Chapter 2

Review of the Literature

2.1. Background of Emissions Permit System

Compared to another important MBI viz. pigovian tax, the concept of marketable emissions permits is relatively new. This section reviews the literature regarding the historical background of the emission permit system, starting from the evolution of the concept, different trading rules for different types of pollutants, pattern of initial permit distribution, situations when permit system is most appropriate and finally the real life problems attached to the system.

2.1.1. Evolution of the concept of Marketable Emissions Permit

The concept of marketable emissions permits emerged in the sixties to overcome some limitations of the tax system. To solve the problem of divergence between social marginal cost (SMC) and private marginal cost (PMC), Pigou suggests a per unit tax system equal to the difference between SMC and PMC at optimal pollution level. All firms will eventually equate their marginal cost of abatement to the given tax and as a result those firms will abate more whose marginal abatement cost is low and vice versa. This is known as equimarginal principle for least cost solution. Pigovian tax approach is based on polluter's pay principle (PPP) and looks for a measure to control polluter's action. But Coase (1960) raised the fundamental point that in doing so, the state action brings about a problem of reciprocal nature. It stops polluters from affecting the victims, but at the same time it helps victims to affect the polluters. Since both polluters and victims are affecting each other, therefore both parties harmful effect should ideally be taken into consideration in deciding on their course of action (Coase 1960).

In a way Coase's theory attacks the polluter's pay principle and gives reasons for victim's pay principle (VPP) in relevant cases. Environment being a common property, just the way people have right to clean air, they should also have their proper amount of right to pollute. But the 'tragedy of commons' reminds us that unrestricted access leads to overuse and deterioration of the common property. Thus well defined property rights are required to protect the common property—environment. With well defined and transferable property rights, the market can play a significant role in valuing these rights properly and also putting them to their best use (Coase, 1960).

In the late sixties Coase's idea of property rights was transformed into a practical program for controlling pollution. Dales described the applicability of environmental property rights for air (Dales, 1968a) as well as water (Dales, 1968b)[1]. The idea was to define property rights for environmental resources and then offer for sale to the highest bidder. The implicit assumptions behind this simplified setting are–the firms are price takers (or absence of market power), the transactions costs associated with trading are small, and firms comply voluntarily with their permit limits (Malik, 2002). In the current system commonly known as marketable/tradeable permit system the pollution control authority determines a target level of environmental quality, translates that into the total amount of allowable emission that can be discharged, and then allots discharge rights to the firms in the form of permits (Sawhney, 1997). The market clearing price that automatically emerges in the system indicates the opportunity cost of waste emissions of the polluters. Since all sources face this equal permit price, equimarginal principle for least cost solution is satisfied. In his seminal paper Montgomery (1972) provides a solid theoretical foundation of marketable permits system and concluded that the efficiency or the least-cost outcome is independent of the initial allocation of the permits.

[1] Crocker (1966) also came up with quite a similar idea (Ellerman, 2005)

2.1.2. Situations when permit is better that tax

When there is no uncertainty about the abatement costs, the tax system (price-based instrument) and permit system (quantity-based instrument) have equivalent impact on environmental quality, but not in the presence of uncertainty (Weitzman, 1974). With uncertainty regarding the costs of pollution control, the preferred policy instrument depends on the relative steepness of the marginal benefit and cost curves. In case the marginal benefits curve is quite steep but marginal control costs curves are more or less constant, it is very important to have a close control over the quantity of emissions. This is because very steep marginal benefits curve imply environmental threshold level, i.e. if pollutants concentration rises only slightly over some range, awful environmental consequences will follow. So naturally in this situation quantity-based instrument (e.g. permit) is better compared to price-based instrument (e.g. tax). Pigovian tax approach is cost-effective (due to its equimarginal principle), but it does not directly control the aggregate emissions[2].

Tradable permit approach is also superior to tax/charge approach because it reduces the need for information by the bureaucracy. While the regulatory agent set the amount of aggregated emissions, it need not has to know anything about firm's individual cost functions. At the same time, in a charge system, the authority needs to adjust the fee periodically (if set in nominal terms) to incorporate real changes due to inflation and growth. Continuing inflation can erode the real value of the tax or fee. At the same time, expanding production of both old and new firms will increase the demand for waste emissions. Both of these will require the fee to be raised from time to time if environmental standards are to be maintained. Under a permit system, market forces automatically accommodate themselves to inflation and growth with no increase in pollution. The rise in demand for permits simply gets translated into a higher price so long as new permits are not issued (Baumol and Oates, 1988).

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[2] The debate on price vs. quantity instruments (tax vs. permit) has been started by Wietzman (1974). Later on economists suggested hybrid approaches combining the merits of both the instruments. Roberts and Spence (1976) suggested the use of licenses supplemented by an effluent subsidy and a finite penalty when regulator is uncertain about firm's abatement costs. Kwerel (1977) suggested a mixed effluent charge-license plan to discover the true aggregate cost function and achieve the optimal level of pollution. But this stream of debate is beyond the scope of our paper.

Although from the viewpoint of the society, tax is only a transfer payment from economic agents (firms in this context) to the government, but no doubt it increases the cost of the firms. On the other hand if the initial distribution of the permits is free of cost among current polluters then it effectively eliminates the added costs for existing firms which can act as a major advantage for permit system's political acceptability (Baumol and Oates, 1988).

2.1.3. Trading rules for different types of pollutants

The trading rule of the permits depends on the nature of the pollutants whether their harmful effect varies or not with distance from the source, or in other words whether the pollutants are uniformly mixed or non-uniformly mixed. For uniformly mixed pollutants (UMPs) (e.g. carbon dioxide) the marginal damage cost would be same across the sources, but for non-UMPs (e.g. sulpher dioxide) marginal damage costs across sources will be different.

In Montgomery's (1972) seminal model there are n industrial sources of pollution (e.g. firms). Some predetermined (e.g. socially optimal) regional standard of environment is denoted by a vector$Q^* = (q_1^*, \dots, q_m^*)$. The emission vector$E = (e_1, \dots, e_n)$ is mapped into concentrations $Q$by a semipositive matrix H, so that $E \cdot H = Q.H$ is nothing but an$m \times n$ matrix of unit diffusion coefficients h_{ij}, which is the mapping of emission of i^{th}source to j^{th}receptor. The target of the regulator is to achieve Q^* at least cost to the polluters (which are typically profit maximising firms).

$$minimise \sum_{i=1}^{n} F_i(e_i)$$

$$subjet\ to\ E \geq 0$$

$$and\ E \cdot H \leq Q^*$$

For each point j, if two firms are trading their pollution licenses, then $\frac{h_{2j}}{h_{1j}}$ gives the marginal rate of substitution between emissions at source 2 and emission at source 1 which keeps air quality constant at point$j$. This is trading rule for non-uniformly mixed pollutant. For uniformly mixed pollutant, the regulator is only concerned about the total emissions, no matter where it is taking place, so licenses can be traded at a one-to-one basis.

The permits or licences as designed by Montgomery (1972) takes two different forms:

Emission license: where certain (optimal) rate of emission is decided by the environmental authority. The right (which is distributed and can be traded further) is to emit pollutant up to a certain rate.

Pollution license: where certain (optimal) rate of emission is decided so that level of pollution is same at a particular point. The right (which is distributed and can be traded further) is to emit pollutant at a rate which will cause no more than a specified amount of pollution level at a certain point.

2.1.3.1. Trading pattern for uniformly mixed pollutants (UMPs)

Emission license system is best suited for UMPs. The problem for the regulator is to choose the vector $E = (e_1, \dots, e_n)$ so that the aggregate abatement cost of n number of profit maximising firms $\sum_{i=1}^{n} F_i(e_i)$ is minimised such that there is non-negative emissions (which is necessary for non-negative output production), but the total emission is less than the predetermined amount. The pollution control authority simply decides on the total permissible amount of the pollutants and then the emission permits are allotted to the firms. The problem of the regulator is the following:

$$minimise \sum_{i=1}^{n} F_i(e_i)$$

$$subject\ to\ E \geq 0$$

$$and\ \sum_{i=1}^{n} e_i \leq \bar{e}$$

Where $\bar{e}$is the total permissible amount of the uniformly mixed pollutant. In this case the trading rule is simple because trades do not require the constraint of local air quality since the location of the emissions is not a matter of policy consequence (Tietenberg, 2005). The permits can be simply traded at a one-to-one basis.

2.1.3.2. Trading pattern for non- uniformly mixed pollutants (non-UMPs)

Most of the literatures deal with non-UMPs because of the complications regarding the trading pattern. In these models a diffusion matrix maps the emission of one particular source to a particular receptor. Montgomery's (1972) seminal model for non-UMPs is like the following:

There are n industrial sources of pollution (e.g. firms). Some predetermined (e.g. socially optimal) regional standard of environment is denoted by a vector$Q^* = (q_1^*, \dots, q_m^*)$. If air pollution is particular area of interest,q_j^*might be annual average concentration of a particular local air pollutant (e.g. sulpher dioxide) at point j among m such points (e.g. air basins). The number 1 stands for one particular pollutant. e_i is the rate of emission of that single pollutant from industrial sources. The emission vector$E = (e_1, \dots, e_n)$ is mapped into concentrations $Q$by a semipositive matrix H, so that $E \cdot H = Q$

H is nothing but an $m \times n$ matrix of unit diffusion coefficients, denoted by

$$H = \begin{bmatrix} \cdot & \cdot & \cdot \\ \cdot & h_{ij} & \cdot \\ \cdot & \cdot & \cdot \end{bmatrix}$$

h_{ij} is the mapping of emission ofi^{th} source toj^{th} receptor.

The target of the regulator is to achieve Q^* at least cost to the polluters (which are typically profit maximising firms). The problem for the regulator is to choose the vector$E = (e_1, \dots, e_n)$ to minimise the aggregate abatement cost$\sum_{i=1}^{n} F_i(e_i)$, such that there is non-negative emissions, but the total emission is less than the predetermined regional standard Q^*. Formally the problem can be written as:

$$minimise \sum_{i=1}^{n} F_i(e_i)$$

$$subjet\ to\ E \geq 0$$

$$and\ E \cdot H \leq Q^*$$

Where $Q^* \geq 0$, $h_{ij} \geq 0$ for all i, j.

The above model is for pollution permit system.

This basic model has been modified by Seskin et al (1983) by incorporating difference in abatement technologies to exploit differences in sources' emissions control costs. Let$e_{ik} \geq 0$ represents emissions of i^{th} source using control technology level k.

$F_{ik}(e_{ik}) \geq 0$ represents the costs of controlling emissions at thei^{th} source using control technology level k. $h_{ikj}$is the contribution of i^{th} source using control technology level k at j^{th} receptor. $Q^* \geq 0$ is the air quality standard that must be met at each of the $m$receptors. With incorporation of difference in technology the least cost problem changes as the following:

$$minimise \sum_{i=1}^{n} F_{ik}(e_{ik})$$

$$subject\ to\ e_{ik} \geq 0$$

$$and \sum_{i=1}^{n} h_{ikj} e_{ik} \leq Q^* \qquad where\ j = 1, \ldots, m$$

In their model of pollution license, technology plays an important role because the cleaner technology a firm uses its cost will reduce accordingly. In this set up marketable permits provide incentives for technological improvement.

To make permit system work better, two different trading rules are suggested in the literature:

(1) The pollution offset approach (Krupnick et al, 1983) which allows offsetting trades among sources as long as they do not violate any ambient air quality standard and

(2) The modified pollution offset (McGartland and Oates, 1985) which allows trades among sources as long as neither the pre-trade air quality nor the ambient standard (whichever is more stringent) is exceeded at any receptor.

In pollution offset approach Krupnick et al (1983) try to incorporate the benefits of emission license system for non-uniformly mixed pollutants. Due to its simplicity, emission licenses make the producer's life much easier because they don't need to manage the entire portfolio of permits corresponding to each receptor. But on the other hand it is very difficult for the authority to design emission permits because designing such a policy needs incorporation of a firm's cost structure so that the trading can be at a one-to-one basis. According to Krupnick et al (1983) the short coming of emission licenses which arises from the restrictive condition on trading, has been overcome by a hybrid approach. The basic idea is to define permits in terms of emissions but the trade should not be on a one-to-one basis. The desirable trading rule for emission rights is that a firm may be allowed to emit up to a level which causes pollution equal to that which would have been caused by the seller (i.e. the amount which has been given up by the seller) so that it does not result into a violation of air quality standard at any receptor point. The source of new emissions must purchase a sufficient number of permits so that the effect is offset. So the new approach is called pollution offset system. Along with the minimising condition, similar to the seminal paper of Montgomery (1972), there is one more non degradation condition. Each firm also faces the constraints

$$h_{ij}e_i \leq \sum_r h_{rj}l_{ir}$$

where $j = 1,2,\dots,m$ and l_{ir} is the emission permits that firm i purchases from firm r. This restriction implies that a transfer of emission permits from one polluter to another must take place in such a way that there is no increase in the level of pollution at any receptor point.

In case of modified pollution offset (McGartland and Oates, 1985), the seminal model changes slightly as the following:

$$minimise \sum_{i=1}^{n} F_i(e_i)$$

$$subject\ to\ E \geq 0$$

$$and\ EH \leq min(Q^*, Q^0)$$

Where $Q^* \geq 0$, $h_{ij} \geq 0$ for all i, j as in the seminal model. Additionally $Q^0 = (q_1^0, q_2^0, \dots, q_n^0)$ is the level of pollutant concentration under the current CAC approach. The trading rule is only a bit stricter in this case which allows trades among sources so that neither the pre-trade air quality nor the ambient standard (whichever is more stringent) is exceeded at any receptor.

2.1.4. Is emission permit trading better in case of UMPs?

ForUMPs or in other words global pollutants particularly, a tradeable permit system is thought to be better than other alternatives like carbon tax (Bertram, 1992, Hahn and Stavins, 1995; Sawhney, 1997). As seen in the previous subsection, the nature of the pollutants influences the choice of trading. For non-UMPs the trading system is complicated. For UMPs, where the impact of pollution is uniform, an emission trading is expected to work especially well. This system allows for aggregate pollution reductions at minimum cost and for UMPs, the ultimate concern is on aggregate pollution levels no matter where the emission is taking place. Thus tradeable permits system is supposed to perform well in the context of international trading of greenhouse gases (GHGs). The permits can be traded among individual participating nations. This system has no contradiction with the fact that individual countries can achieve their respective control obligations through any instrument which a particular country thinks the best.

There are a number of potential advantages in the use of marketable permits to reduce the emissions of GHGs. First of all, there will be a direct control or a cap on aggregate emission level. Secondly, firms and individuals can have greater flexibility in choosing different strategies and technologies for limiting GHGs, as they are not forced to use the best available technology. They can even have proper incentives for the development of innovative approaches to emission reductions. Thirdly, provision for trading among different GHGs will enhance opportunities for cost savings (Hahn and Stavins, 1995). In this case carbon dioxide (the most common GHG) can easily be thought of as the deciding unit. Finally, an international emissions trading can transfer income from developed to developing countries. It is expected that the developed countries will be potential buyer of the permits and the developing countries will be the potential sellers because historically the developed countries have been the big polluters of GHGs.

2.1.5. Issues regarding initial distribution of permits

There is debate over the process of permit distribution. The initial permit distribution can be either free of cost commonly known as grandfathering or through auction. Grandfathering of the permits suggests that on the basis of historical emissions in a base year, permits will be distributed free of cost. On the other hand all permits are purchased by the firms in an auction market. Auctioning of permits is preferred on many grounds. It offers government revenue and overcome entry barriers for the new firms. The major problem with the grandfathering system is due to the fact that licenses are granted to firms which are already major polluters (Bertram, 1992; Schneider and Wagner, 2003; Tietenberg, 2005). But auctioning permits in the international market is not a wise decision because the wealthy developed countries (commonly known as North) are in a position to buy a large share of permits, and the poor developing countries (commonly known as South) have to suffer its economic growth due to its incapability of buying permits. Therefore, in the context of global emissions trading in GHGs, Bertram (1992) suggests an initial distribution is on a per capita basis across the world population. The rents generated through reduced GHG emission and fine for law breaking would accrue to non-polluters, mainly those in the South.

2.1.6. Real life problems regarding emissions trading

All the theoretical arguments in the favour of tradeable permits hold in the realm of some restricted assumptions as mentioned earlier—the transactions costs associated with trading are small, the firms are price takers (or absence of market power), and firms comply voluntarily with their permit limits. But these restricted assumptions are very unusual in the real world, and particularly when we consider international trading of permits to reduce GHGs emission.

In fact transaction costs are quite natural to think in the transfer process of any property rights because parties must find one another, communicate and exchange information. In real world transaction costs can be thought of as the direct financial costs of brokerage services. Stavins (1995) identifies three potential sources of transaction costs in tradeable permit markets: (1) search and information, (2) bargaining and decision, and (3) monitoring and enforcement. It can be easily interpreted that these transaction costs is much higher if the firms of different countries want to engage themselves in international trading of emission permits.

In the global scenario, where permits are being traded among developed and developing countries, the level playground seems to be missing because the developed countries possess some market power. With market power in place, the theoretical promises of permit system are limited. In our thesis we have emphasised on this distortion particularly.

2.2. Literature related to market power in emissions permit system

In his seminal paper, Hahn (1984) challenged the least cost solution of Montgomery in the presence of market power. In the static (one period) model of Hahn, if the firm with market power does not receive an amount of permits equal to the number it chooses to hold in the equilibrium (to maximise its monopoly profit), then the total expenditure on aggregate abatement will exceed the cost minimising solution. This increase in cost (termed as inefficiency) increases in both directions whether the dominant firm (the firm with market power) gets less than or more than the optimal allocation. His model also links the permit price in the market with initial allocation made by the regulator. The more initial allocation is received by the dominant firm; there is a tendency of the permit price to be pushed up. This has intuitive justification. The more permits the dominant firm gets, the chances of it being a net seller increases, and the firm benefits from selling permits at a higher price. The fewer permits it gets, the dominant firm tends to be a net buyer, and the firm tries to keep price low.

The seminal work of Hahn (1984) has been extended in many different branches.

Misiolek and Elder (1989) differentiated between cost minimising manipulation as explained by Hahn (1984) and exclusionary manipulation of the dominant firm, where a firm influences the costs of other firms in the same industry and thereby enhance its monopoly power within the industry group. The dominant firm or in other words the firm with market power practicing exclusionary manipulation will always hold more pollution rights than it otherwise would. The authors note that depending on the initial allocation of permits, this additional strategic effect can sometimes worsen and sometimes alleviate the inefficiencies identified by Hahn (Montero 2009).

The laboratory experiment of Godby (2002) suggests that under this kind of a set up the linkage between permit and production market will help the dominant firm to exploit its market power if the permit trading is implemented. In small countries where smaller markets are dominated by single firm, this issue is a big problem.

A double auction market where both the buyer and seller make public offers to buy (bids) and to sell (asks) limits agent's influences on prices (Friedman 1984). Thus it has been thought as a probable solution to market power related problems. But it is highly debated. On one hand laboratory experiments of Carlen (1999) and Cason et al (2003) prove that dominant firm has difficulties to maintain influence over prices if trade is governed by double auction rule. On the other hand Godby (1999) and Muller et al (2002) show from their laboratory experiments that robustness of double auction to affect pricing of permits in the presence of market power is limited. Apart from double auction, a number of papers design new auction policies or quota system to tackle the problem emerging from market power (Hagem and Westkog, 1996; Sunnevag, 2003; Hagem and Westkog, 2009).

Since market power is very common a problem, this framework has been incorporated by different economists to extend the existing debate on emissions trading.

2.2.1. Literature on the incorporation of market power in compliance decision of firms

Another type of imperfection as explained by Malik (1990) is the imperfect regulation. Due to limited budget of the regulator and excessive monitoring costs, complete enforcement is not possible. This leads to non-compliance of firms. A firm realises that there is a chance of not been caught even if they emit more than the permissible limit (emitting more than the limit is termed as non-compliance). As the regulator penalises a non compliant firm (if caught), each firm maximises its expected profits. In the presence of noncompliance Malik showed that permit market loses its efficiency or least-cost nature. The presence of noncompliance essentially alters the equilibrium price (from MAC as in the benchmark case), but the direction (increase or reduce) of this departure is ambiguous. It depends on the firm's attitude towards risk.

In the presence of a complete compliance of firms market power does not seem to be a significant challenge to environment quality, because by design permit markets hold the aggregate level of emissions constant and thus initial distribution does not matter (Tietenberg, 1985). However, this is not true in the presence of cheating among firms, where the firms trade off between the permit price and the expected penalty for no cheating to decide their compliance level. Egteren and Weber (1996) merged the concept of compliance and market power to answer Tietenberg's (1985) argument.

The chief finding of Egteren and Weber (1996) is that when a firm has market power in the permit market, the initial allocation is fundamental in determining prices and levels of compliance for all participants in the permit market. In particular, they show that if there is a firm with market power (monopsonist buyer or monopoly seller) then an increase in the endowment of permits to this firm, accompanied by an equivalent reduction in the endowment of the competitive fringe, leads to an unambiguous increase in global violations and global emissions as long as the dominant firm is compliant. When the dominant firm is noncompliant, then a redistribution of permits from the competitive fringe to the dominant firm generates an ambiguous impact on global violations and global emissions since a redistribution of permits toward the dominant firm leads to an increase in the equilibrium price of permits. This increase in price leads to an increase in violations and a decrease in emissions among the fringe, but because the dominant firm holds more permits in equilibrium, its violations decrease even though its emissions increase. Since violations and emissions for the two groups move in opposite directions, the overall impact on global compliance and emission levels is parameter specific.

2.2.2. Literature on the incorporation of market power in banking and borrowing of permits

In the seminal paper on banking and borrowing of permits Cronshaw and Kruse (1996) argue that in absence of profit regulation equilibrium in the permit market will guarantee least cost solution, but not if firms are subject to profit regulation. In this situation a firm will be willing to bank permits only if their price rises with the rate of interest. Using a discrete time model, they demonstrate that in a competitive market for transferable and bankable emission permits, firms will allocate aggregate emissions between time periods to achieve the lowest present value of abatement costs. Rubin (1996) extends their work by providing a more general treatment of permit trading in continuous time through the use of optimal-control theory. From firm's point of view banking provides cost savings by allowing them to adjust their own internal rates of emission reductions to an externally set standard. So when social damages are an increasing function of the level of pollution emitted at any one time, then it is good public policy to allow firms to bank emissions by making standards stricter through time. This will lower the social damage. But Kling and Rubin (1997) show that allowing firms to freely bank and borrow emissions does not necessarily lead to a socially optimal solution. Although a banking system would generate the same level of total emissions (summed over all time periods) by construction, it does not follow that social damages will be the same. Total damages over a period of time depend not only on the total quantity of emissions, but also on when the emissions occur, thus emission banking, which allows the movement of emissions between time periods could well increase the present value of social damages.

Liski and Montero (2005) and Chevallier (2008) studied the effect of market power in the presence of banking and borrowing of emission permits but in a full-compliant set up. The former found that the dominant firm might bank the allowance and manipulate the permit price if it owns the entire stock of permits, but if the entire stock is given to the fringe firms then the dominant agent has an incentive to buy permits at the competitive price to build a permit-stock for the next period. The latter model demonstrated that the resultant price-distortion is a function of price elasticity of demand for permits of the dominant firm.

2.2.3. Literature on the incorporation of market power in multi-period models with banking and borrowing of permits in the presence of non compliance

In the inter-temporal set up effects of cheating (Stranlund, Chavez and Costello, 2005) and market power (Liski and Montero, 2005; Chevallier, 2008) have been studied separately. However, recently Sawhney and Mitra (2011) studied the combined effects of market power and cheating in a finite period model. In this set up the efficiency (measured as equimarginal principle) of the permit market is assured only when the dominant firm receives the exact amount of initial allocation it decides to hold in equilibrium. The degree of inefficiency is found to be the inverse of the price elasticity of demand for permits of the dominant firm, except that due to the presence of cheating one cannot equate the dominant firm’s permit trade (without bringing in violations). The compliance decision of the fringe firms is independent of the initial allocation of permits but it is not true for the dominant firm. The permit demand curve becomes more price-elastic in the presence of cheating, compared to a model with no cheating, which reduces the market power of the dominant firm. However the paper also comes up with some new results like conditions when the violations of both fringe firms and dominant firm moves in the same direction and opposite directions. In a multi period permit trading set up, where the initial endowment is expected to reduce over the time, the paper found the conditions for which the dominant firm's violation will reduce with its permit endowment over time.

2.2.4. Gap in the literature

In the literature of enforcement mechanism of emissions permit market (i.e. how penalty designs might affect compliance decision) the concept of restoration rate has gained importance. The restoration rate is the rate at which permit is subtracted in the next period for the amount of permit falling short in any period. This rule exists in the Kyoto Protocol with the rate to be 1.3 (Godal and Klaassen, 2006). The effect of restoration rate has been studied in a perfect competitive set up and it is found to increase the compliance rate (Hovi and Areklett, 2004; Restiani and Betz, 2010).If the dominant firm is a seller, then it can hold back some permit in the first period to push up the price. With banking the discounted permit prices are equalised over time but with restoration rate the permit price of the first period will be that (restoration rate) times higher than the discounted price in the second period (Godal and Klassen, 2006). Thus there is a complex interaction between the restoration rate (increasing compliance decision) and market power (affecting permit price).

However, up to now there is no theoretical model studying this interaction as per our knowledge. Thus, this thesis formulates a theoretical model of profit maximising firms to see whether the presence of a restoration rate alters efficiency and effectiveness of the permit trading market in the presence of two distortions (market and regulatory) in an inter-temporal permit trading market. In the process, the model extends the recent works of Sawhney and Mitra (2011) Egteren and Weber (1996), Rubin (1996), and Chevallier (2008), Godal and Klaassen (2006) and Restiani and Betz (2010).

2.3. Literature related to the inclusion of the aviation sector in the European Union Emission Trading Scheme/System (EUETS)[3]

In the light of the rapid growth of the aviation sector and the resulting CO_2emissions from that in 2006, Commission of the European Communities proposed to include aviation sector in European Union Emissions Trading Scheme/System (EUETS), which started on 1 January 2005, initially covered only energy-intensive industrial installations for the purpose of emission reduction. The 2006 proposal was finally adopted in 2009 and it was decided that, from 2011 all the European flights and from the beginning of 2012, emissions from all domestic and international flights – from or to anywhere in the world – that arrive at or depart from an EU airport will be covered by the EUETS. Like industrial installations, airlines will receive tradable allowances, covering a certain level of CO_2 emissions from their flights per year. After each year, operators must surrender a number of allowances equal to their actual emissions in that year.[4]

The European Commission (2006) proposal came with a detailed impact assessment for consumers, airlines as well as airport operators. According to that report, apart from the environmental benefit of reduced CO_2 emission, the adverse economic effects (increase in price, cost and others) will be insignificant. It suggested that airlines are expected to

[3]This entire part of the literature review (related to EUETS) is written during a research visit at HTW, Berlin (University of Applied Sciences) and later on published as Mitra, S. (2012) "Survey of Literature on the Impacts of Inclusion of the Aviation Sector in the European Union Emission Trading Scheme/System (EUETS)", Working Paper No. 02/2012, Berlin Working Papers on Money, Finance, Trade and Development

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[4]http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm

pass on large extent or even full of the additional costs from participating in the scheme to the consumers. According to the proposal, these additional costs for the consumers would affect demand growth only marginally, since the demand for aviation is not very price sensitive. Due to this small reduction in demand, the competition between airlines would not be significantly affected. These assumptions, on which the proposal is based, however, have been heavily criticised by some economists (Albers et al., 2009). Nevertheless, there are economists who strongly support the view that the economic impacts will be small. This recent debate led to a stream of literature studying different impacts of the inclusion of the aviation sector in EUETS.

In the real world, there have been massive oppositions from the domestic airlines of EU, as a result of which the program for only European airlines (planned to start by 2011) has already been postponed. However, the implementation will start by the beginning of 2012 with both domestic and international flights –that arrive at or depart from an EU airport. The existing literature in this particular area can be divided in some broad categories. Some initial papers focused on the different allocation methods of permits that can bring efficiency. Some papers studied the impacts of the policy on price. This includes both reduction in passenger demand (due to increase in airfare) and change in the existing aviation market structure (due to increase in cost). Since the international flights are also included in the scheme from 2012 onwards, competition among EU and non-EU airlines has also received much attention in the literature. Among other criticisms of the policy, probable carbon leakage has been cited strongly by different economists. However, according to some economists, there is nothing to be much bothered about the adverse effects of the current policy as those will be really insignificant.

2.3.1 Efficiency under different allocation methods of permits

Regarding the allocation method, different aspects of particularly three methods namely, grandfathering, auctioning and benchmarking have been emphasised in the literature. Just after the 2006 proposal, Morrell (2007) studied different allocation methods of emissions permits for only intra-EU flights. In that study, three United Kingdom (UK) airlines were selected to evaluate three main types of allocation: grandfathering, auctioning and benchmarking.

Grandfathering implies allocating free allowances on the basis of some historical emissions. Auctioning allowances implies airlines would need to bid for the CO_2 emissions that they would expect to require for the next year, to the European Commission. Benchmarking is another method of free allocation. It is also, like grandfathering, based on some baseline of historical emissions, however, it adds a sector specific measure. Morell (2007) suggested that revenue ton kilometers (RTKs) per tonne of CO_2 should be used for distribution of allowances to the aviation sector.

According to Morrell (2007), all the different methods have their own pros and cons. The grandfathering system is quite easy to implement, but the problem with this system is that, it in a sense rewards the more polluting airlines by providing more pollution allowance free. Auctioning is a fair method, especially between incumbents and new entrants, as well as faster and slower growing airlines. At the same time, it is revenue enhancing. However, airlines will obviously not prefer the system as it can increase their costs significantly. Benchmarking has the advantage of rewarding airlines that have already introduced efficient aircraft and those have achieved higher efficiency than their competitors. Benchmarking penalises those airlines that are less efficient than the ‘average’ and rewards those that do better. However, this ‘average’ can be formulated in different ways (Morrell, 2009).

Morrell (2007) considered representative airlines of the three major airline business models, namely, British Airways (Network carrier), easyJet (Low Cost Carrier) and Britannia/Thomsonfly (Charter/leisure airline). Based on 2003-04 aircraft or engine type and operating data, the per passenger impact of each allocation option was analysed for each airline.

Depending on operational characteristics, LCC and charter models had higher load factors and higher density seating. Whereas almost all easyJet’s RTKs were within the European Economic Area (EEA), Britannia/Thomsonfly operated longer haul charters to the Caribbean, Mexico, Egyptand Asia. British Airways carries the major part of its

RTKs on routes to/from non-EU countries. From the perspective of fuel efficiency, British Airways was found to be little below the industry average fuel efficiency in both passenger and seat terms. EasyJet performed much better, due to both more seats per aircraft and a higher average passenger load factor. Britannia/Thomsonfly also had high seat density, and even higher load factors, in addition to operating larger aircraft types. Thus, the method of allocation of ETS allowances was thought to be crucial in terms of the impact on various players. The analysis examined the impact over 2005 and 2006, assuming the traffic growth rates to be 4% for British Airways for each year, 30% and 15% for easyJet and 10% for Britannia/ Thomsonfly for both years. Morrell (2007) found, the impact to be greater on the Low Cost Carriers (LCC) in all cases in comparison to the other types of airlines considered, although not by too much.

In reality, all participants interested in receiving emissions allowances, will have to apply for those, a large part (82%) will be issued free of charge by grandfathering based on average historical emission levels between 2004 and 2006 while only 15% will be available for auctioning. The general idea with the EUETS is to increase the number of allowances put up for auctioning in each period. The revenues from auctioning can be used quite freely by each member state but it is suggested they be used for emissions reducing activities such as research for more fuel efficient engines (Kopsch, 2009). At the same time, airlines can acquire additional allowances (most likely from other industries) if they require more (Albers et al, 2009).

The total number of allowances allocated for free to each aircraft operator will be determined by a benchmark which is calculated in three consecutive steps: First, the share of auctioned allowances is subtracted from the overall cap. Second, the remaining amount of CO_2 emissions is divided by the sum of verified tonne-kilometre data for flights falling under the geographical scope of the ETS in the monitoring year 2010, as reported by all participating aircraft operators. Third, the specific amount of allowances each operator receives is calculated by multiplying the respective individual tonne-kilometre value of the monitoring year with the benchmark. Each operator's revenue tonne-kilometres are calculated by multiplying the mission distance (great-circle-distance plus an additional fixed factor of 95 km) by the payload transported (cargo, mail and passengers).Allowances not used in 2012 can be ‘banked’ i.e. carried over for use up to 2020 (Scheelhaase et al., 2010).

Regarding the competition, both the aspects - competition among different types of European flights and international competition between European and non-European flights received much attention in the literature.

2.3.2 Effects on domestic competition

Before the postponement of the planned 2011 phase, the effects of the policy on different types of EU airlines have been studied extensively. Scheelhaase and Grimme (2007) estimated the financial burden of the additional allowances as well as the impacts on travel demand (when these additional costs are passed on to passengers) for domestic LCCs full service network carriers(FSNCs), holiday airlines and regional airlines. The difference was expected because of peculiarities in their network and passenger structures, growth rates and ticket prices. They considered representative airline for each of the four types for illustrative purposes. Ryanair was taken as the LCC, Lufthansa as the legacy network carrier, Condor as the vacation airline and Air Dolomiti as the regional airline.

The impacts of three options were analysed for the period 2008-2012. In Option 1 relatively favourable conditions for airlines have been considered like, relatively generous initial allocation of allowances, low allowance prices, low price elasticities of demand and low rate of emissions growth. On the other hand, Option 3 embodied relatively unfavourable assumptions, such as a reluctant initial allocation, and higher allowance prices, high price elasticities of demand, and emissions growth. In both these options initial allocation was taken to be based on historical emissions, whereas in Option 2 initial allocation was taken to be based on a grandfathering approach. Due to unavailability of route-specific emissions and fuel consumption data, the authors estimated the carbon dioxide emissions for Ryanair, Lufthansa,Condor and Air Dolomiti for 2004 by using a bottom-up approach, which estimated the carbon dioxide emissions as a linear function of publicly available fuel consumption data (Scheelhaase and Grimme, 2007).

Their quantitative analysis showed that the financial impacts on airlines subject to the ETS will be moderate. Among European carriers the relative reduction in demand will be more for low cost carriers (LCCs) compared to high cost carriers, because their passengers are generally more price sensitive. However, according to the authors, even the LCCs are not likely to be adversely affected because their operating margins exceed the market average. Also, Anger and Kohler (2010) emphasised that the high annual growth rate of these airlines easily compensate for these losses.

2.3.2.1. Effects of domestic competition on market structure

Inclusion of the aviation sector into EUETS will result in a cost increase to the airlines. This will imply a rise in cost per passenger or unit of freight. The amount of increase in costs that is not passed onto consumers will reduce company profits (Ernst and Young, 2007) and affect the competition among airlines. Now, the impact on price and competition depend on several factors like, whether the short run or the long run is being considered and the structure of the market. Three possibilities for market structures are competition, monopoly and oligopoly.

According to Forsyth (2008) it is probably best to analyse market structure at the route level, i.e. at the route level, there can be competition, monopoly or oligopoly. Some busy routes could be considered competitive, since there are large numbers of airlines serving the route. Airlines in these markets can be regarded as price takers, and have little scope to employ oligopolistic strategies. In the short run, in a competitive market, the permit system will impose a loss on firms in the market. As long as the price exceeds average variable cost, all airlines will stay in the market, offering the same amount of capacity. Prices will remain the same, and airlines will incur losses. Thus, some airlines will exit from the market. In the long run there will be full pass of the cost rise to the passengers. The reduction in demand will however depend on the elasticity of demand for flights.

The impact on the number of firms will depend on the cost structure of the airlines. The higher costs and prices in the market are likely to be accompanied by fewer firms of about the same scale.

At the other end of the scale, routes could be monopolistic. There are many routes around the world which have only one airline serving- these are typically thin low density routes. While monopolistic, meaning that the airline has some discretion over pricing, these routes will often be marginal, not highly profitable, and airlines may face competition from surface transport. With monopoly, there is little difference between the short and long run cases. Due to an increase in marginal cost, price will increase but not of the full extent. The exact amount that price rise will depend on the elasticity of demand and on the form of the marginal cost function. With the smaller price increase, the monopoly is unable to pass on the full cost increase. The airline will face an unambiguous reduction in profit. This could lead to the route becoming unprofitable in the short and long run. If prices are less than average variable cost, the airline will exit the route in the short run, and if they are less than average cost, the airline will exit in the long run. However, the airlines may continue to serve the market even though they are earning insufficient revenue to cover the cost of the capital they have invested. When demand grows enough to eliminate the excess capacity in the industry, the airline may drop more marginal routes (redeploying capacity to more profitable routes) (Forsyth, 2008).

However, according to the author, the most common market structure in the aviation sector is perhaps oligopoly. There are many routes with around two to four airlines. These airlines possess some market power, and also recognise their interdependence. The distinction between short and long run is important in the oligopoly case, because the number of firms in the market is fixed in the short run, but variable in the long run. In oligopoly, firms may employ different strategies, such as Bertrand or Cournot strategies, and these will affect outcomes. If the airlines on a route indulge in Bertrand competition, then they will initially be unable to increase prices with an increase in cost, and they will face losses (Again, they will exit if prices fall below average variable cost). In the long run they will only continue to serve the market if they are covering their costs. If this is not feasible, firms will exit, allowing prices to rise. The long run outcome of the imposition of the carbon permit requirement will be that the costs will be passed on to passengers, and the profitability of the airlines will be maintained, though there could be fewer firms competing in the market. In the Cournot case, prices can be set above marginal and average costs. If there are very few firms, prices will be below, though close to monopoly prices, while if there are several firms, prices will be closer to competitive levels. In the short run, with a fixed number of firms, a cost increase will lead firms to increase prices, though the per unit price increase will be smaller than the per unit cost increase. The burden of the price will be shared by the airlines and their passengers (Forsyth, 2008).

According to Forsyth (2008), due to an increase in cost, if after all adjustments some airlines decide to exit from the market in the long run, then with this reduction of numbers of airlines, the market power of the larger airlines will increase. This can have a strong effect on market structure. However, after the postponement of the planned 2011 phase, the emphasis of the ongoing literature has shifted more domestic competition towards the international competition, as the policy will be affecting both European and non-European flights from the beginning of 2012.

2.3.3. Effects on international competition

Among international airlines it is expected that the non-European network carriers (which are partially out of the coverage) will most likely gain a significant competitive advantage compared to European network carriers (which are entirely within the coverage) (Scheelhaase et al, 2010).

Scheelhaase et al. (2010) studied competitive impacts of the EUETS on EU- and US-based network carriers and provided a comparison between Lufthansa and Continental Airlines. Lufthansa was chosen as a representative European network carrier, which is heavily dependent on feeder flights for its intercontinental operations. Continental, on the other hand, is an important competitor of European network carriers, whose business model in recent years focussed strongly on decentralised intercontinental services.

Their analysis was divided into three main parts: In a first step, the fuel consumption and CO_2 emissions was calculated, which were prerequisites for estimation of the benchmark used for initial allocation and also the total emissions of the airlines' flights subject to the EUETS. In the second step of the analysis, the initial allocation of allowances was modelled. This included the estimation of the underlying benchmark and the tonne-kilometres performed by each carrier in 2010. In the third step, the total CO_2 emissions for both airlines in 2012 were roughly estimated. In a final step, the resulting impacts of the EUETS on ticket prices and freight rates were estimated.

They found that, in comparison to Continental Airlines, Lufthansa will experience a significantly greater disadvantage from the inclusion in the EUETS. This disadvantage is not only due to the fact that, all long-haul flights arriving at and departing from airports in the EU will be included into the EUETS, but this also holds for all short-haul flights, which are less environmentally efficient than long-haul flights (calculated on the basis of emissions).However, the biggest disadvantage Lufthansa will be facing in comparison to Continental is that all feeder services for its long-haul flights are subject to the EUETS. Continental in turn operates its own feeder network on the other side of the Atlantic and is therefore with this part of its operations not included in the EUETS. Therefore, in total, the distance travelled with Lufthansa under the EU-ETS is more than60% longer than with Continental Airlines (Scheelhaase et al., 2010).

Albers et al. (2007) conducted a route-based analysis, simulating cost and demand implications for selected airlines. Their results also illustrated the differences between the cost increase for European and non-European airlines due to inclusion of the aviation sector into the EUETS. They found an extreme case of New York – Delhi connection which is offered by Continental Airlines as a direct flight and by several European carriers as a one-stop connection via their respective hub. Lufthansa's (EU airline) routing via Frankfurt led to additional costs of 26.79 Euro per trip per passenger (i.e. more than 53 Euro both ways) whereas Continental – not stopping in EUETS territory – is completely unaffected.

Some economists are afraid of the emergence of artificial stops outside EU territory, or even the complete redirection of traffic flows, due to this policy. Artificial stops may occur in nations not covered by the system but close to EU territory (e.g. Switzerland, Turkey), and may be particularly interesting for non-European long-haul carriers on high density routes. While these additional stopovers could lead to reduced emission costs for airlines, they would lead to longer travelling times and incur additional costs like increased airport charges. The complete redirection of traffic flows could lead to a strengthening of hubs within the mentioned territories (e.g. Zurich, Istanbul) and their respective carriers such as Swiss and Turkish Airlines or of more distant hubs (e.g. Dubai, Doha)with carriers such as Emirates and Qatar Airlines (Vespermann and Wald, 2010)[5]. Even though Vespermann and Wald (2010) concluded that emission costs are not high enough to instigate major route reconfigurations among European airlines, however, their results support competitive advantage for carriers outside the EU market, such as airlines from the Middle East.

Apart from the economic problem of competitive disadvantages faced by the European airlines, this probable route configuration (particularly via hubs just outside EU) might even result into an environmental phenomenon commonly known as carbon leakage.

2.3.4. Issues on carbon leakage and other limitations

Carbon leakage is said to happen if due to any carbon emission reducing effort, CO_2emission increase as a result. Since CO_2 is a global pollutant, so it does not matter where the emission is increasing finally. According to Ernst & Young (2007) report the special characteristic of the aviation sector is that it does not manufacture products but provides service. The so called product (a seat offered on a given flight) cannot be stocked and an unsold seat is definitely a loss. Due to a rise in cost and air fares demand

[5]This point has also been reemphasised by Jörg Schulze, Rechtsanwalt Recht, Sicherheit und Umwelt BDF (Bundesverband der Deutschen Fluggesellschaften e.V.) in an interview in 2011 during my DAAD fellowship in Germany.

will reduce and some seats will be empty. EU carriers cannot realistically switch their activities away from EU and move their fleet outside the EU. However, passengers can easily shift to non-EU carriers or use alternative routes if that is less costly for them.Carbon leakage in aviation sector is linked neither to a product nor the place of production. It is not the production facilities (supply driven carbon leakage) but the demand (i.e. passengers and goods) that generate carbon leakage.

The Ernst & Young (2007) study identified few channels for probable carbon leakage:

a) 8% of passenger traffic arriving at EU airports from non-EU origins is connected to non-EU destinations. Those passengers (and possibly some cargo traffic) could bypass the EU and fly to their final destinations via a non-EU hub, for example in Middle East which faces no EUETS costs. The result would be less activity for European carriers and their home airports but an increase in unregulated emissions around the world.

b) In international markets between EU and non-EU airports where no direct flight is available, passengers do not have the option to choose a direct long haul flight from their departure airport and will have to hub either at an EU or a non-EU airport to reach their non-EU destination. Since these passengers care little about their connection points, unless it adds significant time to the journey, they will be highly sensitive to price and could easily switch to non-EU connecting hubs. This might increase the distance travelled and more emission as a result.

d) Cargo airlines could choose to add a stopover outside the EU in order to reduce the distance covered by the EUETS. Russia, non-EU countries in Eastern Europe, Central Asia, the Middle East and North Africa could become potential stops. In some cases these points may be on a longer route generating higher emission than a direct route.

e) Around 25% of passenger traffic at EU airports is generated by non-EU residents travelling into the EU for leisure. Rising prices caused by the EUETS could result in some of these inbound tourists being diverted to non-EU destinations, thereby causing carbon leakage.

f) For intra-EU markets, increased carbon emissions will be caused by the diversion of short-haul air passengers to surface transport modes which are not subject to the EUETS or not covered by other restrictions on carbon emissions. This channel for leakage will particularly affect regional routes where price rise will lead to switching to cars or train.

At the same time airlines in the EU will have an incentive to replace their fleets with newer, lower emissions aircraft, selling their older aircraft to other countries – their reduction in emissions is partly achieved by shifting emissions offshore (Forsyth, 2008).

Apart from the carbon leakage, some authors question the basic potentials of this policy to reduce carbon emission (Anger, 2010; Anger and Kohler, 2010; Vespermann and Wald, 2010).

One purpose of including aviation sector into EUETS is to provide incentives for cleaner technology. Imposing extra environmental costs on the airline operators has the potential to decrease their profitability. This might trigger technological change in the long run to restore profitability through low polluting flights. At the same time, profitability is also closely linked to the ability to pass on the increased costs to the consumers. Increased costs for consumers have a tendency to dampen their demand. According to the proponents of EUETS, this will result in a decrease of emissions as capacity is reduced to match demand. However, this holds only if the reduction in demand is large enough to reduce the number of flights and not just the number of seats occupied in a plane during a flight (i.e. a decrease in the load factor) (Anger and Kohler, 2010). Moreover, the current technology in the aviation market is argued to be mature, so dramatic improvements in fuel efficiency will require fundamental improvements to airframe aerodynamics and engine technology (Anger, 2010).

According to Vespermann and Wald (2010) the relevant literature on modelling of travel demand and resulting emissions is often subject to errors. Although they are based on the most detailed data publicly available, but real data on ticket prices, flight fuel consumption and demand elasticities are only available with airlines. Therefore, some of the data used for these studies are only approximations. As a consequence, potential limitations with respect to the validity of the results lie within the data assumptions. While parts of the data will eventually be published, other data is unlikely to ever be publicly available.

2.3.5. Arguments in favour of the policy

Although this policy is being criticised by some EU airlines, which are afraid of facing a competitive disadvantages and also some economists have highlighted the cost of network reconfigurations due to international competition, however, Albers et al. (2009) argued that the international competitive disadvantage alone is not significant enough to instigate major route network reconfigurations as threatened by individual carriers[6]. Although it is true that the cost will increase in the currently used route in EU, however, compared to the cost increase, which the airlines sustained in recent years due to higher oil prices, the costs incurred due to an ETS will be considerably low (Scheelhaase and Grimme, 2006). Thus, if the route network reconfiguration is not much probable to take place, the threat of carbon leakage due to that is baseless.

Inclusion of aviation sector in the current EUETS has its other benefits as well. Economists argue that an ETS works most efficiently if there is a single price for carbon for all industries, since this would encourage the greatest reduction being achieved in the industries which face the least cost in reducing emissions e.g. power or energy sector (Forsyth, 2008). It is possible that, under an ETS, the reductions in emissions in some sectors such as the aviation may be quite small, because they do not have much scope to reduce. However, this might lead to an increased trade of permits from the other sectors (e.g. power or energy sector) to the aviation sector. So it does not matter really

[6]This point has been accentuated in an interview with Dr. Ing. Jonathan Köhler, Fraunhofer-Institut für System- und Innovationsforschung ISI Sustainability and Infrastructure Systems in the telephonic interview in 2011during my DAAD fellowship in Germany.

particularly in which sector the emission is reducing the most, until the overall carbon cap for EUETS is maintained[7].

2.3.6. Gap in the existing literature

The survey of the relevant literature reveals that the major emphasis is on the distortion of the current competition, both for intra and inter-EU airlines, particularly the international competition between EU and non-EU airlines. In the international routes where the EU airlines compete with non-EU airlines, the fear of a loss of competition for EU airlines has been highlighted as an effect of probable reconfiguration of the current route-network. From environmental point of view carbon leakage is a concern which can take place via two avenues - reduce CO_2 emission in EU and increase it outside EU, or even worse, if the non-EU airlines decide to fly longer distances to save permit costs, then the global emission will even increase as a result.

As per our knowledge, up to now there has been no theoretical work explaining different conditions of these distortions taking place. The theoretical model of Brueckner and Zhang (2010) studies the airlines' response to a policy-induced increase in the effective price of fuel on airfares, fuel efficiency and aircraft size for two competing duopoly airlines. Their results show that emission charges will raise fares, reduce flight frequency, increase load factors and raise aircraft fuel efficiency, while having no effect on aircraft size. However, these results are identical for the two airlines since their model has two homogeneous airlines.

[7]This point has been reaffirmed by Dr. Janina Scheelhaase, Head of Air Transport Economics, Institute of Air Transport and Airport Research, German Aerospace Centre (DLR) in the personal interview in 2011 during my DAAD fellowship in Germany.

This thesis extends Brueckner and Zhang (2010) in the international competition with one EU airline and the other non-EU airline to study how the competition between the two airlines changes in the long run when the permits will be auctioned (thus will add to the cost) compared to the short run when permits will be given free[8] along with the necessary and sufficient condition for a carbon leakage.

2.4. Literature related to gains from trade of technological advanced environmental goods

Environmental goods and services (EGS) as a subset of goods and services were separated out for special attention in the negotiating mandate adopted at the Fourth Ministerial Conference of the World Trade Organisation (WTO) at Doha in November 2001. Paragraph 31 (iii) of Doha Ministerial Declaration contains the negotiations on the reduction or, as appropriate, elimination of tariff and non-tariff barriers to environmental goods and services.[9]

For the developing countries, these are high technology products imported by them from the developed countries, thus, the issue of liberalisation of EGs falls under the realm of gains from trade of technologically advanced goods.

2.4.1. Theory of gains from trade and technology

The comparative advantage of the technologically advanced intermediate good is different from the consumption and production gains that we find in the traditional trade theories of Ricardo and Heckscher-Ohlin. The Research and development (R&D) intensive intermediate goods possess the characteristic of economies of scale or

[8] For simplicity of our model we assumed free permits in the short run, whereas in reality 85% of the total emission permits are given free, with the remaining 15% auctioned currently and movement to a 100% auction system is envisioned in later years (Brueckner and Zhang, 2010)
[9] http://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_e.htm

decreasing cost. The initial cost of R&D is very high and keeps on declining with each unit sold. Thus, producing at one single point and serving a large market creates cost efficiency than producing at different places and serving segregated markets (Ethier, 1979). If trade in intermediate goods of this kind is possible, then it is desirable to produce the goods in the countries where the cost is lower, rather than one country specialising in the entire production of the final good. Studies focusing on gains from trade of technology (Romer, 1990; Grossman and Helpman, 1991) treat trade of commercially oriented innovation efforts, as a major engine of productivity growth (Coe and Helpman, 1995). According to them, R&D spending creates new technology in the form of product designs for new or specialised intermediate goods. The development cost for this purpose, is incurred by a single inventor, whereas many firms can benefit higher productivity from that intermediate good. Trough trade, even industries in different countries can get access to these technologically advanced intermediate goods from different R&D conducting sources (Keller, 2002).

When these goods (like machines) are used as factor of production in the importing country, then these countries gain through an increase in productivity. The increase in the productivity level of the importing country takes place via four channels particularly-through a larger variety of intermediate products and capital equipment; through cross-border learning of production methods, product design, organisational methods and others; through international contacts and knowledge to imitate foreign technologies; and finally through the development of new technologies in the importing country itself (Coe et al., 1997).

Developing countries gain more from trade of technology compared to developed countries, because they hardly invest in their domestic R&D sector (Coe et al., 1997). Price of capital goods is relatively lower in higher income countries, thus, a less developed country (which have comparative disadvantages in the production) can import capital goods from a developed country and can increase its growth rate by combining them with domestic capital goods (Lee, 1995; Estevadeordal and Taylor, 2008). According to Bas (2010) the access to imported inputs boosts the performance of domestic firms in developing countries in two ways. Firstly, the access to more efficient and sophisticated foreign inputs affects factor prices and therefore the competitiveness of the firms. Secondly, improvement of the competitiveness of domestic firms increases expected export revenues, thus, allow more firms to enter the export market (extensive margin of trade) and to increase the volume of their export (intensive margin of trade).

However, according to Chuang (1998), trade openness is just a necessary but not a sufficient condition for trade induced learning or growth. It is more technological advanced trading partners and more technologically advanced goods that stimulate the technology spillover. At the same time, most form of trade induced learning for the developing countries are not automatic. Learning may be costly and it takes time and resources to learn and apply a foreign technology successfully. There are important roles for different government policies as well (Mendoza, 2010). The next section deals with some empirical literature on gains from trade of technology.

2.4.2. Empirical works on gains from trade of technology

Economists had tried to estimate the above mentioned theoretical gains empirically. The empirical works are majorly based on the theoretical models of innovation driven growth of Grossman and Helpman (1991). The intuition behind the theoretical model is that, economy manufactures final output Y from an assortment of intermediate inputs. Now, the inputs can be either horizontally differentiated or vertically differentiated. In case of horizontally differentiated inputs, the measure of available inputs expands as a result of R&D investment. In case of vertically differentiated inputs the effectiveness of an input in manufacturing depends on the number of times it has been improved. Entrepreneurs invest in R&D to improve inputs and inputs that have been improved more times are more productive. Thus, in both the cases total factor productivity (TFP) is an increasing function of cumulative R&D. With output (Y) coming from two inputs capital (K) and labour (L), $Y=f(K,L)$, the TFP is simply defined as $logY - \beta logK - (1-\beta)logL$, where β is the share of capital in gross domestic product (GDP) (Coe and Helpman, 1995).

To apply this theoretical model in order to study the role of international trade, Coe and Helpman (1995) considered an extreme case in which all intermediate inputs are traded internationally. In that situation the above mentioned relationship between TFP and cumulative R&D remains valid, only the relevant measure of R&D capital becomes the entire world's capital stock rather than the individual country's R&D capital stock. However, in this extreme case, there is no possibility of productivity distinction between domestic and foreign R&D. Thus, shifting from the extreme situation of all intermediate to be traded, they finally formulated the empirical equation incorporating both foreign and domestic R&D capital stock as

$$logF_i = \alpha_i^0 + \alpha_i^d logS_i^d + \alpha_i^f logS_i^f$$

Where i is the country index, $logF$ is the log of TFP (equal to $logY - \beta logK - (1-\beta)logL$), S^d represents the domestic R&D capital stock, and S^f represents the foreign R&D capital stock defined as the import-share-weighted average of the domestic R&D capital stocks of trade partners. The importing country's total import has been taken as one and the import share from different exporting countries has been used as weights. It implies that the weights are fractions that add up to one and therefore do not reflect the actual level of imports. Thus Coe and Helpman (1995) finally used a modified equation which captures the interaction between foreign R&D capital stocks and the volume of international trade as:

$$logF_i = \alpha_i^0 + \alpha_i^d logS_i^d + \alpha_i^f m_i logS_i^f$$

Where m_i stands for the share of imports in GDP for the i^{th} country. In the above equation, the elasticity of TFP with respect to the domestic R&D capital stock is α_i^d,while the elasticity of TFP with respect to the foreign R&D capital stock is $\alpha_i^f m_i$, for the i^{th} country. It implies that whenever α_i^f is the same for all countries, the latter elasticity ($\alpha_i^f m_i$) varies across countries in proportion to their import shares.

Empirically, Coe and Helpman (1995) estimated the effects of domestic and foreign R&D capital stocks on TFP for 21 organisation for Economic Cooperation and

Development (OECD) countries plus Israel, for the period 1971-90. Using pooled time series cross section data they found that both domestic and foreign R&D capital stocks have significant positive effects on TFP. At the same time, foreign R&D capital stocks have stronger effect on TFP the larger the share of domestic imports in GDP, which implies that more open economies extract larger productivity benefits from foreign R&D than less open economies. By measuring the importance of the R&D capital stock by the elasticity of TFP with respect to the R&D capital stock, Coe and Helpman (1995) compared the elasticities of domestic and foreign R&D capital stock and found that, foreign R&D capital stock is more important for the countries with lower GDP (and thus lower domestic R&D capital stock), compared to the larger countries in terms of GDP.

The developed countries invest substantially in domestic R&D. However, this is not true for the less developed countries (LDCs). However, they still benefit from the R&D performances of other industrial countries (Coe et al., 1997). In order to study the gains from trade of technology for only the LDCs, Coe et al. (1997) modified the earlier model by omitting domestic R&D capital stock and incorporating human capital and other trend variables relevant for LDCs, as:

$$logF_{it} = \alpha_i^0 + \alpha_i^S logS_{it} + \alpha_i^M M_{it} + \alpha_i^E E_{it} + \alpha_i^T T_t + \mu_{it}$$

Where t index time periods along with the usual country index i, M_{it} is the share of machinery and equipment imports from industrial countries in GDP, in each developing country i in the time period t. Since they took only those LDCs in the sample those hardly invest in R&D themselves, thus only foreign R&D capital stock S_{it} has been considered instead of both foreign(S^f) and domestic(S^d) R&D capital stock as in the case of developed countries. Since productivity also depends on the quality of a country's labour force, i.e. on its human capital, thus, E, the secondary school enrollment ratio was taken as proxy. A time trend T was also allowed to capture the impact of other ongoing secular changes in the LDCs, and μ is white noise error term. They used imports of machines as the weights for the foreign R&D capital stock index.

Expecting important interactions between the foreign R&D capital stocks and import shares as well as secondary school enrolment rates separately, a further modification was done by the authors including the interaction terms as:

$$logF_{it} = \alpha_i^0 + \alpha_i^S logS_{it} + \alpha_i^M M_{it} + \alpha_i^E E_{it} + \alpha_i^{SM} M_{it} logS_{it} + \alpha_i^{SE} E_{it} logS_{it} + \alpha_i^T T_t + \mu_{it}$$

The positive coefficient on the interaction of trade with the foreign R&D capital stock $\left(\alpha_i^{SM} > 0\right)$ implies that the effect of foreign R&D on domestic productivity is larger the more open the economy is to foreign trade, and the effect of foreign trade on productivity is larger the larger is he foreign R&D capital stock. Similarly a positive interaction of education with foreign R&D $\left(\alpha_i^{SE} > 0\right)$ implies that the effect of the foreign R&D capital stock on productivity is larger the more educated is the domestic labour force, and the effect of education on productivity is larger the larger is the foreign R&D capital stock.

The empirical work of Coe at al. (1997) with 77 developing countries over 1971-90 suggested that the R&D spillovers from North (developed countries) to South (developing countries) are substantial. The R&D spillovers were measured by the elasticity of TFP in the South with respect to R&D capital in the North. According to them the LDCs benefit more from foreign R&D spillovers the more open they are and the more skilled their labour force is. The study considered imports of machinery and equipment, rather than total imports of goods and services, which was more consistent with the theory of LDCs and also better explained empirically (Coe et al., 1997).

Some economists have tried to segregate the effects of only R&D intensive intermediate inputs to the overall effects of imports. Lee (1995) empirically investigated the positive link between the growth rate and the ratio of imports in investment by estimating the following regression model:

$$GY_i = constant + aZ + b_i I_i + \varepsilon_i$$

Where, GY_i is the growth rate of per capita income of ith country, $I_i$is a set of variables that are included in the regression as important explanatory variables like initial real GDP, the initial secondary school enrolment rate, the investment share of GDP, the average annual rate of population growth, total import in GDP, government consumption and others. The regression basically tested whether any independent effects exist with respect to the ratio of imported to domestic capital goods (Z). He examined data for 89 industrial and developing countries during 1960-85 and found empirical evidence that the real per capita growth rate of a country tends to be higher if foreign capital goods are used relatively more than the domestic capital goods in the production of capital stock. His results also clearly indicated that the importation of capital goods, not total import, is the key factor that links trade to economic growth.

On the similar lines, according to Busse and Groizard (2007), the imports of R&D intensive goods are the appropriate measure for technology diffusion as a source of productivity growth, rather than the total volume of overall trade. At the same time the paper also highlights the importance of the institutions. Before the empirical estimation, the authors define technology goods on the basis of Standard International Trade Classification (SITC). Then, they estimate the following regression equation:

$$\begin{aligned} log\, m_{ijt} = a_0 + a_1 logD_{ij} + a_2 logA_i + a_3 logA_j + a_4 logP_{it} + a_5 logP_{jt} + a_6 L_i + a_7 L_j \\ + a_8 Cont + a_9 Cont\, logD_{ij} + a_{10} Cont\, logA_j + a_{11} Cont\, logA_j \\ + a_{12} Cont\, logP_{it} + a_{13} Cont\, logP_{ij} + a_{14} Cont\, L_i + a_{15} Cont\, L_j + e_{ijt} \end{aligned}$$

Where m_{ijt} represents technology imports by country i from (OECD) country j divided by the GDP of the importing country at time t. D stands for the distance between countries i and j, A for (land) area and P for population size. $L$is a dummy variable taking the value one when the country i or j has access to an ocean and zero otherwise. $Cont$ represents countries share a common border (value equal to one) or not (zero). Additionally authors included interactions between contiguity and distance, are and population to explore the fact that countries with a common border trade more with each other. In this way, the instrument for technology imports was computed.

Next, these authors assessed the determinants of per capita income levels by estimating the following regression equation:

$$log\ Y_i = \alpha_0 + \alpha_1 I_i + \alpha_2 logT_i + \alpha_3 logM_i + \alpha_4 DE_i + e_i$$

Where Y_i represents GDP per capita in country i, I_i stands for institution, T_i is overall trade as a share of GDP, M_i is the imports of R&D intensive goods as a share of GDP, DE_i is the distance from the equator and e_i is the error term. This equation was estimated on United Nations (UN) data on 108 industrialised and developing countries during 1965-95, to conclude that imports of R&D intensive goods contribute to economic growth, even after controlling for the effects of institutional quality and economic integration.

The above studies deal with economy-wide gains from technology. The importance of trade in advanced intermediate goods for technology transmission is also studied at industry level instead of aggregate data (Keller, 2002). Industry level study is important because R&D expenditures are not uniformly distributed across all industries. Keller (2002) used data on manufacturing for eight OECD countries for the years 1970-1991. The sample of countries considered by him - Canada, France, Germany, Italy, Japan, Sweden, the United Kingdom and the United States- covered a large share of the world's manufacturing output as well as innovative activity in the time period of the study. The two regression equations he estimated are:

$$logF_{cit} = v_t + \varsigma_{ci} + \beta_1 log\left(S_{cit} + \beta_2 S_{cit}^{io} + \beta_3 S_{cit}^{f} + \beta_4 S_{cit}^{f,io}\right) + \varepsilon_{cit}\ \ , \forall\ c, i, t$$

and $$logF_{cit} = v_t + \varsigma_{ci} + \beta_1 log\left(S_{cit} + \beta_2 S_{cit}^{tm} + \beta_3 S_{cit}^{f} + \beta_4 S_{cit}^{f,tm}\right) + \varepsilon_{cit}\ \ , \forall\ c, i, t$$

Where, F is the TFP, c, i, t are respectively country, industry and time indices, v_t and ς_{ci} are the time, country and industry specific variables and ε_{cit} is the error term. io and tmstand for input-output (IO) and technology matrix (TM) specifications respectively. S_{cit} and S_{cit}^{f} denote domestic and foreign own industry R&D variables respectively, whereas S_{cit}^{io} (S_{cit}^{tm}) and $S_{cit}^{f,io}$($S_{cit}^{f,tm}$) represent domestic other industry and the foreign other industry R&D variable in IO (TM) specifications respectively. His results confirmed the earlier findings that R&D investments are positively related to productivity growth at the industry level as well. He found evidence of benefits from other industries' R&D investments too, although own-industry R&D was more important source of increase in productivity.

For manufacturing firms in Indonesia, Blalock and Veloso (2007) tried to estimate whether imports can improve firm technological capabilities, as measured by productivity gains. They obtain establishment-level productivity by estimating a translog production function:

$$\begin{aligned} lnY_{it} = {} & \beta_0 Downstream\_Imports_{jrt} + \beta_1 ln\, K_{it} + \beta_2 ln\, L_{it} + \beta_3 ln\, M_{it} + \beta_4 ln\, E_{it} \\ & + \beta_5 ln^2 K_{it} + \beta_6 ln^2 L_{it} + \beta_7 ln^2 M_{it} + \beta_8 ln^2 E_{it} + \beta_9 ln\, K_{it} ln\, L_{it} \\ & + \beta_{10} ln\, K_{it} ln\, M_{it} + \beta_{11} ln\, K_{it} ln\, E_{it} + \beta_{12} ln\, L_{it} ln\, M_{it} + \beta_{13} ln\, L_{it} ln\, E_{it} \\ & + \beta_{14} ln\, M_{it} ln\, E_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned}$$

Where, Y_{it}, K_{it}, L_{it}, M_{it} and E_{it} are the amounts of production output, capital, labour, materials and energy for establishment i at time t; α_i is a fixed effect for factory i, γ_t is an indicator variable for year t and ε_{it} is the error term, r subbscript stands for region. They found a positive coefficient of $Downstream\_Imports_{jrt}$, indicating that downstream imports are associated with higher productivity in the supply sector. Using panel data they found that firms in industries involved in more import-intensive production experienced higher productivity growth compared to other firms for the period 1988-96 in Indonesia.

Since R&D expenditures are not uniformly distributed across all industries, thus industry specific empirical studies on gains from trade of foreign technology via different channels came up with diversified results for various industries in different countries. For manufacturing sector the effect was generally positive, although neutral or even negative effects of foreign technology was also witnessed in some other sectors (See the literature survey of Liu, 2008).

A firm-level study of the Chinese economy showed that it is even possible that technology spillovers have a negative effect on the productivity of domestic firms in the short run, but a positive effect in the long run (Liu, 2008). For a panel of 17,675 Chinese manufacturing firms for five years from 1995 to 1999, he estimated the following equation:

$$logTFP_{ij} = \alpha_0 + \alpha_1 FDI_{firm_{ij}} + \alpha_2 FDI_{sector_j} + \alpha_3 Time + +\alpha_4 Time * FDI_{sector_j} + \alpha_5 X_{ij} + u_i + \varepsilon_i$$

Where i and j are firm and industry specific indices, and TFP is defined as $TFP = \frac{Q(output)}{L(labour)K(capital)}$, $FDI_{firm_{ij}}$ is the foreign equity share in the firm, FDI_{sector_j} is the foreign investment in the industry, $Time$ captures the time trend, $Time * FDI_{sector_j}$ is the interaction term between the time trend and industry specific foreign investment, X_{ij} captures other relevant control variables, u_i is the firm specific effect and ε_i is the remainder stochastic disturbance. α_2 captures short term spillovers effect i.e. level of productivity whereas α_4 captures long term spillovers effect of productivity growth.

Empirically both α_2 and α_4 came out to be significant but with opposite signs ($\alpha_2 < 0$ and $\alpha_4 > 0$), which implied a long run productivity growth along with a short run decline. Intuitively, although FDI enhances the firm's future productive capacity it diverts managerial time and effort away from current production of output, affecting short-term productivity level of the firm (Liu, 2008).

Although these studies considered the effects of imported technologically advanced inputs, they do not relate the effects to trade liberalisation. The following papers have a distinct departure from tracing productivity gains from trade liberalisation via lowering tariff rates.

Amiti and Konings (2007) estimated the productivity gains from reducing tariffs, separately on final and intermediate goods for Indonesian manufacturing firms from 1991 to 2001. According to him, output tariff liberalisation increase productivity by tougher import competition, whereas cheaper imported inputs increase productivity via learning, variety and quality effects. A fall in tariff on intermediate inputs thus has a double effects- it makes domestic intermediate input more competitive, plus the productivity of the users of these inputs can increase due to the foreign technology embodied in those inputs. To separate the effect of tariff reduction on firms that import these inputs to those firms that compete with them, was possible due to the unique features of the Indonesian census datasheet, which provides information on the proportion of imported inputs at the plant level. The input tariffs were constructed as a weighted average of the output tariffs, where the weights were based on cost shares for nearly three hundred industries.

To determine the effect of trade liberalisation on productivity, they considered a plant with a Cobb-Douglas production function:

$$Y_{it} = A_{it}(\Sigma)L_{it}^{\beta_l}K_{it}^{\beta_k}M_{it}^{\beta_m}$$

Where, output in firm i at time t, Y_{it}, is a function of labour L_{it}, capital, K_{it}, and material, M_{it}. It is the motto to assess whether the productivity of plant i is a function of trade policy, denoted by Σ.

In the first step, the plant level TFP has been estimated, and in the second step it was tested, how productivity can be affected by trade policy. Taking a natural log (and denoting by lower cases), the estimated equation was found as:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + e_{it}$$

In the above equation, the dependent variable was the total revenue at the plant level. Using these estimates of the production coefficients, log of TFP was measured as:

$$tfp_{it}^k = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_m m_{it}$$

In the second stage, they specified the possible links between trade liberalisation and plant level productivity. Using the plant level measures of TFP from the earlier equation, the estimated the next equation:

$$\begin{aligned} tfp_{it}^k = \gamma_0 + \alpha_i + \alpha_{lt} + \gamma_1(output\ tariff)_t^k + \gamma_2(input\ tariff)_t^k \\ + \gamma_3(input\ tariff)_t^k FM_{it} + \gamma_4 FM_{it} + \varepsilon_{it} \end{aligned}$$

Where α_i is the firm fixed effects to control for unobserved firm-level heterogeneity. α_{lt} is the island-year fixed effect to control for shocks over time that affect productivity across all sectors but may vary across different islands within Indonesia. Apart from output and input tariffs, the interaction of input tariffs with a firm-level indicator of importing firms has been considered and denoted by FM , which equals one if the firm imports any of its intermediate inputs, and zero otherwise. Thus, a negative and significant γ_3 would imply that importing firms do reap higher benefits from lower input tariffs than non importing firms. However, γ_4 is expected to be positive, indicating that imported inputs generate some kind of technological externality. A negative and significant γ_2 however, suggest indirect positive effects spreading from importing to non importing firms.

Empirically, using tariff data on nearly 300 industries, authors show that importing firms enjoy the highest productivity gains from reducing input tariffs. They found that the largest productivity gains arise from reducing input tariffs. A 10 % fall in input tariffs leads to a 12% productivity gain for importing firms, at least twice as high as any gains from reducing output tariffs. Compared to 12% production gains for importing firms, they found 3% production gain for non importing firms. The larger impact for importing firms compared to non importing firms suggested that there were direct benefits that accrue from the technology embodied in the imported inputs.

When international trade benefits countries by providing access to new products or new varieties of existing products, it generates some sort of static gains from trade. Now, if these new technologically advanced products also lower the cost of innovation, enabling the creation of new varieties, this generates dynamic gains from trade (Goldberg et al., 2009). For India, the authors dissected changes in the composition of imports in the post liberalization era from 1991. They attempted to illustrate the potential scope for previously unavailable inputs to bolster the performance of domestic firms. The raw trade data for India revealed a large expansion in both products and varieties following the trade reform. While India imported 3,249 products and 23,571 varieties in 1987, these numbers grew to 4,443 and 55,819 respectively by 2000. Out of the overall increase in imports of 130% points between 1987 and 2000, 65% were new HS6 products entering the economy. New products and new varieties cumulatively accounted for 82% of India's import growth during the period. These products mainly served as inputs into production process of Indian firms. These inputs were mainly sourced from more advanced countries. Thus, authors concluded that India's trade liberalization relaxed the technological constraints faced by Indian firms under import substitution policies.

In a later paper, Goldberg et al. (2010) formally studied the effects of tariff reduction on total imports, prices and the variety. This study deals with only firm level data of 4216 Indian manufacturing firms for the time period 1989-2003. They considered variety and price effects to be gains from trade.

For the total imports Goldberg et al. (2010) formed the following regression equation:

$$\log imp\ value\ of\ HS6\ product_t = \alpha_h + \beta\tau_{h,t-1} + \alpha_t + \varepsilon_{ht}$$

Where, $\alpha_h$is the HS 6 fixed effect, $\tau_{h,t-1}$ is the lagged tariff rate at HS 6 digit level, α_t is the year fixed effect and ε_{ht} is the error term. The above regression was run separately for both intermediate and final goods sector and declines in tariffs were found to be associated with higher import volumes.For the price effect, they formed the following regression equation:

$$\log unit\ value\ of\ HS8\ product_t = \alpha_h + \beta\tau_{h,t-1} + \alpha_t + \varepsilon_{ht}$$

Where, all other things being the same, a further disaggregated data was taken at HS 8 digit level. This regression was also run separately for both intermediate and final goods sector. Although, the coefficient was positive and significant for both sectors, magnitude of the coefficient was larger for intermediate sectors. This suggested that, to the extent imported inputs were used in the production process by domestic firms, this decline in unit value would lower the marginal cost of production in Indian firms (Goldberg et al., 2010). For the variety effect, they formed the following regression equation:

$$\log(1 + v_{ht}) = \alpha_h + \beta\tau_{h,t-1} + \alpha_t + \varepsilon_{ht}$$

Where, v_{ht} is the number of varieties within HS 6 product h at time t. Empirically it was found that tariff reductions were associated with an increase in the number of imported varieties. This study was different from the prior studies, which measured the gains as a rise in productivity, whereas this study estimated price and variety gains with a reduction in trade restriction, namely tariff.

However, Bown and Tovar (2010) expressed scepticism over the use of only tariff cuts to proxy for trade liberalisation, particularly for India. They empirically investigated a potential link between trade liberalisation (tariff cuts) and subsequent use of such trade agreement 'exceptions' (safeguard and anti-dumping) that permit import restrictions. They found that, anti-dumping protections were particularly on goods which received larger tariff cuts between 1990 and 1997. Thus, they suggested that relying on only tariff cuts to proxy for trade liberalisation in certain Indian industries runs risk of substantial mismeasurement.

Thus the tariff reduction prescription for environmental goods and services needs to be judged very carefully, when it comes to a country like India, to accrue the benefits of those technologically advanced goods. Also, one should remember that, the main benefits from those particular goods are largely environmental, thus the approach should be different from the earlier literature which talk mainly about productivity gains. In the next section we present the literature talking about the gains from climate friendly technology goods particularly.

2.4.3. Environmental gains from trade of environment friendly technology goods

When the trade in technology leads to efficiency in the use of scarce natural resource or a reduction in pollution emission then the gains from trade get translated into environmental gains. Trade of resource efficient or emission reducing technology can help to close the gap between environmentally aware developed and less-aware developing countries. Thus, greater access of environmental goods (EGs) in the developing countries has been suggested by the World Bank study (2008) in reference to GHG-reducing technologies.

The World Bank study (2008) argued that developing countries have to deal with poverty and other social challenges on a priority basis. As a result, climate change may rank as a low priority to them, whereas their economies are more dependent on climate-sensitive sectors like environment and forestry and thus more vulnerable to impacts of climate change. At the same time, developing countries also lack the infrastructure or resources to respond to the climate change. This gap can be bridged by a smooth inflow of EGs through trade liberalisation. Jha (2008) too highlighted the need of technologically advanced EGs in the Asia Pacific region from dual perspective. According to her, the region is facing ever growing need for energy in the world. This region alone is responsible for 34% of total energy consumption. Energy consumption increased 190% in the period 1987 to 2002 compared to a global average growth of 130% over the same period (1987 to 2002). The growing demand for energy and the use of different types of fuel has subsequently increased carbon emissions.

The literature on gains from trade in technological advanced EGs is still evolving. The pioneering World Bank study (2008) discussed the impact of reduced tariff and non tariff barriers (NTBs) on trade volumes for four technologies (defined by HS6 digit code) viz. clean coal technologies (HS codes 840510, 840619, 841181, 841182, 841199), wind energy (HS codes 848340, 848360, 850230), solar photovoltaic systems (HS codes 850720, 853710, 854140) and energy efficient lighting (HS code 853931).

In the study, trade data was analysed for the top 18 developing countries based on their GHG emissions (in 2004). The countries were: Argentina, Bangladesh, Brazil, Chile, China, Colombia, Egypt, India, Indonesia, Kazakhastan, Malaysia, Mexico, Nigeria, Philippines, South Africa, Thailand, Venezuela and Zambia.The study numerically discussed the impact of reduced tariff and NTBs on trade volumes for these four technologies. Empirically, with 1% reduction in tariff (tariffs and NTBs taken together) increase in the trade volume was 3.6% (4.6%) for clean coal technology, 12.6% (22.6%) for wind power, 6.4% (13.5%) for solar power and 15.4% (63.6%) for the efficient lighting technology. The study also found that each country’s investment situation as well as IPR regime significantly influenced technology diffusion other than tariffs and NTBs. The World Bank study (2008) measured the gains from trade in terms of trade volume, not productivity as done in the previous studies; and the basic purpose was to see how the trade volume reacts to the reduction in tariff and NTBs.

Jha (2008) tried to identify various other macroeconomic factors which determine the flow of a broader range of EGs into developing countries. She studied pooled cross section estimation for nearly 32 developing countries, separately for the categories of air pollution control, management of solid and hazardous waste and recycling system, clean up or remediation of soil and water, renewable energy plant, heat and energy management, waste/potable water management, environmentally preferable products, natural risk management, natural resource protection and noise and vibration abatement. Since 32 developing countries were taken in the sample, GDP was used as an explanatory variable to control for economic size (which influences the volume of trade). According to the author, the link between Foreign Direct Investment (FDI) and trade in environmental goods is twofold. Firstly, FDI is an indicator of openness in an economy. Secondly, surveys have shown that FDI is more likely to be more environment friendly than domestic investment. Since data on environmental services was not available on a systematic basis, she also used FDI as a proxy for environmental services. Thus, where FDI is seen to be correlated to imports of EGs, it also suggested that trade in environmental services may also generate trade in goods. Effect of technical assistance projects between governments of developed countries and those of developing countries was captured through the use of dummy variables. Environmental performance index (EPI: a composite index which traces how close a country is to universal environmental goals) was used to capture the countries' pollution level The degree of industrialisation, i.e. the share of industrial output in GDP was also taken as an explanatory variable, on the assumption that that the higher level of industrialisation leads to higher level of pollution.

Empirically she found tariff reduction to be significant for only two types of EGs: heat and energy management, and RE. Trade in almost all categories of EGs was found to be highly significant to GDP although the sign of the coefficients varied. Particular to RE the correlation with GDP was negative (i.e. poorer the developing country, more dependent on imported RE products). A higher EPI ranking was found significant for remediation of soil and water, heat and energy management and RE plant. For almost all categories, role of FDI was positive and significant. However, the most direct, significant and positive correlation was found with respect to technical assistance projects.

In addressing the challenge of climate change energy supply is of fundamental importance; and breaking the link between energy use and GHG emission through a switch to more renewable forms of energy is a huge step to address global warming. Thus, from a larger list of EGS, the focus got narrowed down to RE products on a priority basis. The particular sector has been identified by the Intergovernmental Panel on Climate Change (IPCC) as one of the critical sectors for mitigation of greenhouse gas emissions (Jha, 2009).

Empirically Jha (2009) analysed trade flows and market drivers for RE technology components and equipments relevant for climate change mitigation efforts. The RE technologies that were covered in the study include: solar energy, wind energy, ocean energy, geothermal energy, hydro power and biomass technologies (including those used in the production of biofuels). She estimated multivariate cross country regression analysis for 34 major trading countries, to identify important drivers. According to her export of RE sector (RES) is a function of import tariffs, subsidies provided to REs (including feed-in tariff), share of renewable in the energy grid and share of global patents. She found tariffs not to be affecting significantly, rather policy variables such as the share of global patents and share of renewables as well as subsidies affected imports of renewables. This analysis pointed out the fact that tariff reduction by itself may not generate trade in RES. Other support policies may be more important in determining trade flows.

Thus Jha (2009) concluded that, the trigger variable in most cases was the subsidies provided by the developed countries, both to the producers and the consumers of RE. This has obviously tilted the playing field in favour of developed countries. In this situation, tariff reduction on RE supply goods would give them a double advantage. This is because their competitiveness has been developed through subsidies, and developing countries which use tariff walls instead of subsidies for the development of their industries would lose such protection. At the same time, it has to be borne in mind that most RE products under consideration here are ‘multiple-end use’ products and that many developing countries may be applying higher tariffs as part of their industrial development strategy or possibly to attract ‘tariff-jumping’ investment.

2.4.4. Significance of trade/import of environment friendly technology goods in India

In energy sector, India faces a two-fold challenge. On one hand, there is energy security problem and on the other hand, there is international pressure to reduce the carbon intensity as well as emission. Among the total energy demand in India electricity possesses the largest share (Kumar et al., 2010) along with a large proportion of the citizens (nearly 34% of the population in 2009) still living with no access to electricity (World Energy Outlook, 2010)[10]. At the same time the share of carbon emission from electricity generation is the highest in India (INCCA report, 2010).Although the current per capita emission is quite low for India[11], pointing on the aggregate emission level, United States has conditioned its entry to the environment treaty (viz. Kyoto Protocol) on further engagement of India (and China). According to the World Bank study (2008) the growth of carbon emissions in the next decades will come primarily from China and India because of their size and growth rate and therefore, the future Kyoto commitments will require participation of these two developing countries particularly. Thus, India urgently needs to develop a sustainable path of energy development, particularly that of electricity generation.

One possible solution to both the challenges (100% electricity access and external pressure to reduce carbon emission) is the use of renewable energy (RE) technologies. India has one of the largest programs in the world for deploying RE products and the only country in the world to have an exclusive ministry for renewable energy development, viz. Ministry of New and Renewable Energy (MNRE). In spite of that the country has a

[10] This electricity demand is projected to be more than triple between 2005 and 2030 (Global Wind Energy Outlook 2010)

[11] 1.7 Mt CO_2 equivalent compared to 23.5 (US), 10.3 (EU), 10.5 (Japan) and 5.5 (China) (Wheeler and Shome, 2010)

large potential but relatively small cumulative achievement which reveals the importance and possibility of India's own capacity installation development. Currently MNRE is providing quite a number of incentives for capacity building. The tariff rates in certain core technology products have also been reduced (few even to zero) to boost up the import of the intermediate goods. Against this backdrop, it will be interesting to study the effect of trade liberalisation (tariff reduction) in the technology products for RE upon the domestic capacity building.

2.4.5. Gap in the literature

Currently, in the context of RE in India, there are some studies focusing on the importance as well as present scenario of it (UK Trade and Investment Report, 2008; Ministry of New and Renewable Energy report, 2010; Kumar *et al.*, 2010). Comparison of different future of scenarios with and without exploitation of REs has also been studied (Mallah and Bansal, 2010)[12]. However, there is no empirical study on the benefits of trade liberalisation for the RE sector in India. In that sense our paper fills the gap in the literature. Now, technology availability is not a major issue now-a-days as several developed countries possess them in almost each field. The question is whether the transfer of these technologies to the developing countries is real in the sense that the transfer facilitates building up significant capabilities in developing countries (Kathuria, 2002). Therefore, the thesis focuses on the *'real'* gains of trade in terms of increase in capacity installation.

[12]Future projection showed that the electrical energy demand will become 5000 terawatt-hour (TWh) in the year 2045 as compared to 600 TWh in base year 2005. Without further exploitation of RE the corresponding CO_2 emissions will become 2.3 billion tonnes in the year 2045. The full potential use of RE will result in a huge reduction (72%) in coal use and same amount (72%) of reduction in corresponding CO_2 emissions, compared to the prior scenario, by the year 2045.