{aligned} \tag{5a}$$

$$\begin{aligned} MC_M\,(x) &= \tfrac{\partial C_M\,(x)}{\partial x} \\ &= 2e_M\,x + t_p \end{aligned} \tag{5b}$$

A firm compares marginal costs associated with production in each region. Optimal location is the one which has a lower marginal cost. From (5a) and (5b), we can say that the marginal cost functions are linear in output level, given pollution tax rates and transportation costs. Their slopes depend on the corresponding pollution tax rates and their intercepts being the corresponding transportation costs.

Proposition 1 *It is optimal for the firm to locate at R if processing results in weight loss.*

When processing causes weight loss, weight of the final output would be lower than weight of raw materials used. As a result, procurement cost would be higher than distribution cost, i.e.,

$$t_p > t_d \tag{6}$$

Using (2) and (6) and comparing (5a) and (5b), we get

$$MC_R\left(x\right) < MC_M\left(x\right) \tag{7}$$

Hence, it is optimal to locate at R. The above result reinstates the Weberian theory.

Proposition 2 *In case that procurement costs equal distribution costs, R serves as the ideal location of production.*

In this case, procurement cost equals distribution cost, i.e.,

$$t_p = t_d \tag{8}$$

Using (2) and (8) and comparing (5a) and (5b), the inequality (7) is restored. Contrary to the Weberian theory, which predicts that the firm will be indifferent as far as locating production is concerned, we find that R is the ideal location for production. This is due to the fact that the two regions are still differentiated in terms of pollution taxes.

Proposition 3 *The optimal location of production depends on the level of output when processing results in weight gain.*

We know that weight of the final output would be higher than weight of raw materials used, in case of processing that results in weight gain. Consequently, procurement cost would be lower than distribution cost. Therefore,

$$t_p < t_d \tag{9}$$

Using (2) and (9) and subtracting (5a) from (5b), we get

$$MC_M(x) - MC_R(x) = 2(e_M - e_R)x - (t_d - t_p) \tag{10}$$

The ideal location of production depends on the two terms in parentheses on the right hand side of (10). The left hand side of (10) will be positive/negative/zero depending upon the relative strengths of the two terms in parentheses on the right hand side.

Setting the right hand side of (10) equal to zero, we get

$$2(e_M - e_R)x - (t_d - t_p) = 0$$

$$\Longrightarrow x^* = \frac{(t_d - t_p)}{2(e_M - e_R)} \tag{11}$$

where x^* is the critical value of the output level at which marginal costs in both the regions are equal. The point of indifference is given by the output level $x = x^*$, where both the regions serve as optimal locations for production. It is clear from (10) that for any level of output lower than x^*, region M serves as the ideal location of production. For output levels greater than x^*, marginal cost at R is much lower than at M, making R the ideal location. Mathematically,

$$Optimal\ location\ decision = \left\{ \begin{array}{c} at\ M;\ if\ x < x^* \\ \\ Indifferent;\ if\ x = x^* \\ \\ at\ R;\ if\ x > x^* \end{array} \right\} \tag{12}$$

Our results are at variance with the Weberian prediction that optimal location will be at M, in case of processing that results in weight gain. It is evident that the location decision is contingent upon the level of output. For higher levels of output, it is optimal to locate at R and not at M, which is completely opposite to what Weber had predicted. This is mainly because of the difference in pollution tax that outweighs difference in transportation costs. Marginal cost at M rises faster than that at R and this is attributed to the fact that the slope of the marginal cost function, which is ideally twice the pollution tax rate, is higher for region M than region R.

To sum up, our analysis is an extension of the Weberian location framework which incorporates pollution taxes as an additional factor along with transportation costs. Our findings suggest that the Weberian result may not always hold true. In case of identical procurement and distribution costs, the site of raw materials unambiguously serves as the ideal location which is in contrast to the Weberian result which suggests that both the point of raw materials and the market serve as ideal locations. Furthermore, market may not always be the ideal location for a firm to locate its plant if processing results in weight gain. For higher levels of output, the marginal cost incurred at the market is higher due to a higher level of pollution tax in the region. As a result, the site of raw materials becomes the optimal location. It is only when processing results in weight loss, the Weberian result holds true. This is because both differences in pollution taxes and transportation costs move in the same direction, re-establishing the Weberian result.

Table 3-1: Optimal location choices determined by transportation costs and pollution taxes

Nature of processing	$MC_M - MC_R$; given that $e_M > e_R$	Optimal location
Weight loss, $t_p > t_d$	Positive	R
$t_p = t_d$	Positive	R
Weight gain; $t_p < t_d$	Negative for $x < x*$	M
	Zero for $x = x*$	Both M and R
	Positive for $x > x*$	R

Marginal cost functions (5a) and (5b) are linear in the level of output. The slope of these functions depends on the pollution tax rates and the intercept is the corresponding transportation cost. Since we have assumed that pollution tax rate at M is higher than at R, MC_M is always steeper than MC_R.It is only the intercept term, given by the transportation cost whose magnitude varies depending on the nature of processing. It is evident that t_p is the intercept term for MC_M and t_d is the intercept term for MC_R.Figure 3.2.1(a) shows the case where processing results in weight loss and hence $t_p > t_d$. This implies that MC_M will always lie above MC_R for all non-negative values of the output. Therefore, R serves as the ideal location for production. Even when $t_p = t_d$, we compare MC_M with MC_R^* (the dotted line) which is an upward parallel shift of the MC_R function. Although, the intercepts are equal, MC_M is still higher than MC_R for all positive values of output, since the slopes still differ. We have R as the ideal location. Figure 3.2.1(b) illustrates the case where processing results in weight gain and hence $t_p < t_d$. Given that $e_M > e_R$, the marginal cost curves intersect at $x = x^*$. For any non-negative value of output lower than x^*,

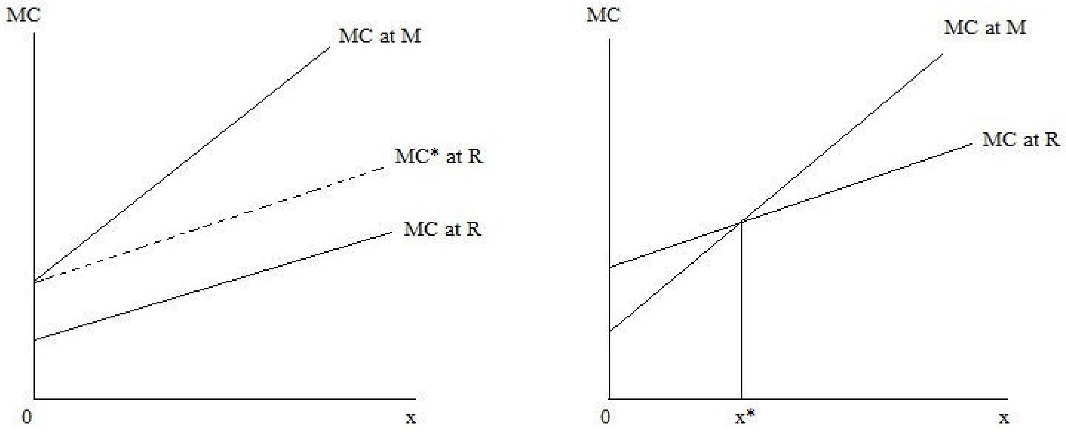

Figure 3-2-1(a): Weight losing production process

Figure 3-2-1(b): Weight gaining production process

Figure 3-2-1: Marginal cost curves of a firm in case of weight losing and weight gaining production process respectively

MC_R is higher than MC_M and M serves as the ideal location. In contrast, MC_M is higher than MC_R for all levels of output above x^*. This is because of the higher tax rate at M which causes MC_M to rise faster with the level of output than MC_R.

3.2.1 Role of infrastructural improvements in transport networks

There are instances when local regulators invest in infrastructural developments of transportation networks. Such possibilities arise when regulators wish to reduce regional inequalities and also to attract producers to their respective regions to undertake production. Under such circumstances, transportation costs may fall owing to development in networks. As a result, there would be downward shifts in the marginal cost curves. If pollution taxes are held constant, such shifts would be parallel. It is quite interesting to note that inequalities in transportation costs based on the nature

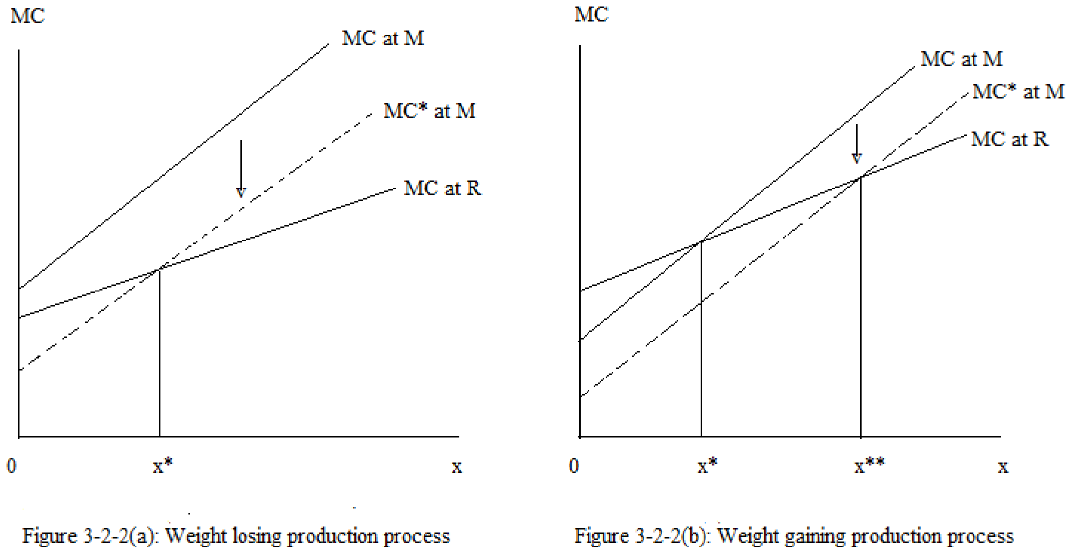

Figure 3-2-2(a): Weight losing production process

Figure 3-2-2(b): Weight gaining production process

Figure 3-2-2: Role of infrastructural improvements in transport networks

of processing might get reversed.

Figure 3-2-2(a) shows a situation where improvements in transport infrastructure in the market results in reduction of MC_M due to reduction in t_p, given that pollution taxes e_R and e_M and t_d are constant. MC_M shifts downwards parallely and intersects MC_R. Consequently, we get a case similar to the one discussed in figure 3-2-1(b) where $t_p < t_d$. A critical level of output x^* is obtained corresponding to the point of intersection of the two marginal cost curves. This shows that an improvement in transportation infrastructure at M results in reduction of procurement costs even below distribution costs. Figure 3-2-2(b) illustrates that a fall in MC_M, given the pollution taxes and t_d, causes a rise in the level of the critical value of the output from x^* to x^{**}. This is because a fall in t_p results in lower MC_M for a greater range of output now. However, as output level exceeds x^{**}, it is the higher pollution tax at

M that results in a higher tax payment and hence a higher marginal cost.

Chapter 4

Horizontal Location of Production

4.1 Background

A firm undertakes production activities to meet its demand. Consumers, who are geographically dispersed across regions, are buyers of the products manufactured by the firm. In the presence of market imperfections, such as in case of monopoly markets, the monopolist may have a single plant or multiple plants to undertake production. The question of multiple plants arises only if there exists more than one market. In a spatial framework, distance is costly. Hence, transportation costs play a crucial role in driving producers to set up multiple plants. In case of oligopoly markets, competition to capture a greater market share is imminent unless firms cooperate. The production structure, in these situations, is horizontal. The firm's problem is to serve the markets. It is important to note that, unlike vertical production structure, no distinction between raw materials and finished good is made.

The predominant factor determining location of firms in a horizontal production structure is transportation cost. If we consider monopolistically competitive firms, their location decision is driven by transportation costs and economies of scale (Hotelling, 1929). For firms practising price discrimination, the spatial distribution of consumers assumes special significance (Lederer et al., 1986). Several studies have put stress on transportation cost as an important factor influencing location decisions of firms (Haaland et al., 1998, Haufler et al., 1999, Usategui et al., 2000; Andaluz et al., 2002; Dalal et al., 2003; Riou, 2003; Matsumura et al., 2005; Ferrett et al., 2010). However, Jovanovi (2003) dismisses the importance of transportation costs in determining location of firms. Technological advancements and improvement in transport infrastructures reduce such costs. Ironically, such experiences are prevalent in developed countries only. The majority of developing countries lack basic infrastructure and the significance of transportation costs cannot be overlooked. Hence, the State and public policies play a major role in building transport networks and proper infrastructure in order to make distance costless.

Other forms of public policies like taxes, exemptions, concessions, etc. also influence location decisions of firms. Since we focus on firms engaged in manufacturing activities, environmental policies seem to be another factor driving location of firms. Manufacturing industries are generally pollution intensive and hence are subject to environmental regulations like emission taxes, standards, permits, etc. Highly developed nations are relatively more environmentally conscious compared to the developing world and impose stringent environmental regulations on polluting industries.

This causes industrial flight from these countries to the developing world where such norms are relatively less stringent. The existing literature addresses this issue as 'Pollution Haven' problem since the Third World countries gradually become a pollution haven as dirty industries prefer to locate there (Helburn, 1943; Chapman, 1980; Levinson and Taylor, 2008). Under certain circumstances, like low marginal damage, host countries my actually benefit from the production undertaken within its territories. Such benefits may be in form of tax revenues, competitive edge in the world market, cheaper products vis-a-vis imports, etc. This gives an impetus to other countries to attract firms to their regions and a situation arises where each country tries to undercut the other in taxes to attract a firm (Kim et al., 1997; Upmann, 1998; Rauscher, 1995; Riuz and Garzon, 2003; Kunce and Shogren, 2005). Celic and Orbay (2011) construct a game theoretic model and show that a developing economy would benefit from FDI if and only if the marginal damage from pollution is sufficiently low. Nevertheless, severe tax competition amongst countries may lead to degradation of environmental quality (Race to the Bottom Hypothesis). However, such misuse of environmental policies to attract firms is absent if governments have other policies like corporate taxes at hand (Dijkstra, 2003; Marsiliani et al., 2004; Withagen, 2013). Infact, high levels of environmental damage may actually result in 'not in my backyard' taxes when countries set higher taxes to discourage firm location (Markussen et al.,1993; Markussen et al., 1995; Rauscher,1995, Pfluger, 2001).

The motivation for constructing a model on horizontal production structure lies in the fact that most studies do not take into account the role of both transportation costs and pollution taxes in determining location of a firm. Our model uses a variant of models constructed by Markussen et al., (1995) and Celic and Orbay, (2011). Although, the seminal work by Markussen et al. (1995) has included both the factors in determining location of a firm, unlike the Markussen/Morey/Olewiler model, we incorporate profits in the regulator's welfare function, a situation of asymmetric information to the regulator, and profit tax on the relocating firm. However, for simplicity, we have assumed that there are no plant set up costs or other variable costs associated with production. As far as basic differences with the Celic/Orbay model are concerned, we have assumed only one firm instead of two and non-zero transportation costs.

4.2 The Model

There are two regions, namely A and B, which are assumed to be identical in all respects. We assume that region A owns the firm and it serves consumers. The firm has two choices: it can either serve both markets from a single plant set up in region A, or build up a separate plant in region B. The firm produces a dirty good that generates only local pollution, γ being the marginal damage, which is assumed to be constant. Apart from that, the firm has to bear a given transportation cost at the rate s per unit of output exported from region A to B. Regional governments impose a pollution tax e_{ij} per unit of output produced (i, j =A, B). We allow region

A to differentiate between production for local consumption and exports since it gives greater flexibility to each region in order to address pollution and market power distortions in a world where plant location is endogenous (Markussen et al., 1995). The regulator in region A has asymmetric information regarding the location choice of the firm. The firm may either serve both markets from the single plant at A with probability ψ or set up a separate plant in region B with probability $1-\psi$. Observing the levels of pollution tax, the firm chooses any one of the two configurations of plants denoted by (1,0) and (1,1). The former denotes that the firm serves both markets from a single plant in region A while the latter denotes separate plants set up in each region. For simplicity, both fixed and variable costs have been normalised to zero. The model has been solved through backward induction method.

The demand function for a representative consumer in region i, j =A, B is given as

$$p_{ij} = a - q_{ij} \tag{1}$$

where $a \in \mathbb{R}_{++}$ and p_{ij} and q_{ij} are the price and output level of the good produced in region i and consumed in region j.

4.2.1 The firm

The firm maximises its profits under each configuration. The profit functions are given as,

$$\pi(1,0) = (p_{AA} - e_{AA})q_{AA} + (p_{AB} - e_{AB} - s)q_{AB} \tag{2}$$

$$\pi(1,1) = (p_{AA} - e_{AA})q_{AA} - (p_{BB} - e_{BB})q_{BB} \tag{3}$$

Using (1) in (2) and then maximising the resultant expression with respect to q_{AA} and q_{AB} yields

$$q_{AA} = \tfrac{a-e_{AA}}{2} \tag{2a}$$

$$q_{AB} = \tfrac{a-e_{AB}-s}{2} \tag{2b}$$

Using (1) in (3) and then maximising the resultant expression with respect to q_{AA} and q_{BB} yields

$$q_{AA} = \tfrac{a-e_{AA}}{2} \tag{3a}$$

$$q_{BB} = \tfrac{a-e_{BB}}{2} \tag{3b}$$

For given level of pollution taxes, the equilibrium profit levels are obtained by substituting (2a) and (2b) in (2) and (3a) and (3b) in (3) as

$$\pi^*(1,0) = \left(\tfrac{a-e_{AA}}{2}\right)^2 + \left(\tfrac{a-e_{AB}-s}{2}\right)^2 \tag{4a}$$

$$\pi^*(1,1) = \left(\tfrac{a-e_{AA}}{2}\right)^2 + \left(\tfrac{a-e_{BB}}{2}\right)^2 \tag{4b}$$

4.2.2 Optimal taxation policies of regional governments

Government in region B

The regulator in region B is aware of the fact that consumers in region B derive utility from consumption of the good produced by the firm in region A. If it imports the good from region A, it loses consumer surplus due to higher price of the product owing to transportation costs. However, region B escapes the environmental damage caused due to production of the dirty good. Under such circumstances, if at all, the government is willing to allow the firm to build a plant in region B, then it levies a pollution tax on each unit of output produced. In addition, it has a stake in the profits of the firm, i.e., a fraction $\theta \in (0, 1)$ of the firm's profits is appropriated by region B since it allows the firm to produce there. This can be interpreted as a profit tax.

The firm, on the other hand, may set up a new plant in region B if transportation costs from A to B are very high; region A imposes high pollution tax on production meant for export; or the good has substantial demand in region B.

Given the pollution tax in region A, the regulator in region B seeks to maximise the social welfare function which is the sum of consumers' surplus, pollution tax revenues net of damage from pollution to the region and share of profits of the firm accruing to region B.

Consumers' surplus, given by the area under the demand curve (1) in region i is given by

$$CS_i = \int_0^{q_{ii}} p_{ii}(r)dr - p_{ii}q_{ii} \tag{5}$$

where CS_i denotes consumers' surplus in region i.

Using (1) in (5) and solving the expression yields

$$CS_i = \frac{q_{ii}^2}{2} \tag{6}$$

Therefore, the social welfare function in region B is given as

$$W_B = \frac{q_{BB}^2}{2} + (e_{BB} - \gamma)q_{BB} + \theta\pi^*(1,1) \tag{7}$$

where W_B denote the social welfare function in region B. On the right hand side of (7), the first term represents consumers' surplus for region B, the second term is the pollution tax revenue earned by the regulator of region B net of total damage and the last term implies the share of profits of the firm accruing to region B.

Proposition 4 *The optimal pollution tax in region B is* $e_{BB} = \frac{a(1-2\theta)+2\gamma}{3-2\theta}$.

From the first order condition, $\frac{\partial W_B}{\partial e_{BB}} = 0$, we obtain,

$$e_{BB}^* = \frac{a(1-2\theta)+2\gamma}{3-2\theta} \tag{8a}$$

Proposition 5 *A rise in the profit tax rate accruing to region B results in reduction of pollution tax rate in region B and vice versa.*

Differentiating (8a) partially with respect to θ yields

$$\frac{\partial e_{BB}^*}{\partial \theta} = -\frac{4a}{(3-2\theta)^2} < 0 \tag{8b}$$

The expression in (8b) shows that a rise in the rate of profit tax imposed on the firm by region B enables the government to appropriate a greater surplus from profits. This is termed as *profit effect.* This reduces the *rent-capturing incentive* of the government in region B with lower pollution tax. However, this has an adverse effect on the environmental quality.

.On the other hand, if θ falls, e^*_{BB} rises. This is similar to the results obtained by Marsiliani et al., (2004) and Withagen (2013). Apparently, governments do not misuse environmental policies to attract firms to their regions if they have other policies like profit taxes at hand. While higher levels of profit tax have a negative impact on pollution tax rates (termed as *a negative profit effect*) which further results in lower environmental quality, lower rates of profit tax induce a higher pollution tax rate (*a rent capturing effect*). This also implies that profit taxes and pollution taxes are strategic substitutes.

Proposition 6 *Pollution tax rate is increasing with the level of marginal damage.*

Differentiating (8a) partially with respect to γ yields

$$\frac{\partial e^*_{BB}}{\partial \gamma} = \frac{2}{3-2\theta} > 0 \tag{8c}$$

Since $\theta \in (0, 1)$, the expression in (8c) is positive. This implies that a rise in marginal damage leads to a rise in pollution tax. This is quite intuitive.

Proposition 7 *The impact of a change in demand on pollution tax depends on the rate of profit tax imposed on the firm by the regulator in region B.*

Differentiating (8a) partially with respect to a yields

$$\frac{\partial e^*_{BB}}{\partial a} = \frac{1-2\theta}{3-2\theta} \tag{8d}$$

We have,

$$\frac{\partial e^*_{BB}}{\partial a} = \left\{ \begin{array}{c} > 0; \theta < \frac{1}{2} \\ \\ = 0; \theta = \frac{1}{2} \\ \\ < 0; \theta > \frac{1}{2} \end{array} \right\}$$

A rightward shift in the demand parameter (increase in market size) results in a rise in optimal pollution tax until profits are shared equally by each region. Due to lower value of θ, the *negative profit effect* is outweighed by the *positive rent capturing effect* with higher tax rate.

With equal shares of profit, the *negative profit effect* counterbalances the *positive rent capturing effect*. As a result, the overall effect on pollution tax rate is zero.

For higher values of θ, *rent capturing incentive* by the government falls short of the *negative profit effect* with lower pollution tax.

Government in region A

Though region A owns the firm, the regulator has asymmetric information regarding the location choice of the firm. The firm may either serve both markets from the single plant at A with probability ψ or set up a separate plant in region B with probability $1 - \psi$. The government in region A maximises the following expected social welfare function:

$$EW_A = \psi[\tfrac{q_{AA}^2}{2} + (e_{AA} - \gamma)q_{AA} + (e_{AB} - \gamma)q_{AB} + \pi^*(1,0)]$$

$$+(1-\psi)[\tfrac{q_{AA}^2}{2} + (e_{AA} - \gamma)q_{AA} + (1-\theta)\pi^*(1,1)] \tag{9}$$

where EW_A is the expected welfare function for the regulator in region A. It is a weighted average of the sum of consumers' surplus, pollution tax revenue net of total damage and share of firm's profits under two configurations, with probabilities being the weights.

Proposition 8 *The optimal pollution tax imposed on production in region A meant for export to region B is* $e_{AB}^* = \gamma$.

From the first order condition, $\frac{\partial EW_A}{\partial e_{AB}} = 0$, we obtain,

$$e_{AB}^* = \gamma \tag{10}$$

It can be seen that despite market imperfections, the regulator imposes a pollution tax equal to the Pigovian tax. Since such a tax is imposed on production of goods for export, consumers' surplus in region A is unaffected. However, profits of the firm, which enter the expected welfare function are adversely affected. Hence, the regulator adjusts the tax on production for domestic consumption while capturing the maximum rent from the Pigovian tax on production meant for export. The Pigovian tax imposed on the exports is a compensation by the consumers in region B in terms of higher prices of the good when environmental damage is completely borne by region A.

Proposition 9 *The optimal pollution tax imposed on production meant for domestic consumption in region A is* $e^*_{AA} = \frac{a[1-2\{1-\theta(1-\psi)\}]+2\gamma}{3-2\{1-\theta(1-\psi)\}}$.

From the first order condition, $\frac{\partial EW_A}{\partial e_{AA}} = 0$, we obtain,

$$e^*_{AA} = \frac{a[1-2\{1-\theta(1-\psi)\}]+2\gamma}{3-2\{1-\theta(1-\psi)\}} \tag{11a}$$

Proposition 10 *A rise in the profit tax rate accruing to region B results in a rise in pollution tax rate in region A, provided the demand is sufficiently high.*

Differentiating (11a) partially with respect to θ yields

$$\frac{\partial e^*_{AA}}{\partial \theta} = \frac{4(1-\psi)(a-\gamma)}{[3-2\{1-\theta(1-\psi)\}]^2} > 0 \tag{11b}$$

(11b) holds true if and only if demand is sufficiently high or marginal damage from pollution is sufficiently low.

In case the firm decides to build a separate plant in region B, the regulator in region A would have an incentive to raise pollution tax as the share of profits of the firm accruing to region B rises. The *negative profit effect* will fall short of the *rent capturing effect.*

Proposition 11 *A rise in the probability that the firm sets up a separate plant in region B results in a rise in pollution tax in region A, provided the demand is sufficiently high.*

Differentiating (11a) partially with respect to $(1-\psi)$ yields

$$\frac{\partial e^*_{AA}}{\partial(1-\psi)} = \frac{4\theta(a-\gamma)}{[3-2\{1-\theta(1-\psi)\}]^2} > 0 \tag{11c}$$

If the regulator in region A thinks that there is a higher probability for the firm to set a separate plant in region B, he sets a higher pollution tax in region A in order to capture the rent from taxation. A separate plant in region B implies loss of tax revenue on the production of goods for export. Besides, the firm has to share a fraction of its profit with region B. This reduces the total surplus accruing to region A.

Proposition 12 *Pollution tax rate in case of asymmetric information is always lower than the case where the probability of serving both regions from a single plant is a sure event, i.e., for* $\psi = 1$.

Putting $\psi = 1$ in (11a), we get,

$$e^1_{AA} = 2\gamma - a \tag{11d}$$

Comparing e^*_{AA} and e^1_{AA},

$$e^*_{AA} - e^1_{AA} = -\frac{2\{a+2\theta\gamma(1-\psi)\}}{3-2\{1-\theta(1-\psi)\}} < 0$$

Hence,

$$e^*_{AA} < e^1_{AA}. \tag{11e}$$

The regulator sets a higher tax when it is certain that the firm will not set up a separate plant in region B. In case of asymmetric information, the regulator in region

A sets a weaker pollution tax in order to encourage the firm to serve both regions from a single plant. Thus, asymmetric information results in lower environmental quality.

Corollary 13 *Pollution tax rate in case of asymmetric information is always lower than the case where the probability of setting a separate plant in region B is a sure event, i. e.,* $\psi = 0$.

Putting $\psi = 0$ in (11a), we get,

$$e^0_{AA} = \frac{a[1-2(1-\theta)]+2\gamma}{3-2(1-\theta)} \tag{11f}$$

Comparing e^*_{AA} and e^0_{AA},

$$e^*_{AA} - e^0_{AA} = -\frac{4\theta\psi(a-\gamma)}{[3-2\{1-\theta(1-\psi)\}][3-2(1-\theta)]} < 0$$

Hence,

$$e^*_{AA} < e^0_{AA}. \tag{11g}$$

These results are in lines with those suggested by Antelo et al. (2009) that taxation policies differ with the type of information, viz. symmetric or asymmetric.

4.2.3 The induced location choice of the firm

Case I: Firm location decision based on only one policy instrument, namely, pollution tax

Throughout the analysis, our primary focus is on the impact of pollution taxes and transportation costs on the location decision of the firm. Hence, we ignore profit taxes for the time being and consider that the firm in region A would prefer to set up a separate plant in region B if $e_{BB} < e_{AB} + s$ is satisfied. Governments in each region declare pollution tax levels in the first stage and e_{AB} only matters when the firm exports its output to region B, we consider its optimal value. $e^*_{AB} = \gamma$ is substituted in the above inequality and we get the following condition:

$$e_{BB} < \gamma + s = \widetilde{e_{BB}} \text{ , (say)} \tag{12a}$$

For any $e_{BB} > \widetilde{e_{BB}}$, the firm would prefer to serve both regions from a single plant rather than setting up a separate plant in region B.

Proposition 14 *The regulator in region B imposes e^*_{BB} as the optimal pollution tax if the profit tax rate imposed on the firm is greater than $\widetilde{\theta} = \frac{1}{2} - \frac{1}{\frac{a-\gamma}{s}-1}$. Otherwise, the optimal pollution tax that can be imposed by region B in order to induce the firm to set up a separate plant in region B will be $\widetilde{e_{BB}}$.*

Substituting the value of e^*_{BB} from (8a) in inequality (12a), we get $\theta > \frac{1}{2} - \frac{1}{\frac{a-\gamma}{s}-1} = \widetilde{\theta}$ (say). Hence, e^*_{BB} is the optimal pollution tax rate in this case. For $\theta \leq \widetilde{\theta}$, e^*_{BB}

cannot be the optimal pollution tax. From (8b), we can see that θ and e^*_{BB} are inversely related. As a result, a lower value of θ induces the regulator in region B to impose a higher pollution tax, otherwise it would lose rent to the firm. The minimum level of pollution tax that the regulator can impose is $\widetilde{e_{BB}}$. Hence, higher values of θ imply lower environmental quality since a higher θ implies a lower pollution tax. If we assume that in case of indifference, the firm will choose to set up a separate plant in region B, then the regulator in region B would impose $\widetilde{e_{BB}}$ as the pollution tax. Mathematically,

$$e_{BB} = \left\{ \begin{array}{c} e^*_{BB}; \theta > \widetilde{\theta} \\ \\ \widetilde{e_{BB}}; \theta \leq \widetilde{\theta} \end{array} \right\} \tag{12b}$$

Given that $\theta \in (0, 1)$, we have

$0 < \widetilde{\theta} < 1$

$\Longrightarrow 0 < \frac{1}{2} - \frac{1}{\frac{a-\gamma}{s} - 1} < 1$ which gives us $\frac{a-\gamma}{s} > 3$. As a result, $\widetilde{\theta} < \frac{1}{2}$.

The optimal levels of pollution tax that the regulator in region B imposes are illustrated in Figure 4-1.

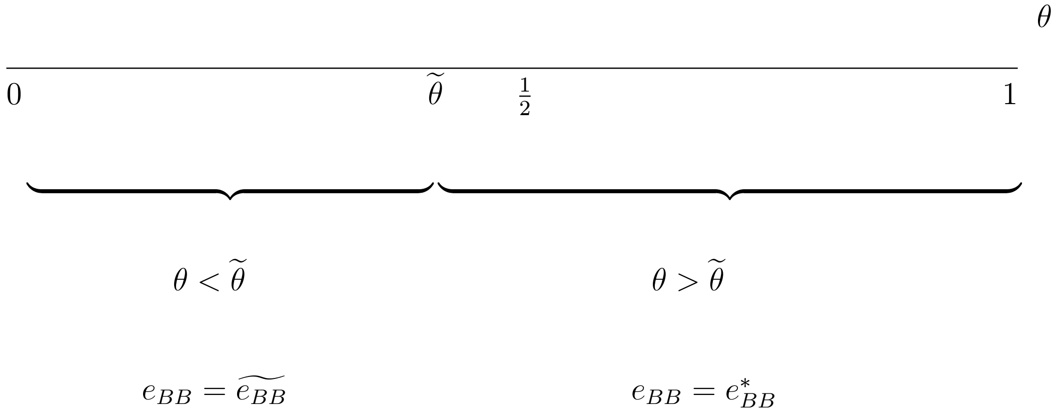

Figure 4-1: Pollution tax rates along different ranges of θ when location decision is driven by pollution tax and transport cost

Case II: Firm location decision based on two policy instruments, namely, pollution tax and profit tax

Suppose, the firm also considers profit taxes while making a location choice, then (12a) changes to

$$e_{BB}+\theta < \gamma+s \tag{13a}$$

(13a) shows that the firm would choose to set up a separate plant in region B if the sum of pollution tax and profit tax imposed by the regulator in region B is lower than the sum of pollution tax on exports from A to B imposed by the regulator in region A and transportation cost.

From (13a), we get

$$e_{BB} < (\gamma + s) - \theta = \widehat{e_{BB}}, \text{ (say)} \tag{13b}$$

For any $e_{BB} > \widehat{e_{BB}}$, the firm would prefer to serve both regions from a single plant rather than setting up a separate plant in region B.

Substituting the value of e^*_{BB} from (8a) in inequality (13b), we get a quadratic expression in θ as

$$2\theta^2 - \{3 - 2(a - \gamma - s)\}\theta - (a - \gamma - 3s) > 0 \tag{13c}$$

The roots of the quadratic equation $2\theta^2 - \mu_1\theta - \mu_2 = 0$ are

$$\theta = \frac{1}{4}\{\mu_1 \pm \sqrt{(\mu_1^2 + 8\mu_2}\} \tag{13d}$$

where $\mu_1 = 3 - 2(a - \gamma - s)$ and $\mu_2 = (a - \gamma - 3s)$

Since we do not know about the signs of μ_1 and μ_2, let us impose sign restrictions on μ_1 and μ_2 and check the results.

(13d) can be further written as

$$\theta = \frac{1}{4}(\mu_1 \pm \sqrt{\eta}) \tag{13e}$$

where $\eta = \mu_1^2 + 8\mu_2$

From (13e), we can ensure that $\sqrt{\eta} > 0$, since we consider only the positive square root.

For the inequality in (13c) to hold, either $\theta < \theta_1$ or $\theta > \theta_2$;provided $\theta_1 < \theta_2$, where θ_1 and θ_2 are the roots given in (13d).

Proposition 15 *When* $\mu_1 > 0$, $\eta > 0$ *and* $\mu_1 > \left|\sqrt{\eta}\right|$, *the regulator in region B imposes* e^*_{BB} *as the optimal pollution tax if the profit tax rate imposed on the firm is greater than* $\overline{\theta}$ *or less than* $\underline{\theta}$. *In case* $\theta \in [\underline{\theta}, \overline{\theta}]$, *the the firm prefers to operate from region A only.*

In this situation, we obtain two values of θ as

$$\overline{\theta} = \tfrac{1}{4}(\mu_1 + \sqrt{\eta}) \tag{14a}$$

$$\underline{\theta} = \tfrac{1}{4}(\mu_1 - \sqrt{\eta}) \tag{14b}$$

Clearly, $\underline{\theta} < \overline{\theta}$

It is evident that the firm will set up a separate plant in region B only when $\theta < \underline{\theta}$ or $\theta > \overline{\theta}$, since such range of θ satisfies inequality (13b). The inequality in (13b) is reversed when $\theta \in [\underline{\theta}, \overline{\theta}]$ and hence the firm has no incentive to set up a separate plant in region B. For all $\theta < \underline{\theta}$ and $\theta > \overline{\theta}$, e^*_{BB} is the optimal level of pollution tax. This is a peculiar case where both higher and lower values of profit tax are associated with the same level of pollution tax. The monotonic relationship between θ and e_{BB} breaks here. This may be attributed to the sufficiently low level of demand or high level of export tax and transport cost (since $\mu_1 > 0$), which induces the regulator in region B to impose a lower level of pollution tax and not $\widehat{e_{BB}}$ in order to attract the firm, even when profit tax is low. Figure 4-2(a) illustrates this situation.

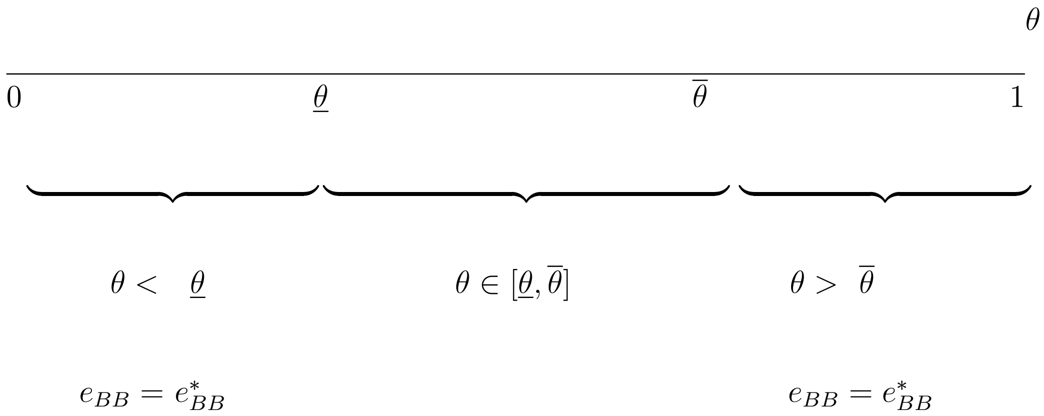

Figure 4-2(a): Pollution tax rates along different ranges of θ when location decision is driven by pollution tax, transport cost and profit tax

Proposition 16 *When $\mu_1 < 0$, $\eta > 0$ and $|\mu_1| < \sqrt{\eta}$, the regulator in region B imposes e^*_{BB} as the optimal pollution tax if the profit tax rate imposed on the firm is greater than $\widehat{\theta}$. Otherwise, the optimal pollution tax that can be imposed by region B in order to induce the firm to set up a separate plant in region B will be $\widehat{e_{BB}}$.*

The above sign restrictions ensure that $\theta \in (0, 1)$. We have only one feasible value of θ in this case, i.e.,

$$\widehat{\theta} = \tfrac{1}{4}(\mu_1 + \sqrt{\eta}) \tag{15}$$

For inequality (13b) to hold, $\theta > \widehat{\theta}$. As a result, the firm will have an incentive to set up a separate plant in region B only when $\theta > \widehat{\theta}$. Hence the optimal pollution tax for all $\theta > \widehat{\theta}$ is e^*_{BB}. For all $\theta \leq \widehat{\theta}$, the minimum level of pollution tax that the regulator can impose is $\widehat{e_{BB}}$ [figure 4-2(b)].

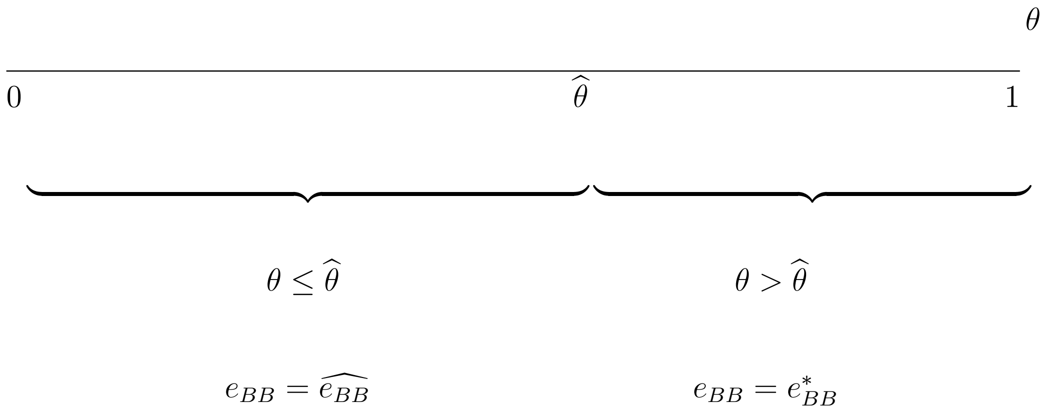

Figure 4-2(b): Pollution tax rates along different ranges of θ when location decision is driven by pollution tax, transport cost and profit tax

To conclude, the present model emphasises on both transportation costs and pollution taxes as factors determining whether a firm operating in one region sets up a separate plant in another region. The decision of building a separate plant is also contingent upon the profit tax imposed by the regulator in the prospective location. As far as the government in the prospective region is concerned, it imposes a lower pollution tax for a higher profit tax rate and vice versa. Hence, profit tax and pollution tax are strategic substitutes for the government. On the other hand, the government in the host region has asymmetric information whether the firm would operate from a single plant or set up a separate plant in the other region. As a result, despite market imperfections the regulator imposes a pollution tax on production meant for export equal to the Pigovian tax. Since such a tax is imposed on production of goods for export, consumer surplus in region A is unaffected. However, profits of the firm, which enter the expected welfare function are adversely affected. Hence, the regulator adjusts the tax on production for domestic consumption while capturing the maximum rent from the Pigovian tax on production meant for export.

Chapter 5

Case studies

The present chapter discusses few case studies related to location of industries in India. Although it is difficult to relate these studies exactly to the type of location problem discussed in the theoretical models in the previous chapters, they provide some idea about the location problem and the factors determining location decisions. While considering environmental regulations, it is apparent that a price based instrument like pollution tax is hardly incorporated in the policies tailored for environmental regulation in India. It has been predominantly the standard based instruments that are more popular. Nevertheless, our objective to provide some evidence of such factors influencing location of firms is met.

The relocation policy (1996) pertaining to hazardous industries in the National Capital Territory of Delhi has been discussed in detail. This is accompanied by another case study of an important manufacturing industry in India, Tata Motors Limited, focusing on geographical distribution of its plants in several Indian states and implications thereof.

5.1 NCT of Delhi

The union territory of Delhi has experienced a rapid economic growth over the years. At constant (2004-2005) prices, GSDP has increased from Rs.100325 crores in 2004-05 to Rs.236156 crores in 2013-14 registering annual compound growth rate of 9.98 per cent. For 2013-14 annual increase of 9.35 per cent was recorded in GSDP at constant prices.[1] The growing dependence on industry and commerce has resulted in unabated in-migration from neighbouring states like Uttar Pradesh, Bihar, Haryana and Punjab. The Census Report of 2011 shows that the population has grown at the rate of 21.2 per cent from 2001 to 2011, with an enormous decline in the growth rate of rural population by 55.6 per cent accompanied by 26.8 per cent increase in the urban population. This trend of growing urban population dates back to the year 1961. In order to address the issue of urban sprawl, the Ministry of Urban Development had launched the first Master Plan for Delhi (1961-81). The Master Plan had a vision of a clean and aesthetically planned metropolitan city accompanied with proper infrastructure and decent quality of life for the inhabiting population. In order to boost up growth, the government undertook rapid urbanisation as well as industrialisation in the NCT which resulted in commensurate rise in urban areas since 1980s. In the 1981 census, 27 census towns were added to the urbanised area. As a result, the issue of environmental pollution and negative externalities associated

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[1] Estimates of State Domestic Product of Delhi, 2013-14, Directorate of Economics and Statistics, Government of National Capital Territory of Delhi.

with industrial production came into limelight. Besides, the rising population flouted land use norms and aggravated the problem. Over the years, the number has been on the rise with 135 urbanised villages in the census of 2001.

In the event of such circumstances, M.C. Mehta, a lawyer and environmentalist filed a Public Interest Litigation (PIL) in 1985. The litigation sought action against industries operating in residential or non-conforming areas of Delhi and flouting the provisions of the Master Plan (1962). The Supreme Court delivered its judgement on July 8, 1996 ordering either the shifting of 168 hazardous industries to conforming areas or their complete closure by November 30, 1996. The rationale for such a verdict was basically the mounting pressure on land and degrading ambient air quality due to rapid industrial and commercial activities as well as large scale illegal occupation of land and improper housing. The directives issued by the court were based on several incentives provided to the workers such as shifting bonus and compensation, wage payments for the period between the closure and the restart of an industry at the new site after relocation.

The policy of direct ban of hazardous industries draws much attention since it is too extreme. It is most likely that all other instruments of taxes/standards had failed to achieve the desired outcome. A study by Bentinck and Chikara (2001) suggests that ground verification of factories in Delhi confirmed operations flouting provisions of the Master Plan of Delhi. Furthermore, local political parties in areas like Samaipur in outer Delhi enjoyed political patronage from the factory owners and

Table 5-1: Industries shut down and/ or relocated outside Delhi

Date of Order	Type of Industry	Date of Closure
08-07-1996	168 (hazardous industries)	30-11-1996
06-09-1996	513 (ordered to relocate outside Delhi)	31-01-1997
10-10-1996	46 (Hot mix plant)	28-02-1997
26-11-1996	243 (Brick kilns - to stop functioning and relocate outside Delhi)	30-06-1997
26-11-1996	21 (Arc/induction furnaces)	31-03-1997

Source: White paper on Pollution in Delhi with an Action Plan, Ministry of Environment and Forests, Government of India.

Table 5-2: A list of few heavy and hazardous industries that were relocated

Name of the unit	Deals in	Shifted to
Birla Textile Mills	Textile	Solan, Himachal Pradesh
Sri Ram Food and Fertiliser	Food & Fertiliser	Rajpura, Punjab
Swatantra Bharat Mills	Textile	Tonk, Rajasthan
Rathi Steel	Steel	Ghaziabad, UP
Super King	Tyres	Sahibabad, UP

Source: Chand, 2012

this triggered insouciance amongst factory owners to disregard regulations pertaining to the environment.

5.1.1 Rationale for relocation policy

Illicit land use and environmental pollution associated with industrial activity had been the two most crucial factors driving the relocation or complete closure of the industries. Bentinck and Chikara (2001) have emphasised on the above factors while studying two urbanising villages in Delhi, namely, Gopalpur and Samaipur. Due to large scale in-migration of the poor in search of work from the neighbouring states, the pressure on land has been on the rise. For instance, the 'lal dora' legislation which provided residential land to the villagers in the city's fringe had aimed to promote rural industry. The land within the lal dora was subject to lesser land use regulations and taxes. Infact, such land was extremely attractive to small entrepreneurs who wished to avoid taxes.

On the other hand, cheap accommodation and inexpensive infrastructure like illegally tapped electricity, free drinking water, transport facilities have attracted poor migrants to these regions. While small entrepreneurs willing to employ cheap labour set up factories in these areas, employment opportunities accelerated the influx of poor migrants to such villages. The factories, mostly unregistered, included electrical spare parts, assembling of auto spare parts like car head lights, manufacturing and packing of seat covers, wire- making, manufacturing of wrist watch cases, plastic bags, iron smelting, etc. Production activities undertaken by these factories cause severe environmental degradation in form of improper disposal of solid waste, misuse of water, noise pollution, etc. Suspended particulate matters, sulphur dioxide, suspended nitrates and carbon monoxide are the major pollutants. Combustion of fuels and wastes, emissions from manufacturing activity degrade the ambient air quality. Solid as well as fluid wastes which are not treated properly result in ground water contamination.

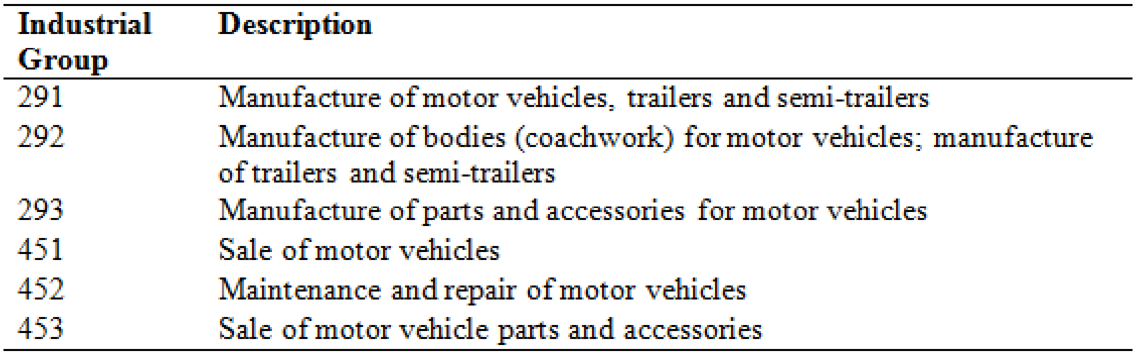
Consequently, the residents were the worst hit by the unhealthy and unplanned production activities. The ill effects of pollution from industrial activities called for immediate policy intervention. The government took initiatives to relocate industries from the non-conforming areas, set up common effluent treatment plants and electrostatic precipitators for thermal power plants and incorporated action programme for mass scale utilisation of fly ash. This shows how environmental regulations driven by environmental pollution have an impact on the location of these industries. Since such regulations had a substantial impact on the location of production, the impact of transportation costs, albeit significant, was completely outweighed by them.

5.2 Location of manufacturing industries: A study of Tata Motors Limited

Established in 1945, Tata Motors Limited is India's largest automobile company, manufacturing passenger as well as commercial vehicles. The consolidated revenues of the company were INR 2,32,834 crores in 2013-14. It serves both domestic as well as international markets with cars and utility vehicles, trucks and buses, etc. Over 8 million Tata vehicles ply on Indian roads. The company's manufacturing base in India is spread across Jamshedpur (Jharkhand), Pune (Maharashtra), Lucknow (Uttar Pradesh), Pantnagar (Uttarakhand), Sanand (Gujarat) and Dharwad (Karnataka).

Being an automobile industry, which falls under the 'red' category of industries (i.e., highly polluting industries), identified by Ministry of Environment and Forests, Government of India, manufacturing activities are highly polluting in nature. Emis-

Table 5-3: Sectors that the company is engaged in (with 3-digit NIC code)



Industrial Group	**Description**
291	Manufacture of motor vehicles, trailers and semi-trailers
292	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
293	Manufacture of parts and accessories for motor vehicles
451	Sale of motor vehicles
452	Maintenance and repair of motor vehicles
453	Sale of motor vehicle parts and accessories

Source: Business Responsibility Report for financial year 2013-14, Tata Motors Ltd.

sion of hydrocarbons, nitrogen oxides, carbon monoxide and carbon dioxide cause air pollution. As a result, Tata Motors has been compelled to promote eco friendly technology through improved R&D and widespread awareness among stakeholders. All manufacturing plants in India are certified to ISO 14001 Environmental Management Systems (EMS) standard. Such measures have been a result of environmental regulations imposed by the State. As far as impact of such regulations on the location of plants is concerned, we have used the environmental sustainabilty index[2] of 2011 for the Indian states where manufacturing plants are located.

It gives us some idea that the states with lower ESI are the ones hosting the plant. The highly sustainable states are Arunachal Pradesh, Himachal Pradesh, Manipur,

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[2] ESI has been defined as *"a comprehensive measure of environmental achievements, challenges and priorities. It includes a state's general environmental condition, achievements of policies and natural resource conservation strategies. The indicators reflect anthropogenic activities like production, consumption and distribution that exert pressure on the environment; state of air quality, water quality, land use, forests, biodiversity; impact of extraction activities on the ecosystem and policy responses."*

Table 5-4: Environmental Sustainability Index 2011 of states with manufacturing plants

Region	**State**	**Sustainability based on ESI, in the year 2011**
Jamshedpur	Jharkhand	Least sustainable
Pune	Maharashtra	Moderately sustainable
Lucknow	Uttar Pradesh	Least sustainable
Pantnagar	Uttarakhand	More sustainable
Sanand	Gujarat	Least sustainable
Dharwad	Karnataka	Moderately sustainable

Source: Environmental Sustainability Index for Indian states 2011, Centre for Development Finance, Chennai.

Mizoram, Nagaland and Sikkim. Another important observation is that most of the high ESI states are in northeastern India. However, these states may not provide the appropriate infrastructure like easy access to raw materials, power supply, transport facilities, market access to the industry and thereby do not serve as an ideal location. It is extremely difficult to isolate the impact of environmental regulations on location of plant unless we undertake a regression analysis. For instance, a report in the year 2014,[3] stated that Tata Motors had decided to relocate its Lucknow plant to Rudrapur (Uttarakhand) in order to cut costs. It has been found that Tata Motors' demand for subsidy was scrapped by the U.P. government. Furthermore, the Uttarakhand government had provided several incentives to attract the plant from Lucknow. Although, it is evident that government policies have an impact on location decision of the firm, the joint role of environmental regulations and transportation costs can be explained only through detailed empirical analysis.

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[3] Rawat, V. S. (2014), Tata Motors to shift production from Lucknow plant to Uttarakhand, [Online: web] Accessed July 23, 2015 URL: http://www.business-standard.com/article/companies/tata-motors-to-shift-production-from-lucknow-plant-to-uttarakhand-114012700747_1.html

Chapter 6

Conclusion

Our study, primarily theoretical, attempts to explain how pollution taxes and transportation costs jointly determine the optimal location of production. We have addressed two types of location problems, namely, vertical location of production and horizontal location of production.

A review of the existing literature on each of the two types of location problem suggests that most studies do not incorporate pollution taxes while analysing the impact of transportation costs on location decisions and vice versa. It has been found that pollution taxes have not been considered in the Weberian location theory based on vertical production structure. Consequently, we have extended the Weberian model by including pollution taxes in the framework and our results show that the ideal location, as predicted by Weber, may not hold true under all circumstances. Optimal location choice is driven by the nature of processing as well as differences in inter-regional pollution taxes along with transportation costs.

In case of horizontal location problem, we develop a variant of models constructed by Markussen et al. (1995) and Celic and Orbay (2011). Although, the seminal work by Markussen et al. (1995) has included both the factors in determining location of a firm, unlike the Markussen/Morey/Olewiler model, we incorporate profits in the regulator's welfare function, a situation of asymmetric information to the regulator, and profit tax on the relocating firm. However, for simplicity, we have assumed that there are no plant set up costs or other variable costs associated with production. As far as basic differences with the Celic/ Orbay model are concerned, we have assumed only one firm instead of two and non-zero transportation costs. Our results show that a firm's location decision is driven by both transportation costs and pollution taxes, which further depend on the profit tax accruing to a region which serves as a potential host to the firm.

Our theoretical approach has been accompanied by two case studies based on location of industries in India. The first study discusses the relocation scheme of hazardous industries in the National Capital Territory of Delhi. It shows that rapid urbanisation and industrialisation in the NCT has increased pressures on the environment which induced the Government of Delhi to regulate operations and activities of heavy and hazardous industries in the NCT. Due to failure of regulatory instruments like standards, the government was forced to impose direct ban on operation of hazardous industries in the region. The other study is based one of the popular automobile industries in India, Tata Motors Limited. We find that Tata Motors Limited has plants set up in multiple regions. However, the regions/states which serve as hosts are mostly the ones with lower environmental regulations (measured by ESI). This gives us an idea that environmental regulations along with transportation costs do play an important role in determining the location of production.

It must be noted that our analysis is mainly theoretical. Empirical studies would help us understand the issue in more depth. This requires comprehensive data on pollution taxes and transportation costs for industries. Most environmental regulations in India are quantity based (e.g. emission standards), which makes the analysis more complicated. Physical distance can be used as a proxy for transportation costs. Further research on these empirical issues is desirable.

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