ADDENDUM in respect to the PhD Review for the thesis entitled "Capital Inflows, Production Fragmentation and Environment" submitted by Supratik Guha

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Chapter 1

Introduction

1.1 Motivation

In recent decades, the rapid increase in the pace of globalization led to significant increase in world trade and production of goods and services (Antweiler and Trefler, 2002). With the advent of globalization and liberalization in international trade, countries across the globe witnessed a huge increase in their trade volumes and their economies got integrated with each other. The surge in international trade led to an immense increase in the productive activities across trading countries. The rapid increase in the production of goods and services due to increase in demand from trading partners not only led to increase in per-capita income and GDP of the trading country but also it led to the degradation of world environment. The increase in trade leads to economic growth which in turn is expected to affect the environment. Economic growth can be explained either by growth in per capita income or growth in GDP of a country. Growth was found to solve many problems and countries were also witnessing higher growth trajectories. But for the last few decades there have been concerns about environmental degradation due to growth. Growth puts severe pressures on natural resources and environment. The rate of extraction or exploitation exceeded the carrying capacity or the assimilative capacity of the Earth. This puts severe limits to growth as well as on the well- being of the people. The relationship between economic growth and the environment is, and will always remain, controversial. Some see the emergence of new pollution problems (both global and local) with the growth of a country while others see the glass as half full. They note the tremendous progress made in providing urban sanitation, improvements in air quality in major cities and marvel at the continuing improvements in the human condition made possible by technological advance. Now regarding the source of growth, it is attributed either to domestic factors or to international factors. Trade has been also considered as one of the key drivers of economic growth. The classical doctrine of 'Trade as an engine of Growth' may give a clear explanation of how Trade creates growth within an open economy. So, in a globally connected world, this relation between growth and environment is closely linked with that between trade and environment. Whether openness leads to degradation of environmental quality is an important query.

Now to reap on the benefits of international trade and gain further from cost advantages, gradually with time, the production processes of several traded products has been split up into several stages and global value chains.[1] The international production fragmentation also led to several other economic activities like outsourcing and trade in intermediate goods. All these activities which are driven by fragmentation may also have detrimental effects on the environment of several countries of the world due to the involvement of different types of production technologies at different stages of a production process. In this thesis, we try to focus on a central theme, i.e., how production fragmentation is related to environment? Although the issue of trade and environment has been addressed by many studies, but this particular area of research has been neglected in the existing literature. Before moving on to the main analysis, the next few sections discuss several concepts of production fragmentation, the research questions which this thesis addresses, the methodologies used this thesis, the summary of empirical results and a brief chapter outline of the whole thesis.

[1] Global value chains (GVCs) involve international production sharing, where the production process is broken into several parts and fragments which are produced in different countries. Along with the fragments, countries are specialises to carry out different activities based on their cost advantages at any particular stage of production.

1.2 Production Fragmentation, Trade in Intermediate Goods and Outsourcing

Production fragmentation, also known as global value chains (GVCs) or supply chain fragmentation, refers to the process where the production of goods is divided into distinct stages that are carried out in different countries. This phenomenon has been accelerated by technological advancements, reduced transportation costs, trade liberalization, and global economic integration. Companies are able to distribute production processes across borders, taking advantage of regional strengths such as lower labor costs, specialized expertise, or access to raw materials. While this division of labor has enhanced efficiency and led to economic growth, it also presents significant environmental challenges. The global distribution of production processes contributes to an increase in carbon emissions, resource depletion, and ecological footprints, as goods and intermediate products are transported across long distances. Moreover, some countries with less stringent environmental regulations may experience a concentration of pollution-intensive industries, leading to localized environmental degradation.

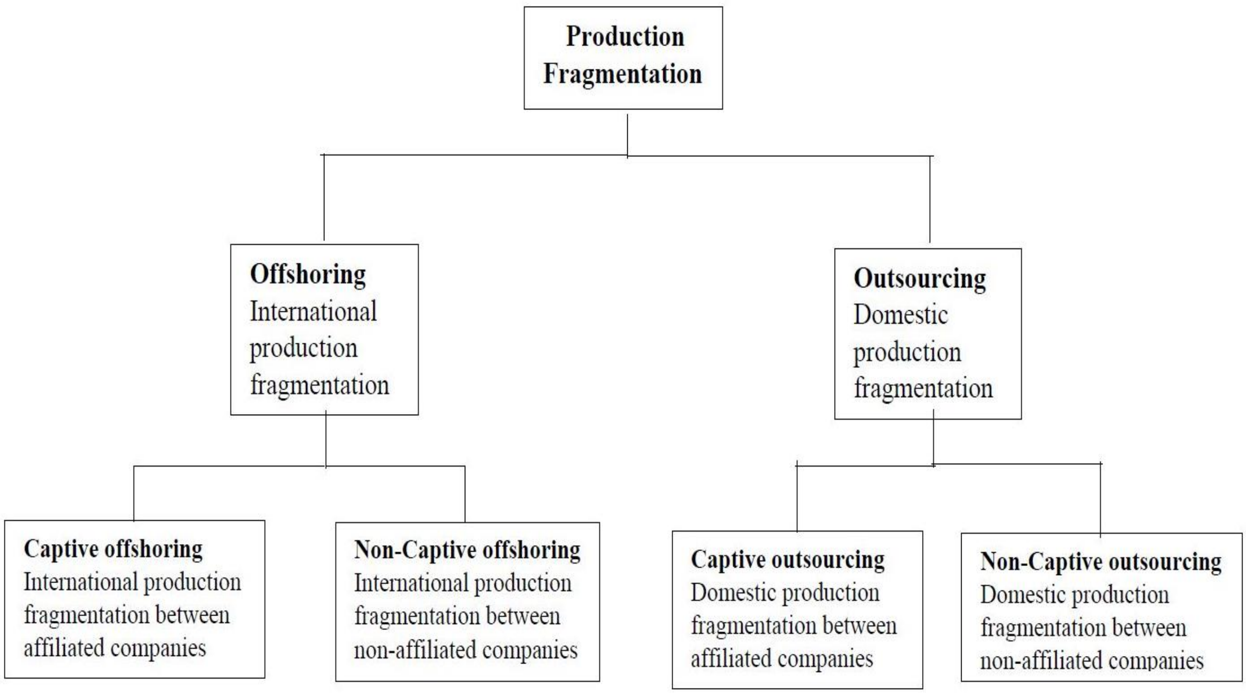
Understanding the environmental impact of production fragmentation is crucial as countries and corporations seek to balance economic benefits with sustainable practices. This research seeks to explore the complex relationship between fragmented production networks and environmental sustainability, focusing on identifying both the opportunities for minimizing environmental damage and the trade-offs that exist between economic and ecological concerns.

Apart from the trade in final goods, there is growing importance of trade in intermediategoods among the trading partners. The increased production fragmentation also led to the rapid growth of trade in intermediate goods especially within the emerging economies. The demandfor intermediate goods increased significantly in the last few decades and such increase can beattributed to the fragmented production activities across countries worldwide. The share of intermediate goods in world merchandise trade has been increasing sharply. The intermediate goods mostly include intermediate inputs which are used as raw materials for production of

consumption goods for both domestic consumers as well as abroad. Production fragmentationis closely related to intermediate goods trade.

The different aspects of production fragmentation have been pictorially depicted inFigure 1.2 below.

Figure 1.2: Production Fragmentation and its key terms



The growth of production fragmentation induced trade in intermediate goods and greater intensity of outsourcing is often associated to increase in production of pollution intensive commodities. This raises a serious concern worldwide since the extent of damage caused by these economic activities is often unmeasurable and lead to severe economic cost, loss of human life and threat to the future generations. Thus, the growing importance of production fragmentation and the rapidly increasing volumes of trade in intermediate goods raises a concern among the environmentalists as to what extent such economic activities damage the environment. Given the context, it is of utmost importance to delve into this matterand analyse whether international production fragmentation plays an important role in causingserious environmental issues and how such fragmentation induces other economic activities

that causes environmental degradation. Despite a significant amount of literature that deals with trade and environment are present which deals with the trade-environment nexus, the role played by production fragmentation in affecting the environment has been mostly ignored in the previous studies. The following section discusses the objective of the thesis and the research questions addressed by it, followed by another section which lays out the chapter outlines.

1.3 Objective, Research Questions and Chapter Outline of the Thesis

The primary objective of this thesis is to investigate the environmental implications of production fragmentation. The thesis aims to evaluate how the dispersion of manufacturing and production processes across different regions contributes to environmental degradation, including carbon emissions, resource depletion, and pollution. This objective would allow the thesis to critically examine the trade-offs between economic efficiency gained through production fragmentation and the environmental costs it incurs, while also offering potential solutions. The thesis also suggests potential policy frameworks and technological innovations that can mitigate the environmental damage associated with production fragmentation, promoting sustainability in global value chains. The central research questions which have been addressed by this thesis are:

a) Is there any link between fragmentation in production process and environment?

b) Does the decision to outsource (which arises due to greater degree of production fragmentation) is influenced by the change in the price of environmental inputs?

c) Does fragmentation-induced trade in intermediate goods leads to more emissions in developing countries?

d) Does trade policies play any role in influencing the emissions level of a country?

The above research questions have been addressed by carrying out two empirical exercises and one theoretical modelling. For both the empirical analysis, panel data have been used and in the theoretical framework, a mathematical model has been constructed. In the previous literature, very few studies dealt with the relation between fragmentation and environment and there is a dearth of literature which considered developing countries like India and South Asian countries in their study. Our study addresses this research gap and tries to make a significant contribution to the existing growth-environment debate.

The thesis has been structured keeping in mind the central theme of this research, i.e., whether production fragmentation and environment is related or not. **Chapter 2** deals with the survey of the existing literature on trade-growth-environment debate and also discusses the studies which considered the analysis of production fragmentation and intra-industry trade and their impact on environment. In **Chapter 3**, we consider one aspect of production fragmentation, i.e., outsourcing and empirically validated the relation between outsourcing and energy prices for the case of Indian manufacturing firms. Using firm level panel data for seven industries, namely Cement, Chemical, Leather, Machinery, Metal, paper and Textile industries for the period 2005-2018, we found significant statistical evidence that energy prices influences the outsourcing decisions of Indian manufacturing firms. The objective of this chapter is to find out whether energy price is an important determinant of outsourcing intensity of manufacturing firms. The empirical results of this empirical exercise indicate that the results indicates that the formal firms fail to substitute energy input with other inputs; thus, they take the channel of outsourcing to save on other input costs. The relocation of certain production processes may lead to generation of more pollution due to the fact that the smaller firms are equipped with inferior abatement technologies. Static and dynamic panel estimates with a variety of robustness analyses which have been also carried out, supports the main conjectures.

In **Chapter 4,** we focus on another aspect of production fragmentation namely intra- industry trade. In this chapter, we framed the following hypothesis: How does trade in intermediate commodities affect the emission levels in South Asian countries? To empiricallytest the above hypothesis, we use panel regression technique and an augmented Environmental

Kuznets Curve (EKC) framework) between 1998 and 2018 for South Asian countries (namely Afghanistan, Bangladesh,Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka to estimate if export and import of intermediate products affect the emission of CO2 in these countries. The chapter uses a number of covariates including trade taxes, trade with rich countries and interaction with degree of industrialization in these countries. The main results indicate that greater fragmentation indeed leads to more emission, although deepening industrial base moderates the overall impact.

In **Chapter 5**, a theoretical model has been constructed to find out how both trade policy and environmental policy changes the pollution level of a country in the presence of intermediate goods. A comparative static analysis has been performed to find out the impact ofa change in tariff on emissions level of our hypothetical country and how abatement costs influence the relationship. The results of our theoretical model suggest that with decrease in tariff rate the domestic production of the intermediate goods falls that lead to a reduction in pollution, i.e., for a given level of abatement cost, a reduction in tariff rate may actually lower emissions. The results suggest that withdrawal of tariff rate may actually reduce emissions which indicates that free trade is actually good for the environment in the presence of an intermediate import competing good. This is just the opposite of the pollution haven hypothesis. From the model it can be inferred that trade policy can be used as an environmental policy to curb emission if the abatement costs are lower than a threshold level.

Finally, **Chapter 6** concludes with some discussions and policy suggestions. This chapter also highlights the negative side of production fragmentation and how it plays a role inaffecting the environment. Additionally, it also throws some light on future research and discusses the limitations faced by studies in this context.

Chapter 2

Literature Review

2.1 The Trade-Growth-Environment Debate

While economic growth has produced many benefits such as raising standards of living and improving quality of life across the world, it has also resulted in the depletion of natural resources and the degradation of ecosystems. There has been much debate over whether or not it is possible to achieve economic growth without unsustainably degrading the environment, and a growing realization that economic growth at the current rate of depletion and degradation of environmental assets cannot continue indefinitely. Here comes the concept of sustainable development. According to the UNCED (United Nations World Commission on Environment and Development) defines sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". So, it is a serious concern that whether a country's growth following a green path or leading them to a more vulnerable condition in terms of environmental degradation.

During the 20th century, massive economic growth not only increased the quality of human life significantly but also resulted in huge level of environmental degradation and depletion of natural resources. Such degradation has severe impact on the ecosystem in the form of climate change, water, soil and air pollution, loss of biodiversity, reduction in agricultural productivity and scarcity of natural resources. These outcomes on the other hand poses a serious threat not only to the human life but also to their economic wellbeing. Since

economic growth is attained with the help of environment, thus the damage to the environment is bound to hamper the long-term growth trajectories of the world. Due to the importance of economic growth in solving several economic problems, it should be the priorities of all the governments across the globe to amend the existing growth models and incorporate strategies to sustain economic growth in a way that the environment is protected. To achieve this, the idea of green growth [2] has been suggested by several environmentalists. The green growth strategy should incorporate welfare enhancing and efficient allocation of resources in such a way that it opens up new sources of growth, creates new markets and new jobs, encourages innovation and increased productivity. All these should be done through increased demand for environmental goods and services and green technologies. Majority of the Sustainable Development Goals (SDGs) follows this green growth principle. The main aim of the SDGs is to dissociate economic growth from environmental degradation by 2030 through resource efficiency in production and consumption. For this, trade in environmental goods and services should be encouraged and gradually help countries worldwide to switch to a green economy.

Growth can affect the environment of a country through three different channels: (a) Scale effect, (b) Composition effect, and (c) Technique effect. Greater economic growth increases the economic activities which in turn raises the demand for all inputs, including environment as free input, and hence increases emissions. This is the Scale effect. On the other hand, with growth the income of the people rises and thus they will increase their demand for a clean environment since environment is assumed to be a normal good. This is the income effect which will lead to an imposition of a higher effluent charge. Since higher effluent charges encourage firms to shift toward cleaner production processes, this Technique effect tends to reduce emissions. On top of this, if income growth shifts preferences toward cleaner goods, i.e., if clean goods are relatively income elastic, then the share of pollution-intensive goods in output will fall. The change in the composition of output due to growth is called the Composition effect. Initially economic growth leads to industrialization (and as the goods

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[2] According to World Bank, Green Growth can be defined as "growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters. And this growth needs to be inclusive" (World Bank, 2012).

balance shifts from agriculture to manufactured products, environmental damage increases); but the balance then shifts from producing manufactured goods to producing services, due to both demand- and supply-side changes, reducing the level of domestic environmental damage. The relative size of these three effects determines the relationship between economic growth and the environment. The source of economic growth is also important in determining the income growth and the pollution level of the growing country.

The relationship between economic growth and environmental quality can be best captured by the Environmental Kuznets Curve (EKC). The EKC is named after Kuznets (1955) who hypothesized income inequality first rises and then falls as economic development proceeds. So, the original relationship which was analyzed with the help of the Kuznets curve is the relationship between growth and inequality. The EKC concept emerged in the early 1990s with Grossman and Krueger's (1991) path breaking study of the potential impacts of NAFTA and Shafik and Bandyopadhyay's (1992) background study for the 1992 World Development Report. The EKC theme was popularized by the World Bank's World Development Report 1992 (IBRD, 1992), which argued that: "The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments" and that "As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment". The EKC refers to the hypothesis of an inverted U-shaped relationship between economic output per capita and some measures of environmental quality. The shape of the curve can be explained as follows: As GDP per capita rises, so does environmental degradation. However, beyond a certain point, increases in GDP per capita lead to reductions in environmental damage.

The possible explanations for the inverted U-shaped nature of EKC may be:

(a) At low incomes, pollution abatement is undesirable as individuals are better off using their limited income to meet their basic consumption needs. So initially with rise in income the pollution first rises as rising income means rising economic activity which further implies rising level of pollution. So initially the scale effect dominates the other two effects which leads to the upward rising portion of the EKC.

(b) Once a certain level of income is achieved, individuals begin considering the trade- off between environmental quality and consumption, and environmental damage increases at a lower rate. Also, the composition of a country's GDP change. As a country grows, its primary sector becomes less dominant and its manufacturing sector start getting a lion's share out of total output and hence a rise in pollution. Here both the scale effect and the composition effect will dominate the technique effect and this leads to the upward rising part.

(c) After a certain point, spending on abatement dominates as individuals prefer improvements in environmental quality over further consumption, and environmental quality begins to improve alongside economic growth. The composition also changes as the service sector or the tertiary sector dominates which leads to the decrease in pollution. The technique effect also comes into play at this juncture and finally the composition effect and the technique effect dominate the scale effect. This leads to the downward falling part of the EKC.

If the EKC hypothesis holds true always then we can infer that growth is the only objective since with growth the country can achieve the environmental targets and decrease the environmental pollution. But through numerous empirical exercises conducted in several literatures it has been found that the inverted U relation between the per capita income and the level of pollution is not always true since for many pollutants the EKC is upward rising which signifies that with growth the emission of such pollutants increases. So, countries focusing on growth strategies to reduce pollution may ultimately lead to increased level of pollution. So, getting rich is not the only solution and simply relying on laissez faire theory will not help to reduce the pollution level in poor countries. Some policy intervention has to be done.

While growth can be attributed to domestic factors, it can also take place if a country participates in international trade. The relation between trade and growth dates back to the classical theory of "Trade as an engine of economic growth" (Sir Dennis Robertson). International trade expands the consumption set by making available the foreign goods to the domestic consumers. Also trade liberalization can help a country to achieve those points which are outside the Production Possibility Frontier (PPF) by the expansion of markets.

The growth-environment linkage is often linked with trade-environment nexus. Trade and Environment as an issue is not new in the literature. With increase in liberalization, a country will witness a higher growth trajectory which in turn can deteriorate the environment through scale effect due to increased economic activity. When a country opens up then the composition of its output vector also changes since with trade different countries specialize in different commodities. Here comes the concept of composition effect. The composition effect can have either a positive or negative impact on the environment of a country depending on the pattern of specialization of a particular country. The pattern of specialization of a country depends on many factors such as Trade policies, Factor Endowments, Demand side and Supply side factors, Production technologies, etc. The trade-environment debate basically revolves around the basic research question: how environmental policies play an important factor in the determination of the trade vector of the countries participating in trade. "The link between trade and environmental protection — both the impact of environmental policies on trade, and the impact of trade on the environment — was recognized as early as 1970. Towards the end of the Uruguay Round (1986–1994), attention was once again drawn to trade-related environmental issues and the role of the soon-to-be-created World Trade Organization" (WTO).

While discussing about trade and environment, we can never ignore the "Pollution Haven Hypothesis (PHH)". Both the theoretical and empirical literature have been saturated with discussions of the PHH. The Pollution Haven Hypothesis (PHH) predicts that under free trade, the dirty goods industries will migrate to those countries which have a laxer environmental regulation and thus taking advantage of low environmental costs. According to this hypothesis, it is the developing countries which have less stringent environmental regulation which leads to the migration of pollution to these countries. Over time, developing countries will develop a comparative advantage in pollution-intensive industries and become "havens" for the world's polluting industries. Thus, developed countries are expected to benefit in terms of environmental quality from trade, while developing countries will lose. In the literature two sets of goods have been mentioned- dirty goods and clean goods. By dirty goods we mean those goods which are either emits pollution or are pollution intensive. Clean goods are those goods which are produced through clean process and which emits negligible or very less amount of pollution. With trade liberalization, some countries will specialize in dirty goods' production while some will specialize in the clean goods. Now, what determines the specialization pattern for the dirty goods? It is of course the environmental policies implemented in several countries. The environmental policies may differ across countries and thus the specialization of dirty goods will also vary from country to country. "The link between trade and environmental protection — both the impact of environmental policies on trade, and the impact of trade on the environment — was recognized as early as 1970. Towards the end of the Uruguay Round (1986–1994), attention was once again drawn to trade-related environmental issues and the role of the soon-to-be-created World Trade Organization" (WTO). International competition through trade openness initially leads to increasing environmental damage, up to the point when developed countries start reducing their environmental impact but also outsource polluting activities to poorer countries. This model is known as 'race to the bottom'. The factor endowment hypothesis (FEH), on the contrary, asserts that it is not the differences in pollution policy, but the differences in endowments or technology that determine trade. It predicts that the capital abundant country will specialize in capital intensive goods while the labour abundant country will specialize in labour intensive goods. Since the pollution intensive goods are generally capital intensive, then by the FEH it is the developed countries which will specialize in the dirty goods. The FEH predicts just the opposite to the PHH. In the literature also these two contrasting hypotheses have been tested. Whenever the PHH was found to be invalid, it was concluded that the FEH to be valid. Again, which hypothesis explains the impact of trade on environment better is an empirical question which has been addressed in existing literature. From the review of literature one can find that the existing empirical evidence on the PHH is quite ambiguous, while that on the FEH seems to be largely lacking.

The arguments in favour of PHH go like this. With trade, a country grows and its real income rises. According to Copeland and Taylor (2003), the response of pollution policy to rising real incomes is very important in this context. If the demand for environmental quality rises with real incomes, then pollution policy will become more stringent as trade liberalization proceeds. So, with trade openness, the rich developed countries will have more stringent pollution policy while the LDCs will have laxer environmental regulations. This will lead to the delocalization of the polluting industries to the developing countries. The developing countries that do not control pollution emissions will 'voluntarily become the repository of the world's dirty industries' (Baumol and Oates (1988) p.265). Like growth, trade's impact on the environment also works through three effects – scale, composition and technique effects. With increased trade, scale of economic activity increases which further increases pollution. This is the scale effect from international trade. With trade the composition of the commodity basket of a trading country change. The composition effect is determined by the two contrasting hypotheses – PHH and FEH. So, the impact of this effect on the environment is ambiguous. Finally comes the concept of technique effect. According to this effect, with openness there is a rise in the real income which in turn will lead to a decrease in pollution since environmental goods are normal goods. The PHH is thus purely an empirical phenomenon, and the hypothesis has been tested in numerous numbers of empirical studies in the existing literature. The literature on trade-environment nexus is vast and exhaustive but the studies focusing on the relation between production fragmentation and environment is negligible. In the following sub section, the very few studies which dealt with the issue of fragmentation and environment has been discussed and thus builds a strong ground for our research.

2.2 Production Fragmentation and Environment: Empirical Evidences

Although there has been extensive research in the area of trade and environment, but there are very few studies which deals with production fragmentation and outsourcing. This section discusses the existing literature and highlight those studies which investigated the growing importance of production fragmentation and its relationship with environment. To understand the implications of production fragmentation, firm level or industry level studies will give clearer picture than the traditional country-level approach. Dean and Lovely (2010) expanded the trade-environment model proposed by Copeland and Taylor (2004), to include FDI and production fragmentation. They found that increases in FDI contribute to a decline in the pollution intensity of China's trade. On the other hand, it has been shown in several papers that the trade-environment nexus is also affected by the level of economic development of a particular country. Swart (2013) considered the heterogeneity in production of intermediate producers. By assuming the producers of final products decide the type (clean/dirty) of intermediate goods to employ and pay for the pollution, Swart found that all countries are better off in a free trade scenario, while development level and transportation cost jointly influence the effects of trade in intermediate products. Benarroch and Weder (2006) examined the effects of intra-industry trade in intermediate products on the pollution level of a country in the context of increasing return, and found that trade in intermediate goods leads to a decrease in aggregate pollution of at least one country.

Dietzenbacher, et al. (2012) recently found that the processing exports generate less emissions for the Chinese economy. They argued that the existing estimates of the CO_2 content of China's export is overestimated and that the production fragmentation has not been taken into account appropriately in the existing input-output tables. They used a unique tripartite input-output table[3] to find out the CO_2 emissions embodied in the processing of exports, separately from the normal exports. Their results depicted that China's emissions embodied in exports are overestimated by 60% or more, if the above distinction between processing and final exports is not made. Dean and Lovely (2008) suggested that China's case does not fit well with the traditional model, given that China's trade growth is highly dependent upon international fragmentation. They also pointed out similar kind of phenomenon for China previously. They found that China's processing of exports (which used imported intermediates) gradually increased overtime and these are cleaner than processing imports. They argued that the FDI inflows can contribute to cleaner exports through increased size of fragmented sector since the foreign capital brings in greener technology to the fragmented sector. They inferred that foreign investment and integration into global production chain has reduced the environmental cost of China's growth process.

Chaudhuri and Mukhopadhyay (2013) on the contrary found that foreign capital inflow in the formal sector might aggravate pollution even though it brings in EST. It is assumed that the formal sector has access to EST. They found that the inflow of capital which are used both in formal and informal sector reduces pollution while the capital which is specific to the formal sector (both in presence or absence of EST) generates pollution under some reasonable conditions. Their finding is striking and interesting since it defers the traditional belief about

[3] The tripartite I-O table approach distinguishes among the three types of production (i.e., processing trade, normal trade, and domestic final demand) which enables the estimation of the impact of trade on the environment relatively more precisely.

FDI bringing in improved technologies, which helps to reduce pollution.

The fragmentation of production in the recipient country can also be distributed between formal and informal sectors. The desperate attempt to achieve economic well-being, particularly in the last few decades after liberalization has accentuated environmental degradation. The presence of urban informal sector makes it debatable while analysing the impact of capital inflows on the host countries' environment. The informal sector[4] constitutes a large part of the manufacturing and the service sector in a developing economy. Empirically evidences suggest that the urban informal sector plays an important role in producing the intermediate inputs for the formal sector on a sub-contracting basis. Informal activity constitutes a significant part of the labour market in developing countries although it is a common feature of most countries. Most of the informal sector activities are responsible for generating environmental pollution since this sector does not comes under the supervision of the regulatory authority. The formal sector on the other hand faces stringent environmental regulation which in turn compels them to outsource the dirty production to the informal sectors. Perrings, et al. (1995) argued that it is economical for the formal sector to subcontract the informal counterparts so that they can avoid investment in Environmentally Sound Technology (EST). In this process the formal sector evades the high environmental costs and increase their profit margins. The reason is that the informal sector firms lack incentives to prevent pollution since they do not come under the supervision of the regulatory authorities. Later, Chaudhuri and Gupta (2003) showed that under some reasonable conditions, foreign capital inflow raises domestic pollution in the presence of informal sector (assuming that the informal sector produces a dirty intermediate input for the formal sector).

However, these papers do not explore the conditions under which production fragmentation

[4] Informality refers to that share of a country's production of goods and services which does not comply with government regulation (see Marjit and Kar, 2011 on variety of institutional structures of informality). Essentially, it consists of unregistered and geographically dispersed firms, which are also difficult to identify.

within a country and that across countries takes place and what are the factors that affect a firm's decision to outsource their activities to other firms within an industry. Recently Chakraborty and Sundaram (2019) analyzed for the first time how import competition from China leads to significant increase in production fragmentation of Indian manufacturing firms which further instigates the firms to outsource their activities. They used the novel dataset on outsourcing of manufacturing jobs by Indian firms from the Prowess database for their analysis. But to the best of our knowledge, there are no studies which incorporates the environmental input price as a determining factor of outsourcing by manufacturing firms.

Generally speaking, the conclusions of the empirical studies that deal with such issues vary not only across regions but also across the timeframe of the studies. However, one question remains unanswered – with the shift in trade from final goods to intermediate goods, will the conventional trade-environment theory change? How the traditional trade theories change when we bring in environment as an additional input of production and factor in production fragmentation at the same time, is a question which need to be pondered upon.

In earlier studies, less priority was given to intermediate goods trade. But with globalization over the years the intensity of intermediate goods trade has sharply increased. Thus, it is required to incorporate the intermediate goods along with the final goods in the trade models to get more robust results. Melvin (1968) used a two-factor and three commodities framework, where the intermediate goods can be used both as consumption goods and as an input for production of final goods. Batra and Casas (1973) used an extended Hecksher-Ohlin (HO) Model which included intermediate good to determine the pattern of trade. Several other studies included intermediate goods in their models. Similarly, Deardorff (2001) incorporated the concept of production fragmentation in the HO model and found that when the benefits from fragmented production processes exceeded the cost of fragmentation, then only firms across the countries are willing to adopt the new production technology.

The lower trade barriers, progress in Information and Communication Technologies (ICTs) and different technological innovations have also led to cheaper production processes through slicing up the value chain. This phenomenon is mentioned as international production fragmentation. Production fragmentation can be defined as disaggregating a product into its constituent parts, components and accessories (PCAs). The PCAs are produced by different countries based on their comparative advantage with each country specializing in a particular stage of production sequence. This leads to the slicing up the value chain thus creating cost advantages for the firms through marginal differences in costs, resources, markets and logistics. With the advent of globalization, apart from the increase in the volume of trade of goods and services, other economic activities also increased. International production fragmentation is one of such activities which witnessed significant rise in post liberalization era along with rapid advancement in information and communications technologies (Krugman 1995, Fennestra 1998, Grossman and Helpman 2005). Fort (2017) recently showed that a greater degree of fragmentation is associated with the investment in ICTs by a firm. The recent growing literature dealt with production fragmentation and found significant evidence of fragmentation in production processes due to increased competition both at the domestic and international product market.

According to Gereffi (2001), the phenomenon of international production fragmentation can take place through two channels. The first is by subcontracting, which involves arm's length transactions, wherein a firm can contract an overseas supplier to manufacture parts and components, while retaining key service functions, such as research and development and designing. The second involves creating international production networks (via FDI), resulting in vertically specialized trade. FDI-led international production networks are largely driven by multinationals involved in high technology, capital intensive production of customized and specialized parts and components wherein quality considerations are paramount. Gereffi

(2001), therefore, classifies production fragmentation into two categories based on its drivers. The first is buyer-driven production fragmentation, which is more common in industries that exhibit low barriers to entry in production and possibilities of arms-length transactions, such as in garments, footwear, furniture and toys. The related global commodity chains of the above industries are usually controlled by large firms at the design and retail ends of the value-added chain, with little or no scope for vertically specialized trade. The second category is producer-driven fragmentation, which is significant in industries that are characterized by industrial capital and vary in their core competencies and entry barriers. In this case, the producer-driven types of commodity chains are controlled by large manufactures at the point of production, research and development, and design and are usually led by multinational corporations playing the central roles of coordinating production networks that include backward and forward linkages. Such linkages create opportunities for vertically specialized trade and are mainly driven by cost and quality considerations based on international division of labour and economies of scale (Helpman, 1984). Industries, such as semiconductors, automobiles and heavy machinery, are typically characterized by producer- driven fragmentation, enabling different countries in the production network to gain from contributing to the global value chain of an industry.

The international fragmentation in production involves splitting up the production process into several segments or fragments or component stages (Jones and Kierzkowski, 2001). Such cross-border dispersion of production components within vertically integrated industries induces the demand for imported components and intermediate inputs. For OECD economies, the intermediate inputs consist of more than 50 percent of the imported goods and approximately three fourth of the imports for emerging economies like China, India, Brazil, etc. Also, it has been noted that sectors which witnessed huge export growth in the past few decades (for eg machinery) are the ones which experienced the largest growth in vertical specialization (Nordas, 2003).

Similarly, another activity which reflect the phenomenon of product fragmentation is outsourcing. In case of international production fragmentation, some of the production processes is outsourced and located in different countries. For example, the developed countries often face stringent regulations and high labour costs to carry out certain production processes. In that case, to save on the cost of production, the rich countries tend to outsource and offshore certain stages of production to the developing countries. The rising volumes of trade in intermediate goods is again linked to growing international outsourcing since it has been observed that greater the volumes of intermediate goods that are used in the production of final goods under a particular company leads to higher intensity of outsourcing by that firm (Feenstra and Hanson, 2003). More and more countries are outsourcing some stages of their production process with growing trade in intermediate goods. This signals the deepening structural interdependence of the world economy (Athukorala 2005, Ando 2006). Often there is a confusion between offshoring and outsourcing. By offshoring it means getting the work done by a third party in different countries (which means outside the country or border) while outsourcing refers to getting work done by a third party either domestically or abroad (Radlo, 2016).

To illustrate let us consider Copeland and Taylor's two-commodity two-factor framework of a small open economy. Suppose, for any given factor price ratio, the dirty good uses more capital than labour relative to the use of these factors by the production process of the clean good. If growth occurs via the accumulation of physical capital, by the well-known Rybczynski theorem, the production of the dirty goods expands whereas that of the clean good declines. This Composition effect of growth thus raises pollution levels. That is, income and pollution are positively and monotonically related. On the other hand, if growth takes place through accumulation of human capital (that is the growth in labour force), then the composition of output will shift towards the production of the clean good. Hence growth will lower pollution. Thus, we can expect different income and pollution paths for different internal sources of growth.

2.3 India's Position in this Debate

India's experience has been different when we consider its growth path and openness to international market. Despite its geographical proximity to East Asia, the Indian economy followed an entirely different growth strategy. India was excluded from the global division of labour prior to 1990s especially when it comes to parts and components production. Since independence India followed a socialist planning model. Until 1991, Indian government focused mainly on self-reliance and import-substitution for achieving growth targets. Compared to the most East Asian countries, India undertook an outward-oriented growth strategy about a decade later. According to Tewari, Veeramani and Singh (2015) one of the main reasons for India not participating in international production fragmentation in trade of manufactured goods initially was the failure of its policymakers to improve the competitiveness of the Indian manufacturing sector and addressing several supply side bottlenecks. Although India's trade basket's composition changed considerably in recent decades. The traditional resource-based products (such as textiles, clothing, gems and jewellery) which were predominant in early 1980s was replaced by skill-intensive-based goods, such as metal and non-metal goods and chemicals, in second-half of the 1990s. The commodity basket is observed to be moving towards towards technologically intensive-based goods (Felipe, Kumar and Abdon, 2013).

The Indian economy has been growing rapidly and is currently the third largest economy in the world in terms of purchasing power parity (PPP). India's ranking in world trade in goods and services has also improved significantly. Starting from a relatively insignificant player in international trade pre 1980s (India ranked below 40 globally) to a significant competitor in global market (India's ranking climbed to 16th among the world's merchandise exporters and 7th among the world's merchandise importers in 2018). India's position in trade in commercial services is much better than in merchandise trade. Among the developing countries, India is just behind China as an exporter of commercial services (WTO, 2018). Considering the recent developments, it is very interesting to examine how production fragmentation is taking place in India's manufacturing process and how outsourcing is emerging in the country's manufacturing industries and products.

Various studies such as Veeramani (2002, 2009), Srivastava and Sen (2011, 2012), and Amighini (2012) have investigated production fragmentation using indices of intra-industry trade, but for a shorter time-span up until 2008. But Srivastava and Sen (2015) have separated IIT in parts and components into horizontal and vertical IIT for capturing the extent of global production fragmentation evolving in intermediate goods trade. Tewari, Veeramani and Singh (2015) in the context of analyzing production fragmentation in bilateral trade between India and ASEAN during the period 2000-2011, noted that in spite of low volumes, there is evidence of increasing vertically specialized trade between them.

The developed nations are outsourcing emissions to India. With rise in export to developed countries, India's emissions also rose at a rapid rate. According to a report by economic consultancy KGM & Associates and Global Efficiency Intelligence, in 2015 nearly 20% of India's emissions were linked to production of goods for exports, primarily to the US. Many cities in India rank among the world's most polluted. It is estimated that air pollution cost Indians about 1.5 years of their lives. India also ranked in top five when it comes to exporting embodied carbon dioxide emissions through their product. So, it is a matter of concern for India that how the industries carry out their production processes. Until and unless the government takes some necessary steps to reduce pollution, the harmful effects from such pollution will be a great concern for our coming generations.

Table 2.3 (a): Top five importers of embodied CO_2

Country	Embodied CO2 in imports (Gigatonnes of CO_2)
US	1.452
China	0.706
Japan	0.567
Germany	0.395
UK	0.368

Source: The Carbon Loophole in Climate Policy Report, 2018

Table 2.3 (b): Top five exporters of embodied CO_2

Country	Embodied CO2 in imports (Gigatonnes of CO_2)
China	2.186
USA	0.734
Russia	0.625
India	0.488
Germany	0.355

Source: The Carbon Loophole in Climate Policy Report, 2018

Table 2.3 (c): Top largest-growing embodied emissions flows from 1995-2015, ranked in absolute terms and shown as percentage growth rate

Origin	Destination	Growth Rate
China	U.S.	317%
China	Hong Kong	217%
South Korea	China	1431%
China	Japan	145%
China	UK	333%
India	U.S.	350%
Japan	China	594%
China	Germany	240%
China	India	874%
Russia	China	522%

Source: The Carbon Loophole in Climate Policy Report, 2018

The US was the largest recipient of embodied emissions from imported goods coming from India. And between 1995 and 2015, the flow between the two countries spiked by 350%, ranking among the world's largest-growing flows. This doesn't let India off the hook; rather it proves that taking on climate change will require systematic change in many sectors, going far beyond renewable energy targets and electric cars.

While the government has gradually promoted investments in renewable energy and electric vehicles to address emissions from fuel combustion, which form the bulk of India's total emissions, embodied emissions haven't received as much attention. The growth of India's embodied emissions has accelerated since 2010, with the leather, handloom, and industrial machinery sectors accounting for the largest share, the researchers say (as shown in Table 2.3 (d)).

Table 2.3 (d): Top sectors with highest emissions attributable to production for exports

Sectors	Share of emissions induced
Leather footwear	55
Leather and leather products	49
Khadi, cotton textiles (handlooms)	44
Industrial machinery	42
Motorcylces and scooters	36
Bicycles, cycle-rickshaws	34
Electrical appliances	33
Tea	31
Coconut farming and processing	30
Organic heavy chemicals	29

Source: The Carbon Loophole in Climate Policy Report, 2018

In recent years, due to availability of firm level data and disaggregated trade data and the improvement of statistical tools, the empirical studies involving trade in intermediate goods is on the surge. Mainly two techniques are used by studies which involves intermediate goods trade in their analysis: trade flow analysis and analysis using the world input output (I-O) trade table. Kleinert (2003) used the input output tables for OECD countries and found that international fragmentation in production is responsible for the rise in intermediate goods trade. They also found evidence of increased intensity of outsourcing (through FDI channel) due to fragmentation in production processes. There are many factors which induces fragmentation in product, many of which has been pointed out by the previous studies. According to Jones and Kierzkowski (2001) production fragmentation is driven by economies of scale. The importance of trade in intermediate goods in influencing the wage gap between skilled and unskilled labours has been highlighted by Feenstra and Hanson (2003) in their study. In a more recent study by Zhang (2015), it has been empirically found for the case of East Asia that both intermediate goods trade and energy consumption is statistically significant and positive when the impact on carbon pollution is tested. By using an interaction term, the paper also suggests that intermediate goods trade can be beneficial to reduce the negative impact of energy consumption on environment, i.e. fragmentation can promote transfer of improved technologies and adoption of cleaner production techniques. The net impact of international production fragmentation on a country's environment and the robustness of such results needs to be addressed more in the different countries or time points.

The most interesting part of the fragmentation process is that firms or countries can be at different stages of the global value chain of a product. Some countries may be involved in the initial stages of production process while some may specialise in the middle and later stages. Different stages of production use different technologies or different methods. This suggest that some parts of the production process may be pollution intensive while some may use improved cleaner technologies. It is expected that the developing countries are mostly involved in the pollution intensive production processes due to less stringent environmental regulations. To validate this point, we therefore chose developing countries (South Asian countries including India) as our subject of study. According to the figures provided by the United Nations, ASEAN+6 (the Association of Southeast Asian Nations, China, Japan, South Koran, India, Australia and New Zealand) accounted for 39 percent of the world's intermediate goods exports in 2008 (Ueki, 2011). South Asia is an interesting region to study because the trade in intermediate goods in this region has rapidly expanded in recent years, particularly trade in vertically related markets. This study focuses on the economic perspectives rather than the geographic perspectives. Another reason for choosing India and South Asian countries is that there are very few studies which considered these regions. For India, there is a dearth of studies which dealt with the relation between production fragmentation and environment. Thus, in Chapter 3, we find out the relation between outsourcing and energy prices for the case of India and in Chapter 4, we find out whether fragmentation significantly affects the pollution level of the South Asian countries. In this thesis, the linkage between production fragmentation and environment has been addressed through multiple channels with the help of two empirical exercises and one theoretical model. The theoretical model has been constructed in Chapter 5 of this thesis and finally Chapter 6 concludes the study summarizing the results and suggesting some policy implications.

Chapter 3

Energy Prices and Production Outsourcing: An Empirical Analysis

This chapter focuses on the relationship between energy prices and the outsourcing decisions by Indian manufacturing firms. Specifically, this chapter emphasises on the testing of the relationship empirically and tries to validate the fact that apart from traditional factor costs (wages and rent), the costs of environmental inputs play an important role in determining the productive activities carried out by firms (in this case the intensity of outsourcing at the firm level is considered). Although there is an extensive set of literature on trade and environment, this specific area of research stayed largely unsettled in the existing literature. Before moving onto the main empirical exercise, a brief discussion of the research background and motivations, followed by a discussion of a number of conceptual issues and research questions have been laid out.

3.1 Production Fragmentation and Outsourcing

Production fragmentation can be defined as disaggregating a product into its constituent parts, components and accessories (PCAs). The PCAs are produced by different countries based on their comparative advantage with each country specializing in a particular stage of production sequence. This leads to the slicing up the value chain thus creating cost advantages for the firms through marginal differences in costs, resources, markets and logistics. Athukorala and Yamashita (2006) defined international fragmentation production as "cross-border dispersion of component production/assembly within vertically integrated production processes, with each country specializing in a particular stage of the production sequence". So, it can be noted that trade in intermediate goods and international production fragmentation are closely related concepts. One of the main reasons behind producer driven fragmentation is vertical integration. International production fragmentation can occur through two channels: arm's length transactions or via FDI. Further production fragmentation can be of two types: consumer driven fragmentation and producer driven fragmentation. In consumer driven fragmentation, the economies of scope provide the main basis of comparative advantage (e.g., in labour intensive industries like foot wear, garments, toys, etc.). On the other hand, producer driven fragmentation is observed in capital and technology intensive industries (e.g., automobiles, semi-conductors and heavy industries). These industries are generally characterized by industrial capital and MNCs play a huge role in such industries. In this process, vertically integrated production network system (via FDI) is set up to carry out production. Several countries participate and gain from production fragmentation along the global value-added chain.

One of the most important and identifiable patterns of international fragmentation is outsourcing. The term 'outsourcing' has been used for the first time in scientific publications in early 1980s.Outsourcing is a business practice where companies contract an outside supplier to produce goods and services on their behalf (Bhagwati, Panagariya and Srinivasan, 2004). More and more countries are outsourcing some stages of their production process with growing trade in intermediate goods. This signals the deepening structural interdependence of the world economy (Athukorala 2005, Ando 2006). Radlo (2016) explored the literature studies and found that even in 1980s very few articles used the term outsourcing but in early 1990s the term 'outsourcing' started gaining much popularity. In his research paper he goes on to distinguish the several concepts: production fragmentation, outsourcing and offshoring. There is often a slight confusion between the terms outsourcing and offshoring. By offshoring it means getting the work done by a third party in different countries (which means outside the country or border) while outsourcing refers to getting work done by a third party either domestically or abroad. Thus, outsourcing is a much broader concept. Similarly, researchers sometimes confuse "outsourcing" and "sub-contracting". The latter concept means that part of the work is transferred to another company that has special skills or resources that allow it to perform tasks clearly specified in better conditions. In other word, a subcontractor works for the buyer in specific limits, while a seller cooperates with a buyer. Subcontract involves only the transfer of the specifications of the product or service. On the other hand, production fragmentation is a phenomenon in which the production processes are divided into separate components that are produced by different companies, either sharing common ownership or have different entity and located in one or more countries. With increased fragmentation in production processes, firms tend to outsource certain segments of the production sequence in order to save costs and stay competitive in international product market. Like outsourcing is related to domestic production fragmentation, similarly offshoring is a phenomenon related to international production fragmentation.

3.2 Outsourced Jobs and Outsourced Pollution

In the last few decades, researchers across the developed and the developing nations have expressed their growing concerns for the rising environmental damage due to greater degree of openness in capital flows and trade in PCAs (see Kar and Majumdar, 2015 for the direction of impact of most-favoured-nations tariff on emission in developing countries). With the increase in volume of trade and rapid growth in world output, the pace of environmental degradation surged (Antweiler, Copeland and Taylor, 2001; Dean and Lovely, 2010). Human actions have played a significant role in environmental degradation leading to severe environmental issues like growing greenhouse gas emissions (resulting in global climate change and environmental pollution). Such degradation of the environment resulting in distorting the balance of the ecosystem and affecting human life and property (Meehl, et al., 2000). Thus, environmental pollution caused by human actions has been receiving greater attention from researchers across the world. Many developing countries have already witnessed the devastating effects of environmental damage (e.g., the hazardous-level air pollution in China in recent years have led to rapid increase in the number of cases of lung damage in the population). Thus, while dealing with globalization, trade, production fragmentation and increase in economic activities, one must also address and examine the environmental implications of such activities.

Most of the developed nations have claimed that they have made major strides in reducing their greenhouse gas emissions at home. This trend is often considered as a sign of progress in the stride against climate change. But once trade is taken into account, the efforts and the claims made by the countries across the world looks deceiving and the result a lot less impressive. Majority of the wealthy countries tend to outsource a huge chunk of their carbon emissions overseas, rather than producing it domestically. The developing nations (which faces relatively laxer environmental regulations) produce these dirty goods (pollution-intensive goods) on behalf of the developed countries. This led to the migration of energy-intensive industries or production processes from developed nations to developing counterparts. If we consider the total global emissions arising out of production of total world output and take into account the volume of emissions taking place for producing things to meet the consumption needs of the wealthy nations, then the total carbon footprint for the developed nations actually increased overtime. Thus, the countries which have claimed to be meeting its climate goals are actually not making any progress to improve the environment since they are simply outsourcing their emissions overseas.

Dr. Hasanbeigi in a report on "The Carbon Loophole in Climate Policy, 2018", estimates that 25 percent of the world's total emissions are now being outsourced in this manner. This report analyses global trade from 15,000 different sectors — from toys and office equipment to glass and aluminium and builds on previous academic research to provide one of the most detailed pictures yet of the global carbon trade. According to the report, the "carbon loophole" arises since countries rarely scrutinize the carbon footprint of the goods they import. "On average, one-quarter of the global carbon footprint is embodied in imported goods. These hidden flows evade most types of carbon policy," they added. Among all the countries, the US is the largest global importer of embodied emissions, while China is by far the largest exporter. India also ranks among the top five exporters. So, the numbers which has been reported by several developed nations world-wide for their carbon emissions are misleading. If the pollution generated from manufacturing the cars, clothing and other goods that the developed countries uses are taken into account, the nation's carbon dioxide emissions would be much bigger than its domestic numbers suggest.

Even under the Paris climate agreement, countries are held responsible only for the emissions produced within their own borders. But this migration of industries like cement and steel overseas are more damaging to our environment since the production shifts to a less-efficient factories governed by laxer environmental regulations in developing countries. Although, some environmentalists see it as the next frontier of climate policy. One possible solution for this shifting of emissions may be to impose a global carbon tax applied equally over all countries. But in the real world, that is unlikely to happen anytime soon. Before designing any climate change policies, it is also very important for us to understand the complex trading relationships among countries.

Such arguments motivate us to think on how environment plays an important role in determining the level of economic activities. Environment is often considered as a factor of production since all economic activities involves environment in their production process. Thus, if the government regulates the usage of environmental inputs or changes the prices of such inputs, the scale or composition of the economic activities is likely to be affected. While some effects of international production fragmentation have been dealt with in the existing literature, such as that on productivity, wages, investment patterns, and generally production reorganization at the firm level, very few studies considered the impact of change in energy prices on firm level outsourcing decisions. It is expected that with rising energy prices, the larger firms tend to outsource some parts of their production processes to the smaller firms[5], since smaller firms can produce these at a lower cost. It can be also noted that the bigger firms

[5] We may also refer smaller firms as informal firms since the informal units faces lower input costs due to underdeveloped input markets and does not have strict labour laws since it is not under the purview of the government.

come under the supervision of the governmental regulations and has to bear stringent laws with respect to factors of production.

The objective of this chapter is to see that how rising energy prices hurt formal firms and how they tend to outsource more in order to cut back on other costs of production. Another dimension is that rising fuel costs hampers the profitability of larger firms, thus restricting them to carry out other productive activities. Coming to the link between such outsourcing activities and environment, it can be argued that the production processes that has been outsourced to the smaller sectors is expected to be more pollution-intensive and the increase in outsourcing may generate more pollution. However, we do not have any explicit abatement cost or carbon market in India, we leave this argument to be scientifically tested in the future. The outsourcing may also be dispersed geographically, rather than being located in a visible enclave. But these are open to further empirical verifications, since we do not have data to support these conjectures presently.

The rest of the paper is organized as follows. Section 3.3 offers the empirical analysis of how energy prices affect firm-level outsourcing decisions along with several other factors. Section 3.4 discusses the empirical results in case of seven Indian manufacturing industries separately and finally Section 3.5 concludes.

3.3 The Empirical Specification, Data and Methodology

Based on the exhaustive research on trade and environment, it can be observed that how economic activities degrades environment and how trade is one of the main drivers of economic growth. It has been argued in the trade-environment literature that trade promotes shifting of dirtier industries to less developing countries and how strict environmental regulations instigates countries or firms to shift their production base or outsource the pollution intensive production processes to countries or firms which face relatively less stringent environmental regulations (Pollution haven effect). Such arguments motivate us to think on how environment plays an important role in determining the level of economic activities. Environment is often considered as a factor of production since all economic activities uses or takes help of environment. Thus, if the government regulates the usage of environmental inputs or changes the prices of such inputs, the scale or composition of the economic activities is likely to be affected. To address this issue, the following hypothesis has been framed and the research question is validated using an empirical analysis.

Hypothesis: Energy price is an important determinant of outsourcing intensity of *manufacturing firms.*

The main research question which has been addressed in this chapter is: "Does rise in energy costs (indicating rise in the price of environmental input) leads to greater outsourcing intensity?" The above question has been empirically tested in this chapter and the empirical analysis suggest that with increase in the prices of energy inputs (e.g., prices of power, fuel and water), the intensity of outsourcing by the Indian manufacturing firms tends to increase. The energy prices are expected to play a major role in decisions regarding production organization since India is considered as world's third largest energy consuming country (India Energy Outlook, IEA 2021). According to the report, India's energy use has doubled since 2000 with more than 80 percent of their energy demand has been fulfilled by coal, oil and biomass.

For the empirical analysis, four Indian manufacturing industries have been considered (viz. Chemical Industry, Machinery Industry, Metal Industry and Textile Industry). The manufacturing sector is one of the key drivers of India's economic growth, contributing around 15 per cent to India's Gross Value Added (GVA). It is also the second-largest contributor to carbon dioxide (CO_2) emissions (25 per cent) after electricity generation (Biswas *et al*., 2019; Gupta *et al.*, 2019). This sector is by nature energy-intensive resulting in large emissions of greenhouse gases and is also sensitive to technological change. Basic metals, non-metallic minerals, chemicals, textiles, food industries and refineries are the largest contributors to CO_2 emissions comprising around 80 per cent of the emissions from the manufacturing sector. These sectors play a vital role in creating employment and provide crucial support to the economic development of the country, but they also have high CO_2 emissions per unit GVA. Amongst the key sectors, the manufacture of electrical equipment has undergone a reduction in aggregate emissions due to the reduction in energy consumption on account of greater energy-efficient production processes. It is noteworthy that the growing share of electricity in the energy consumption basket is also responsible for increasing CO_2 emissions. It is because even though the direct emission from electricity is zero, the use of fossil fuels in power generation emits around 2.5 times more CO_2 than the direct combustion of coal after accounting for the loss of heat during power generation and loss of electricity during transmission. The Indian manufacturing industry generated 16-17% of India's GDP pre-pandemic and is projected to be one of the fastest growing sectors. India has the capacity to export goods worth US$ 1 trillion by 2030 and is on the road to becoming a major global manufacturing hub. With 17% of the nation's GDP and over 27.3 million workers, the manufacturing sector plays a significant role in the Indian economy. Through the implementation of different programmes and policies, the Indian government hopes to have 25% of the economy's output come from manufacturing by 2025. India's manufacturing sector is poised to reach US$ 1 trillion by 2025-26, led by Gujarat, Maharashtra, and Tamil Nadu, fuelled by investments in automobile, electronics, and textile industries. Government initiatives like Make in India and PLI schemes drive growth, attracting FDI and enhancing industrial infrastructure. The Indian manufacturing industry generates around 17% of India's GDP and is projected to be one of the fastest-growing sectors. Manufacturing exports have registered highest ever annual exports of US$ 447.46 billion with 6.03% growth during FY23 surpassing the previous year (FY22) record exports of US$ 422 billion.

India's chemical industry is one of the largest in the world, playing a pivotal role in the country's industrial and economic development. This industry is crucial for sectors like agriculture, textiles, healthcare, and consumer goods, providing the foundation for many of India's exports and domestic products. Covering more than 80,000 commercial products, India's chemical industry is extremely diversified and can be broadly classified into bulk chemicals, specialty chemicals, agrochemicals, petrochemicals, polymers, and fertilisers. India is the 6th largest producer of chemicals in the world and 3rd in Asia, contributing 7% to India's GDP. The Indian chemical industry is currently valued at US$ 220 billion and is expected to reach US$ 300 billion by 2030 and US$ 1 trillion by 2040. However, the rapid expansion of the chemical industry has also led to severe environmental challenges, especially pollution, which affects air, water, and soil quality and poses significant health risks.

India's textile industry is one of the oldest and largest in the world, deeply ingrained in the cultural and economic fabric of the nation. From traditional handlooms to modern industrial-scale operations, the sector plays a crucial role in India's economy, contributing around 2% to the country's GDP and employing over 45 million people. The industry is also a significant player in global markets, being one of the top exporters of textiles and garments. This industry remains an active hub of opportunities, even in an environment of global uncertainty. India is the 5th largest producer of technical textiles in the whole world with a market size of nearly $22 Bn, which we hope to build up to $300 Bn when we turn 100 by 2047. The textiles and apparel industry in India has strengths across the entire value chain from fiber, yarn, fabric to apparel. The Indian textile and apparel industry is highly diversified with a wide range of segments ranging from products of traditional handloom, handicrafts, wool, and silk products to the organized textile industry in India. The organized textile industry in India is characterized by the use of capital-intensive technology for the mass production of textile products and includes spinning, weaving, processing, and apparel manufacturing. However, despite its economic importance, the textile industry is a major contributor to environmental degradation, producing significant pollution in the form of water, air, and soil contamination. The environmental impact of textile production, dyeing, and processing has led to growing concerns about the sustainability of the industry.

On the other hand, India's machinery industry plays a critical role in the nation's economic growth, being one of the largest sectors contributing to industrialization, manufacturing, and technological advancement. This industry encompasses the production of various machines such as industrial equipment, automotive machinery, and agricultural machinery, making it a significant pillar of India's manufacturing landscape. However, the machinery industry is also a substantial source of pollution. From air and water pollution to hazardous waste, the environmental impact of this sector is a growing concern. India's machinery industry has seen significant growth, driven by both domestic demand and global opportunities. It serves numerous sectors such as agriculture, transportation, energy, and construction, providing crucial tools and equipment. With a focus on Make in India initiatives and the vision of becoming a global manufacturing hub, India has boosted its machinery production capacity over the last few decades. The sector contributes to employment, technological advancement, and economic stability, while also supporting other industries like automobile, textile, and heavy engineering. Air pollution from the machinery industry comes from the release of harmful gases and particulate matter during the manufacturing process. Industries typically rely on the combustion of fossil fuels, which emit large amounts of carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and volatile organic compounds (VOCs). These emissions contribute to climate change, smog, respiratory diseases, and acid rain. Additionally, many factories do not have adequate pollution control systems, which worsens the situation. Several regions in India have faced severe environmental challenges due to industrial pollution from machinery manufacturing. In states like Gujarat and Maharashtra, where industrial clusters are densely located, air quality levels have frequently breached safe limits, endangering the health of the local population. Moreover, the Yamuna River, a crucial water source in northern India, has faced severe pollution due to industrial discharges from nearby factories, including those involved in machinery production.

India's metal industry, comprising sectors such as steel, aluminum, copper, and zinc production, is one of the most crucial pillars of its industrial framework. Metals are integral to various industries, including construction, infrastructure, transportation, and manufacturing.

India ranks among the world's top producers of many essential metals, contributing significantly to both its domestic economy and exports. India's metal industry is expansive, driven by increasing urbanization, industrialization, and infrastructure development. The country is the second-largest producer of steel globally, with major players such as Tata Steel, Steel Authority of India Limited (SAIL), and JSW Steel leading the market. Aluminum production is also significant, with companies like Hindalco and National Aluminium Company (NALCO) playing a crucial role. Other key sectors include copper, lead, and zinc production, all of which serve both domestic needs and international markets. This industry has been a cornerstone of India's economic growth, providing employment to millions of people and contributing to India's GDP. However, the rapid expansion of metal production facilities has exacerbated environmental challenges, particularly with pollution from mining, refining, and smelting processes. However, this rapid growth has led to severe environmental consequences. The metal industry is responsible for generating vast amounts of pollution, including air, water, and soil contamination, which poses a serious threat to ecosystems and public health. The metal industry is one of the largest contributors to air pollution. The production of metals, especially steel and aluminum, involves the combustion of large quantities of coal and fossil fuels, which emit significant amounts of carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter (PM). These emissions lead to the degradation of air quality, contributing to global warming, acid rain, and respiratory diseases in nearby communities. In addition, the release of volatile organic compounds (VOCs) and heavy metals such as mercury and lead further exacerbates the impact on air quality.

The following table (Table 3.3) summarizes the pollution generated by the four industries, the export and import shares of GDP (in percentage), intermediate product share (in percentage) and the share of employment (in percentage) in all these four industries.

Table 3.3: Industry-wise Pollution Level, Export and Import Shares, Intermediate Goods Share and Employment Share

Industry	**Pollution Level (Index)**	**Export Share of GDP (%)**	**Import Share of GDP (%)**	**Intermediate Product Share (%)**	**Employment Share (%)**
Chemical Industry	4.2 (High)	4.5	4	30	2.5
Machinery Industry	3.8 (Medium-High)	2.8	3.5	25	3
Metal Industry	4.0 (Medium-High)	3.2	3.8	32	3.5
Textile Industry	3.5 (Medium)	5	2.5	20	5

Key Observations:

- Chemical Industry: Despite its significant contribution to exports, it faces high pollution concerns.
- Machinery and Metal Industries: Both industries have moderate pollution levels but are crucial for India's manufacturing sector.
- Textile Industry: While it has a relatively lower pollution level, it's a major contributor to exports and employment.

Data Sources:

- **Central Pollution Control Board (CPCB):** For pollution data and environmental regulations.
- **Ministry of Commerce and Industry:** For export-import data.
- **Ministry of Labour and Employment:** For employment data.

With increasing production fragmentation for the last few decades, firms tend to outsource several parts of their production. This outsourcing is often been influenced by several factors. One of the most important factors is the 'cost' factor. The costs incurred in production of goods and services comprises of several types. Apart from the factor prices and the traditional input costs, firms in recent times have been charged with higher prices for using environment as an input for their production process. Many of the industries suffer from rising cost of energy while product prices tend to drop. In order to survive, firms tend to outsource some parts of their production activities to smaller units. The reason may be that the larger firms fail to substitute energy use with other inputs of production. If firms can substitute energy with something else then firms tend not to outsource even if energy prices rise. However, many formal firms will not be able to reduce labour costs or interest charges in the face of rising energy prices. This may be one of the reasons why they might outsource to firms outside their ambit, hence can substitute higher energy prices with lower labour costs for example. The informal sector production could be a case in point. However, we do not know if abatement costs are also borne by the informal sector because we do not have adequate information on this account. It will be tested in future research that energy price rise has substitution impact on other factor inputs or not. In this current study, we only put emphasis on the relationship between energy prices and outsourcing intensity. So, we try to establish the fact that how firms attach importance on the price of energy while making their outsourcing decisions apart from other factors.

For the empirical analysis, firm-level panel data has been collected from the PROWES Database (by CMIE). The period of this empirical analysis ranges from 2005 to 2018.[6] This empirical analysis uses data on outsourcing activity by Indian manufacturing firms. In this paper we have selected firms from India's four industries namely chemical industry, machinery industry, metal industry and textile industry. There are several reasons behind the selection of these industries for our empirical study. Firstly, these industries are responsible for generating a significant amount of pollution in the Indian economy. Secondly, the employment generated by these four industries industry is also huge and plays a significant role in meeting basic needs of people and also improving the quality of life. Finally, and most importantly the number of firms enrolled in these four industries are huge compared to the firms enrolled in other industries in the PROWES database. The availability of so many observations was helpful to carry out this empirical analysis. Although the primary interest of the study rests on investigating the effect of change in energy prices on the outsourcing decisions by the firms while controlling for the firm-specific factors. In order to capture such firm-specific effects, six control variables have been considered namely salaries and wages, welfare and training expenses, sales, profit after tax, dividend rate, foreign exchange earnings and an interaction

[6] The year 2005 has been chosen as the starting year of our analysis due to several reasons. The year 2005 has been marked by huge FDI inflows, several overseas acquisitions by big Indian companies, stock market prices rose significantly, India's capital market performance was commendable, and several multi-billion-dollar investment plans were announced by Intel, Cisco and Microsoft in India.

between energy prices and forex earnings.[7] Although there are several papers which have used the CMIE database to observe relationships between outsourcing and some economic variables but none of them used energy prices (power, fuel and water charges) as one of the control variables.

The regression model has been set up as:

$$outsource_{it}^{j} = f(energy\ cost_{it}, \underline{X}, \varepsilon_{it})$$

where, $energy\ cost_{it}$ is the charge that the firms pay for the use of non-renewable energy such as power and fuel.

$\underline{X}$ includes other firm level characteristics.

ε_{it} is the random error term.

3.3.1 Data Sources:

In this section, the data and its sources have been described. Data for the dependent variable and all the independent variables are collected obtained from the Prowess Database (maintained by the CMIE). We considered the firm level data of all the financial and detailed records of several companies for the selected industries. The four industries include (1) Chemical (2) Machinery, (3) Metal, and (4) Textile. Apart from these four industries, we also take three more manufacturing industries for our study, the results of which are reported in the appendix. The period chosen for the analysis is 2005-2018. So, we are basically considering a panel data where we will analyse each industry separately. Our main objectives are to find out whether the change in energy intensities (which is used as a proxy for rise in pollution generation) for the production of commodities affects the outsourcing decisions of Indian firms and to subsequently check out for industry wise differences in the findings.

3.3.2 Variable Description

For the purpose of the study, the following variables has been considered:

(i) Outsourced manufacturing jobs:

This variable is considered as the dependent variable and our key interest. In prowess database, this data field captures the amount spent by a company on outsourcing

[7] The selection of control variables has been motivated from Beladi, Dutta and Kar (2016); Chakraborty and Sundaram (2019); Mukherjee (2018); Stiebale and Vencappa (2018); Kar and Banerjee (2022); Kar and Dutta (2018).

any manufacturing jobs. It includes all the expenses that a company bears for contracting the outside parties to carry out their manufacturing processes. The expenses incorporate labour charges, processing charges, fabrication charges, machining charges, fettling charges, etc. paid to outside parties. It also includes conversion charges, contracted production and sub-contracted production.

(ii) Power, fuel and water charges:

Since the main objective of this paper is to find out whether a firm's outsourcing decision is influenced by energy prices, this variable has been considered as our key independent variable. This variable in the prowess database captures the costs incurred by firms which includes expenditures on energy sources like coal, electricity or non-conventional energy, petroleum products and water charges. The expenses on power and fuel includes the cost of consumption of energy for carrying out the economic activities of a company or firm. The cost includes the expenditure on consumption of electricity and petroleum products (e.g., coal, diesel, naphtha, and other energy sources). Apart from the power and fuel charges, this data field in prowess also reports water charges which includes the cost borne by the firms for consumption of water. Several industrial firms, water parks or entertainment companies sometimes report their expenditure on water consumption.

(iii) Salaries and Wages:

The salaries and wages include all the periodic payments made to the employees (including workers and managers) for the services provided by them. This variable in prowess refers to all allowances paid to the employees (e.g., as LTA, DA, HRA, etc.). It also incorporates the compensation paid to them in kind.[8] But payments such as bonus, contribution to provident funds and gratuities, ex-gratia, are excluded from this variable since all of these are recorded under separate headings in prowess. This variable has been considered as one of the covariates to control for other expenses which is expected to impact the outsourcing decisions.

(iv) Staff welfare and training expenses:

This variable captures the total expenses on welfare and training of employees. Apart from the regular wage payments, various amenities are also provided to the employees for their welfare, which are referred to as staff welfare. The staff welfare

[8] In some industries such as tea and sugar industry, companies often make their payment in kind to their workers.

expenses include transportation facilities, free or subsidized medical treatment, recreation facilities, staff food, canteen expenses, etc. These expenses generally are not a part of the employee's salaries but are borne by the employers for the benefit of their employees. Staff training, on the other hand primarily represents the expenses incurred by the companies to train their employees.

(v) Sales:

Another important covariate which has been considered to control for size of the firms is the volume of sales. The sales variable includes income from non-financial services and sale of industrial goods (which includes sale of goods, scrap, electricity, from repairs, job work and construction). Sales also refers to fiscal benefits received by a company. In the prowess database, sales are recorded in gross figure and is inclusive of all indirect taxes, rebates and discounts.

(vi) Profit after tax:

In prowess, this variable refers to the net profit of the company after tax. It includes the residual value after deducting all revenue expenses from the sum of total income and change in stocks. Thus, the following equation holds:

Profit after tax = Total income + Change in stocks - Total expenses.

where total income denotes the gross income from sale of industrial goods, income from financial services, income from non-financial services, income from prior period, extra-ordinary transactions and other forms of income. On the other hand, the change in stocks incorporates the net increase in closing stocks of finished goods, work-in-progress and semi-finished goods. Finally, the total expenses comprise of several expenses that the firm has to incur including raw materials, purchase of finished goods, stores and spares, packaging, etc. This variable has been considered in this study to take care of the firm's profitability criterion.

(vii) Dividend Rate:

The income that an investor receives from an investment is captured by dividend rate. The source of this dividend may be from the stocks or other investment funds or from a portfolio. In prowess database, the dividend rate refers to the payments made by a company to its shareholders. It is thus expected that the companies which are earning higher profits often pays out higher dividends. This variable therefore captures another aspect of profitability of the firms.

(viii) Total forex earnings:

Total forex earnings capture the total earnings of a company in terms of foreign exchange which includes earnings (earned in foreign currency) from goods and services exports, dividends earned from investments made in foreign companies and the value of foreign currency that the company can receive in the form of interest (which can be earned either from direct investments or on loanable funds provided to a foreign company). Thus, this variable captures the degree of openness of the firms or the degree of interconnectedness to international market.

3.3.3 Econometric Specification:

The following econometric specification has been used for the purpose of this study:

$$outsourcing_{it} = \alpha_{it} + \beta power_{it} + \gamma X_{it} + \varepsilon_{it} \quad (1)$$

where, $outsourcing_{it}$ depicts outsourced manufactured jobs by i^{th} firm at period 't'. $power_{it}$ is the main exogenous variable (which stands for power, fuel and water charges) for firm 'i' at period 't' and finally X_{it}includes the set of six control variables namely, salaries and wages, staff welfare expenses, sales of companies, profit after tax, dividend rates, total foreign exchange earnings and the three interaction terms between power and wages, between power and profit after tax and between power and forex earnings. The full structural form specifications to answer our hypothesis is as follows:

$$outsourcing_{it} = \alpha_{it} + \beta_1 power_{it} + \gamma_1 wpay_{it} + \gamma_2 pat_{it} + \gamma_3 forex_{it} + \gamma_4 sales_{it} + \gamma_5 divr_{it} + \gamma_6 welfare_{it} + \gamma_7 (powerXforex)_{it} + \varepsilon_{it} \quad (2)$$

where the variables are defined as follows:[9]

$$outsourcing_{it} = \left(\frac{outsourced\ manufactured\ jobs}{total\ capital}\right)_{it}$$

$$power_{it} = \left(\frac{power, fuel \,\&\, water\ charges}{total\ capital}\right)_{it}$$

[9] *Here we deflate each variable by total capital and make all the variables size neutral and take care of firm size heterogeneity.*

$$wpay_{it} = \left(\frac{salaries\ and\ wages\ paid}{total\ capital}\right)_{it}$$

$$pat_{it} = \left(\frac{profit\ after\ tax}{total\ capital}\right)_{it}$$

$$forex_{it} = \left(\frac{Total\ foreign\ exchange\ earnings}{total\ capital}\right)_{it}$$

$$divr_{it} = \left(\frac{dividend\ rate}{total\ capital}\right)_{it}$$

$$welfare_{it} = \left(\frac{staff\ welfare\ \&\ training\ expenses}{total\ capital}\right)_{it}$$

$$sales_{it} = \{\log\ (total\ sales)\}_{it}$$

$$(powerXforex)_{it} = \left(\frac{power\ X\ forex}{total\ capital}\right)_{it}$$

We estimate equation (2) using fixed effects regression model[10] where α_{it} represents the industry fixed effects. The error terms are given as ε_{it}. Further, it is important to report the functional nature of the empirical relation and therefore, the *identification* is of concern, which performs best under strict exogeneity of factors affecting the dependent variable. Indeed, one of the foremost challenges that an empirical study with panel data can potentially face is that of presenting a clear identification strategy with regard to the empirical analysis. Identification issues can arise due to reverse causality, or omitted variable bias, or both. For equation (2) one can argue that outsourcing decisions taken by firms may affect the energy prices through increased demand for energy rather than energy prices driving the need for production reorganization. Thus, we offer results from dynamic panel regressions to rule out possible

[10] The Hausman Specification Test has been conducted and the test result suggests that our data best fits the fixed effects model. The test results have been provided in the appendix.

endogeneity biases.

In standard applications, the identification strategy uses multiple estimation methods with greater emphasis on the panel fixed effects. It is well-known that time invariant factors like geographical location, stock of natural resources, cultural and social capital, etc. can affect both production and outsourcing decisions taken by several entities. Fixed effect estimates can take into account these (slow-moving) time invariant factors and can ensure that our estimates are only capturing the variation across firms in the industry. Besides, considering the right-hand side variables only, especially the potentially endogenous ones in contemporaneous terms will not solve the endogeneity problem. Lagged explanatory variables are less likely to be influenced by or correlated with the error term. So, in the dynamic model we offer for equation (2) accommodates this specification. We show that the lagged structure retains the estimates under fixed effects.[11] Difference or System GMM analysis takes care of robustness for our benchmark model. The dynamic panel estimators, as adopted subsequently, use internal instruments generated via moment conditions employing several lags of the endogenous covariates. Generally, this reduces the sample size in the process. However, at the firm level analysis, the model functions well given the available data points.

3.4 Regression Results

The empirical results for the fixed effects regression analysis of all the four manufacturing industries are presented in subsequent tables (separate regression tables has been used for different industries). Each table represents six separate regression models for all the industries. This estimation strategy has been taken is to check the marginal contribution of each additional variable across specifications, rather than using all variables in all specifications. Before moving on to the fixed effects regression results, if we look at the scatter plots (See Appendix) between the power variable and the outsource variable, we can see a positive relation between them. The positive relation as hypothesised represents the fact that firms tend to outsource more when price of their environmental input increases. The other scatter plots in respective figures also displays positive signs as expected. Similarly, the descriptive statistics and correlation matrices for the variables are provided in the appendix.

In all the six regressions presented here, we find that the coefficient associated with

[11]For recent applications, see, Dutta and Mallick, 2018; Dutta and Williamson, 2016; Dutta and Sobel, 2016; Asiedu and Lin, 2011; Dollar and Kray, 2002, to mention a few.

outsourcing is positive and statistically significant for all the four industries. This indicates that irrespective of the industries to which the firms belong, the formal and larger firms are expected to increase their outsourcing intensity with rise in energy prices. This validates our hypothesis that formal firms which are under the purview of government regulations outsource production in parts to smaller firms in order to cope with rising energy prices and increase their profitability. The formal firms will not be able to reduce labour costs or interest charges in addition to rising energy prices. This may push the formal firms to outsource outside their ambit, in order to substitute higher energy prices with lower labour costs. This can be one of the reasons for the outsourcing of activities to informal sectors. We add important covariates along with the 'power' variable such as forex earnings, wages, total sales, profit after tax, dividend rate and welfare expenses. All the variables have been deflated by total capital as discussed above. The 'wpay' variable is positive and significant and it holds true for all the industries implying the fact that with rise in factor cost (in this case labour cost) firms' outsourcing intensity rises since they outsource some segments of the production process in order to save on the cost of production. Same logic may go for the positive sign attached to the 'welfare' variable. It can be argued that it is profitable for firms to outsource those production processes which involve greater costs of training and other welfare expenses. The 'profit after tax (pat)' also carry a positive sign since firms earning higher profits tend to outsource more to gain efficiency and higher productivity. In the previous literatures it has been argued that the more productive firms are busy in organising the production process, in designing several marketing models, involved in decisions regarding product packaging, advertising, etc rather than carrying out certain production processes in-house. The firms with higher profit are found to outsource more since higher profitability indicates that they are more efficient which drives them further to outsource in order to maintain the high level of profits. Similarly, the 'sales' variable is positive and significant implying that larger firms have higher outsourcing intensity. The firms which report higher values of sales are basically large firms which are expected to outsource more and more production processes to become more efficient and productive in order to meet the increasing demands. The 'divr' variable like the other variables also have a positive sign. Firms which offer higher dividend rates for their shareholders are expected to be financially sound and profitable firms (since their share values are also higher). On the other hand, a higher value of foreign exchange earnings indicates greater integration of the firms to international market which in turn is seen to instigate firms to outsource higher volumes of production processes in order to cop-up with greater scale of production and high demand for their products (both domestic and foreign demand). This may justify the positive significant coefficient for the 'forex' variable.[12] On the contrary, the dividend rate variable carries a negative sign for the chemical industry but positive significant for all other industries.

Besides the usual covariates, we have introduced an interaction term. In the interaction term, we chose to interact energy prices with total foreign exchange earnings of the firms in the various industries. The coefficient is expected to capture the net effect of a rise/fall in power variable on outsourcing for a firm for a given level of foreign exchange earnings, or conversely the net effect of foreign exchange earnings on outsourcing for a given level of energy prices. Technically, the coefficient of the interaction term captures the joint effect of energy prices and forex earnings on outsourcing intensity. It is possible that the overall impact is neutralized or even reversed under interaction effects, because structurally it comes from the following relation (3), where the variable *Interaction* is a product of $[(power)_{it} * (forex)_{it}]$determining the marginal impact of a one unit rise in one variable on the intensity of outsourcing at a given value of the other variable:

$$outsource_{it} = \alpha_i + \beta_1 * power_{it} + \gamma_i * \underline{X}_{it} + \gamma_j * Interaction + \varepsilon_{it} \qquad (3)$$

$$\frac{\partial outsource_{it}}{\partial (power)_{it}} = \beta_1 + \gamma_j * (forex)_{it} \qquad (3a)$$

$$\frac{\partial outsource_{it}}{\partial (forex)_{it}} = \beta_k + \gamma_j * (power)_{it} \qquad (3b)$$

where $k \in i = 1,2 \ldots n$ and $j \neq i$.

Hereβ_1 is the direct coefficient of power on outsourcing and γ_j is the coefficient of the interaction term which shows that the power charges of a manufacturing firm should rise if the degree of openness of the firm rises. γ_j can be positive or negative depending on the direction in which power and forex earnings interacts and has its effects on the outsourcing decision of a firm. The net impact should depend on the relative strengths of β_1 and γ_j.

From the fixed effects regression results it can be seen that the interaction term is negative and statistically significant. The negative sign of the interaction term del(outsource)/del(forex)= (coefficient of forex) + (mean power cost) x (coefficient of interaction) implies that for a given average value of power expenses, as the foreign earnings

[12] A recent paper by Chakraborty and Sundaram (2019) empirically validated that a rise in import competition leads to a greater outsourcing intensity for Indian firms.

rise, firms tend to outsource less, perhaps because the export market demands compliance and certificates from environmental authorities, which outsourcing to smaller uncontrolled units does not support. So, firms under this criterion should keep larger output in-house, hence the negative interaction effect, which is statistically significant. The empirical results for each of the four industries have been provided in table format (Table 3.4 (a) to 3.4 (d)). In each regression table, the results for all the possible regression models have been presented. A summary of the regression results for all four industries (including expected signs and actual signs of all the independent variables) have been consolidated in Table 3.4 (f). We can see that in all the industries, our key variable 'power' is positive and strongly significant. Apart from 'power' variable, all the other independent variables, the actual signs match with the expected signs, except for Metal industry, the 'welfare' variable becomes negative. For Textile industry, the 'wpay' and 'welfare' variables loses their significance. The strong significance of the 'power' variable in all the regression models validates our hypothesis.

Table 3.4 (a): Fixed Effects Regression Results (For Chemical Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
power	0.0239**	0.0605***	0.0224**	0.0241**	0.0188*	0.0190*
	(0.0102)	(0.00886)	(0.0102)	(0.0104)	(0.00998)	(0.0100)
forex	0.00554***	0.00906***	0.00598***	0.00758***	0.00447***	0.00474***
	(0.00153)	(0.00146)	(0.00153)	(0.00155)	(0.00148)	(0.00139)
wpay	0.0494***		0.0516***	0.0660***	0.0685***	0.0520***
	(0.00694)		(0.00695)	(0.00691)	(0.00588)	(0.00687)
sales	0.188***	0.208***		0.227***	0.180***	0.176***
	(0.0408)	(0.0410)		(0.0414)	(0.0375)	(0.0401)
pat	0.0359***	0.0406***	0.0371***		0.0362***	0.0330***
	(0.00315)	(0.00310)	(0.00315)		(0.00310)	(0.00309)
divr	0.00162*	0.00130	0.00176**	0.000475	-0.00258***	0.00144*
	(0.000842)	(0.000847)	(0.000844)	(0.000837)	(0.000804)	(0.000842)
welfare	0.342***	0.618***	0.364***	0.377***		0.365***
	(0.0811)	(0.0717)	(0.0812)	(0.0825)		(0.0808)
power x forex	-2.65e-06**	-3.85e-06***	-1.66e-06	-1.73e-06	-2.30e-06**	
	(1.19e-06)	(1.18e-06)	(1.17e-06)	(1.21e-06)	(1.17e-06)	
Constant	-0.991***	-1.125***	0.368***	-1.260***	-0.888***	-0.905***
	(0.295)	(0.297)	(0.0258)	(0.300)	(0.269)	(0.291)
Observations	4,352	4,352	4,352	4,353	4,631	4,375
R-squared	0.221	0.210	0.216	0.193	0.216	0.220
Number of id	792	792	792	793	835	792

Standard errors in parentheses

*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*

Source: Own calculations.

Table 3.4 (b): Fixed Effects Regression results (For Machinery Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
power	0.672***	0.689***	0.697***	0.651***	0.809***	0.670***
	(0.0558)	(0.0555)	(0.0561)	(0.0559)	(0.0554)	(0.0554)
forex	0.0114***	0.0114***	0.0104***	0.0158***	0.0288***	0.0116***
	(0.00295)	(0.00295)	(0.00297)	(0.00284)	(0.00258)	(0.00240)
wpay	0.0258***		0.0362***	0.0122	0.0802***	0.0252***
	(0.00955)		(0.00951)	(0.00924)	(0.00897)	(0.00954)
sales	0.626***	0.660***		0.675***	0.552***	0.616***
	(0.0896)	(0.0885)		(0.0895)	(0.0900)	(0.0891)
pat	0.0178***	0.0148***	0.0202***		0.0238***	0.0186***
	(0.00337)	(0.00322)	(0.00338)		(0.00347)	(0.00333)
divr	0.000988**	0.00111***	0.00101**	0.00128***	0.00106**	0.000984**
	(0.000411)	(0.000408)	(0.000414)	(0.000409)	(0.000431)	(0.000411)
welfare	1.712***	1.917***	1.759***	1.903***		1.694***
	(0.192)	(0.173)	(0.194)	(0.190)		(0.182)
power x forex	-1.77e-05	-1.46e-05	-1.84e-06	-3.18e-05	-8.51e-05***	
	(2.11e-05)	(2.11e-05)	(2.12e-05)	(2.10e-05)	(2.14e-05)	
Constant	-3.540***	-3.682***	0.676***	-3.818***	-3.052***	-3.477***
	(0.607)	(0.605)	(0.0688)	(0.608)	(0.606)	(0.604)
Observations	3,686	3,688	3,686	3,686	3,834	3,687
R-squared	0.270	0.297	0.258	0.263	0.264	0.278
Number of id	715	715	715	715	733	715

Standard errors in parentheses
*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

Table 3.4 (c): Fixed Effects Regression results (For Metal Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
power	0.159***	0.252***	0.157***	0.174***	0.203***	0.134***
	(0.0183)	(0.0157)	(0.0183)	(0.0178)	(0.0188)	(0.0166)
forex	0.0153***	0.0118***	0.0155***	0.0156***	0.00655***	0.0155***
	(0.00100)	(0.000949)	(0.00100)	(0.00100)	(0.000822)	(0.00100)
wpay	0.219***		0.230***	0.220***	-0.0345**	0.228***
	(0.0232)		(0.0227)	(0.0233)	(0.0147)	(0.0231)
sales	0.138**	0.251***		0.161***	0.221***	0.116*
	(0.0594)	(0.0594)		(0.0592)	(0.0583)	(0.0591)
pat	0.0295***	0.0308***	0.0316***		0.0415***	0.0364***
	(0.00828)	(0.00846)	(0.00824)		(0.00852)	(0.00803)
divr	0.145***	0.155***	0.144***	0.154***	0.153***	0.144***
	(0.0156)	(0.0159)	(0.0156)	(0.0154)	(0.0162)	(0.0157)
welfare	-1.853***	-0.883***	-1.912***	-1.900***		-1.827***
	(0.130)	(0.0818)	(0.128)	(0.130)		(0.130)
power x forex	-3.06e-06***	-4.14e-06***	-2.81e-06***	-3.90e-06***	-2.28e-06**	
	(9.28e-07)	(9.41e-07)	(9.23e-07)	(9.00e-07)	(9.71e-07)	
Constant	-0.646	-1.329***	0.372***	-0.806*	-1.011**	-0.474
	(0.438)	(0.441)	(0.0345)	(0.437)	(0.429)	(0.436)
Observations	2,533	2,533	2,533	2,533	2,723	2,533
R-squared	0.402	0.376	0.401	0.399	0.332	0.399
Number of id	510	510	510	510	550	510

Standard errors in parentheses
*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

Table 3.4 (d): Fixed Effects Regression results (For Textile Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
power	0.159***	0.164***	0.179***	0.146***	0.163***	0.0726*
	(0.0423)	(0.0408)	(0.0424)	(0.0403)	(0.0412)	(0.0393)
forex	0.0237***	0.0240***	0.0273***	0.0394***	0.0264***	0.0109**
	(0.00543)	(0.00536)	(0.00541)	(0.00511)	(0.00478)	(0.00493)
wpay	0.00876		0.0207	0.0324	0.0194	0.0134
	(0.0224)		(0.0224)	(0.0224)	(0.0210)	(0.0224)
sales	0.524***	0.528***		0.523***	0.458***	0.516***
	(0.101)	(0.101)		(0.0995)	(0.0952)	(0.102)
pat	0.0679***	0.0690***	0.0811***		0.0672***	0.0813***
	(0.0190)	(0.0188)	(0.0190)		(0.0187)	(0.0190)
divr	0.0678*	0.0679*	0.0649	0.0968**	0.0612	0.0713*
	(0.0404)	(0.0404)	(0.0406)	(0.0395)	(0.0398)	(0.0406)
welfare	0.116	0.163	0.197	-0.186		0.105
	(0.370)	(0.350)	(0.372)	(0.278)		(0.371)
power x forex	-3.30e-05***	-3.30e-05***	-3.23e-05***	-4.09e-05***	-3.50e-05***	
	(6.14e-06)	(6.13e-06)	(6.17e-06)	(5.90e-06)	(5.91e-06)	
Constant	-2.717***	-2.742***	1.043***	-2.802***	-2.198***	-2.482***
	(0.734)	(0.731)	(0.0978)	(0.730)	(0.681)	(0.737)
Observations	2,783	2,783	2,783	2,786	3,004	2,788
R-squared	0.068	0.067	0.057	0.172	0.072	0.055
Number of id	474	474	474	474	512	474

Standard errors in parentheses
*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

We summarize the regression results in the following table which includes the expected sign of the independent variables taken in our study and the actual signs from the regression analysis for all the four industries.

Table 3.4 (e): Summary table for the empirical results including the expected signs and the actual signs of the independent variables

Independent Variables	**Expected Signs**	**Actual Signs (Chemical Industry)**	**Actual Signs (Machinery Industry)**	**Actual Signs (Metal Industry)**	**Actual Signs (Textile Industry)**
Power, fuel and water charges **(power)**	**+ ve**	**+ ve****	**+ ve*****	**+ ve*****	**+ ve*****
Total foreign exchange earnings **(forex)**	**+ ve**	**+ ve*****	**+ ve*****	**+ ve*****	**+ ve*****
Salaries and wages **(wpay)**	**+ ve**	**+ ve*****	**+ ve*****	**+ ve*****	**+ ve**
Total sales **(sales)**	**+ ve**	**+ ve*****	**+ ve*****	**+ ve****	**+ ve*****
Profit after tax **(pat)**	**+ ve**	**+ ve*****	**+ ve*****	**+ ve*****	**+ ve*****
Dividend rate **(divr)**	**+ ve**	**+ ve***	**+ ve****	**+ ve*****	**+ ve***
Staff welfare and training expenses **(welfare)**	**+ ve**	**+ ve*****	**+ ve*****	**- ve*****	**+ ve**
Interaction term **(power x forex)**	**- ve**	**- ve****	**- ve*****	**- ve*****	**- ve*****

*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

3.5 Endogeneity and Robustness Check

In this empirical analysis, we have found strong and robust evidence for our hypothesis which states that energy prices influence firm level outsourcing decisions. Our results are robust after controlling for other factors which might affect a firm's outsourcing decisions. The impact of prices of environmental inputs on outsourcing intensity continues to be robust even across all other manufacturing industries (The results of other manufacturing industries have been reported in the appendix). Our variable of interest continues to be positive and significant even after running dynamic panel models.

Apart from controlling for firm level heterogeneity, we must also ensure that there are no endogeneity issues. It may be the case that outsourcing intensity and energy prices can be simultaneously determined, the power variable can be endogenous. Moreover, the 'power' variable can be endogenous due to omitted variable bias. Thus, we take into account endogeneity issues and explain it in detail. The strategy to take into account endogeneity concerns is by considering dynamic panel estimators. The dynamic panel estimators, as described below, use internal instruments generated via moment conditions employing several lags of the endogenous covariates. This reduces the sample size considerably. Although this is not a concern for chemical, machinery, metal and textile industries since the sample size is large enough to compensate for the reduction in data. But for industries like cement, paper and leather, such estimations reduce sample size significantly which may change the level of significance for certain variables (The results of these industries are presented in Appendix).

Before we go on to describe the dynamic panel estimators, it is important to acknowledge a bias associated with fixed effect estimators. One serious difficulty with linear dynamic panel data (DPD) models like fixed effect estimators is that the demeaning process gives rise to a bias called 'Nickell bias". Specifically, the demeaning process is applied to remove unobserved heterogeneity that is present in ordinary least squares models. The demeaning which entails subtracting the individual's mean value of y (the dependent variable) from each X (independent variable) results in a correlation between the regressor and error. This is particularly problematic when fixed effect estimators are applied for large 'N' and small 'T' samples. We definitely have such a sample where N (number of firms) is greater than T (number of years). As Nickell (1981) points out, the correlation results in a bias in the estimate of the coefficient of the lagged dependent variable and this bias is not mitigated by increasing N. Nickell further stresses that in small 'T' context, the bias can be sizeable. The bias will be relatively reduced for large 'T' context. It should be further noted that the bias arises even if the error process is independent and identically distributed. First differencing the model takes care of this problem as suggested by the Anderson–Hsiao (AH)estimator. Yet, as suggested by Arellano and Bond (1991), the Anderson–Hsiao estimator, while consistent, fails to take all of the potential orthogonality conditions into account. As explained later, we resort to Difference GMM estimator that solves the concern of Nickell Bias by first differencing the data as well as meets all orthogonality conditions. The presence of Nickell Bias has been tested in this chapter, and it is found to be absent in this analysis.

Now coming to the dynamic panel estimators. In recent decades, the use of dynamic panel estimators for cross country panel empirical investigation have steadily increased (see, Dutta and Mallick, 2018; Dutta and Williamson, 2016; Dutta and Sobel, 2016; Cooray et al., 2017; Asiedu and Lien, 2011; Dollarand Kraay, 2002; Bond et al., 2001 to mention a few). By allowing us the dynamic process of economic activity, dynamic panel estimators have become popular in cross country panel estimation because of being well suited to handle varied panel data challenges. Such models help us to control for unobservable heterogeneity. We apply this estimation technique to control for firm level heterogeneity. For OLS or fixed effect models, the unobserved individual effect can be correlated not only with the endogenous regressors but also with predetermined regressors. The Difference GMM (DGMM) model was proposed by Arellano and Bond (1991) that removes the unobserved individual effect and its associated omitted variable bias by first differencing the equation. It is designed for small 'T' large 'N' panels, a dependent variable that is dynamic in nature, an equation including right hand side variables that are not strictly exogenous and a panel that is subjected to unobserved heterogeneity, a panel with fixed country effects and presence of heteroskedasticity and autocorrelation within countries (Baum et al., 2003). Our firm level panel for each industry meets all these criteria and, thus, the dynamic panel estimators are very suited for our case.

In the case of DGMM, the model is set up as a system of equations, one per time period, where the lags generated via the method of moments are used as instruments and the instruments applicable to each equation differ. Arellano and Bond points out that the estimator is similar to the Anderson–Hsiao estimator but is a better estimator since it takes into account all of the potential orthogonality conditions (Baum et al., 2003). It is important to report tests like Sargan that check the externality conditions of the instruments. The Arellano–Bond estimator sets up a generalized method of moments (GMM) problem in which the model is specified as a system of equations, one per time period, where the instruments applicable to each equation differ (for instance, in later time periods, additional lagged values of the instruments are available). The results for Arellano and Bond for the above four industries: Chemical, Machinery, Metal and Textile have been presented in Tables 3.4 (f)-3.4 (i). In all regression models, a one-period lag of the dependent variable has been considered in the right-hand side of the regression equation. It can be observed that the results continue to support the FE estimates and are robust. For all the industries, the 'power' variable still carries the expected positive sign and at the same time significant for most of the regression models.

Table 3.4 (f): Dynamic Panel Estimates (GMM Estimation for Chemical Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
outsource $_{t-1}$	0.364***	0.396***	0.364***	0.388***	0.338***	0.363***
	(0.0176)	(0.0173)	(0.0177)	(0.0178)	(0.0173)	(0.0176)
power	0.168***	0.213***	0.170***	0.195***	0.162***	0.157***
	(0.0184)	(0.0179)	(0.0184)	(0.0185)	(0.0186)	(0.0182)
forex	0.00558***	0.00882***	0.00601***	0.00890***	0.00513***	0.00234
	(0.00186)	(0.00183)	(0.00186)	(0.00187)	(0.00187)	(0.00174)
wpay	0.0621***		0.0645***	0.0627***	0.0867***	0.0638***
	(0.00884)		(0.00882)	(0.00902)	(0.00860)	(0.00880)
sales	0.215***	0.253***		0.232***	0.232***	0.165**
	(0.0678)	(0.0688)		(0.0692)	(0.0668)	(0.0669)
pat	0.0363***	0.0365***	0.0366***		0.0353***	0.0338***
	(0.00416)	(0.00424)	(0.00416)		(0.00427)	(0.00410)
divr	-0.00357***	-0.00304***	-0.00361***	-0.00190***	-0.00383***	-0.00338***
	(0.000737)	(0.000746)	(0.000738)	(0.000726)	(0.000726)	(0.000736)
welfare	0.0818	0.162**	0.0939	0.0924		0.0787
	(0.0772)	(0.0769)	(0.0771)	(0.0787)		(0.0772)
power x forex	-7.65e-06***	-8.71e-06***	-6.96e-06***	-6.44e-06***	-7.82e-06***	
	(1.67e-06)	(1.70e-06)	(1.65e-06)	(1.70e-06)	(1.71e-06)	
Constant	-1.738***	-1.936***	-0.173***	-1.867***	-1.879***	-1.358***
	(0.495)	(0.503)	(0.0359)	(0.505)	(0.483)	(0.490)
Observations	2,788	2,788	2,788	2,788	2,957	2,811
Number of id	622	622	622	622	656	623

Standard errors in parentheses
*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

Table 3.4 (g): Dynamic Panel Estimates (GMM Estimation for Machinery Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
outsource $_{t-1}$	-0.109***	-0.0947***	-0.106***	-0.0763***	-0.0119	-0.113***
	(0.0181)	(0.0172)	(0.0182)	(0.0199)	(0.0173)	(0.0184)
power	0.0577	0.140**	0.0618	0.149**	0.215***	0.0925
	(0.0666)	(0.0685)	(0.0668)	(0.0730)	(0.0599)	(0.0673)
forex	0.0359***	0.0319***	0.0365***	0.0584***	0.0381***	0.0227***
	(0.00312)	(0.00329)	(0.00313)	(0.00329)	(0.00252)	(0.00265)
wpay	0.206***		0.214***	0.0577***	0.218***	0.199***
	(0.0129)		(0.0128)	(0.0116)	(0.0139)	(0.0131)
sales	0.442***	0.752***		0.760***	0.318***	0.429***
	(0.108)	(0.113)		(0.118)	(0.114)	(0.110)
pat	0.0868***	0.0408***	0.0890***		0.0852***	0.0914***
	(0.00412)	(0.00351)	(0.00409)		(0.00435)	(0.00413)
divr	0.000940**	0.00241***	0.000984**	0.00329***	0.000983**	0.000760*
	(0.000454)	(0.000474)	(0.000455)	(0.000486)	(0.000488)	(0.000459)
welfare	0.461**	1.036***	0.439**	-0.107		0.881***
	(0.197)	(0.187)	(0.198)	(0.217)		(0.192)
power x forex	-0.000139***	-0.000123***	-0.000138***	-0.000201***	-0.000130***	
	(1.80e-05)	(1.91e-05)	(1.81e-05)	(1.97e-05)	(1.89e-05)	
Constant	-2.806***	-3.777***	0.194*	-4.022***	-2.135***	-2.761***
	(0.739)	(0.783)	(0.0995)	(0.813)	(0.770)	(0.749)
Observations	2,286	2,288	2,286	2,286	2,383	2,286
Number of id	570	570	570	570	588	570

Standard errors in parentheses
*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

Table 3.4 (h): Dynamic Panel Estimates (GMM Estimation for Metal Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
$outsource_{t-1}$	0.107***	0.124***	0.107***	0.115***	0.122***	0.106***
	(0.0169)	(0.0170)	(0.0169)	(0.0165)	(0.0169)	(0.0169)
power	0.208***	0.315***	0.208***	0.220***	0.147***	0.176***
	(0.0347)	(0.0308)	(0.0347)	(0.0343)	(0.0295)	(0.0296)
forex	0.0113***	0.0101***	0.0115***	0.0132***	0.0114***	0.0104***
	(0.00350)	(0.00355)	(0.00349)	(0.00338)	(0.00163)	(0.00349)
wpay	0.199***		0.198***	0.183***	0.169***	0.213***
	(0.0321)		(0.0320)	(0.0311)	(0.0313)	(0.0311)
sales	0.0450	0.0911		0.0827	0.0523	0.0224
	(0.0892)	(0.0904)		(0.0885)	(0.0882)	(0.0888)
pat	0.0216**	0.00560	0.0213**		0.0106	0.0281***
	(0.0103)	(0.0101)	(0.0102)		(0.00969)	(0.00961)
divr	0.234***	0.237***	0.233***	0.239***	0.210***	0.235***
	(0.0208)	(0.0212)	(0.0208)	(0.0207)	(0.0207)	(0.0209)
welfare	-1.460***	-0.887**	-1.454***	-1.302***		-1.314***
	(0.387)	(0.383)	(0.387)	(0.376)		(0.380)
power x forex	-2.41e-06**	-4.32e-06***	-2.35e-06**	-3.21e-06***	-1.17e-06	
	(1.15e-06)	(1.13e-06)	(1.14e-06)	(1.07e-06)	(1.12e-06)	
Constant	-0.150	-0.374	0.188***	-0.440	-0.185	0.0266
	(0.669)	(0.679)	(0.0443)	(0.663)	(0.656)	(0.665)
Observations	1,582	1,582	1,582	1,582	1,676	1,582
Number of id	389	389	389	389	421	389

Standard errors in parentheses
*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

Table 3.4 (i): Dynamic Panel Estimates (GMM Estimation for Textile Industry)

Dependent variable: outsourced manufacturing jobs/total capital (outsource)

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
$outsource_{t-1}$	0.105***	0.112***	0.103***	0.101***	0.0950***	0.107***
	(0.0198)	(0.0198)	(0.0198)	(0.0206)	(0.0193)	(0.0197)
power	0.0264	0.106*	0.0298	-0.00874	0.0207	-0.0211
	(0.0645)	(0.0610)	(0.0645)	(0.0665)	(0.0573)	(0.0585)
forex	0.0290***	0.0283***	0.0324***	0.0778***	0.0262***	0.0215**
	(0.00954)	(0.00958)	(0.00938)	(0.00837)	(0.00668)	(0.00856)
wpay	0.183***		0.195***	0.228***	0.172***	0.175***
	(0.0499)		(0.0495)	(0.0502)	(0.0458)	(0.0491)
sales	0.406**	0.499**		0.245	0.398**	0.394**
	(0.200)	(0.199)		(0.207)	(0.183)	(0.199)
pat	0.0490**	0.0613**	0.0532**		0.0513**	0.0527**
	(0.0244)	(0.0243)	(0.0243)		(0.0230)	(0.0242)
divr	0.163***	0.176***	0.165***	0.162**	0.141**	0.171***
	(0.0607)	(0.0609)	(0.0607)	(0.0631)	(0.0561)	(0.0604)
welfare	-0.127	0.389	-0.0896	-0.730		-0.198
	(0.465)	(0.446)	(0.465)	(0.482)		(0.462)
power x forex	-2.57e-05**	-2.24e-05**	-2.50e-05**	-4.44e-05***	-2.49e-05***	
	(1.08e-05)	(1.08e-05)	(1.08e-05)	(1.11e-05)	(9.66e-06)	
Constant	-2.412*	-2.839*	0.553***	-1.631	-2.214*	-2.219
	(1.461)	(1.464)	(0.183)	(1.515)	(1.330)	(1.454)
Observations	1,899	1,899	1,899	1,901	2,033	1,905
Number of id	381	381	381	381	408	381

Standard errors in parentheses
*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

3.5 Concluding Remarks

The rise in global volumes of trade and greater integration to world market although helped many countries to grow at a rapid pace, but it proved detrimental to the environment. Human actions have played a significant role in environmental degradation leading to severe environmental issues like growing greenhouse gas emissions (resulting in global climate change and environmental pollution). Such degradation of the environment resulting in distorting the balance of the ecosystem and affecting human life and property (Meehl, et al., 2000). Thus, environmental pollution caused by human actions has been receiving greater attention from researchers across the world. Many developing countries have already witnessed the devastating effects of environmental damage (e.g., the hazardous-level air pollution in China in recent years have led to rapid increase in the number of cases of lung damage in the population). Thus, while dealing with globalization, trade, production fragmentation and increase in economic activities, one must also address and examine the environmental implications of such activities.

The previous literature on industrial organization and outsourcing although considered the cost-saving and productivity motives of firms as one of the reasons behind producer driven fragmentation, but did not consider the impact of change in costs related to use of energy on the process of production fragmentation. In this study, the gap has been addressed and the relation between price of energy and outsourcing intensity is empirically tested. With the help of Indian firm level panel data for four industries – chemical, machinery, metal and textile between 2005 and 2018, it is found that there is positive significant relation between energy prices and outsourcing intensity. This signifies that the firms attach importance to the energy cost while taking outsourcing decisions. Since outsourcing is considered as one of the forms of fragmentation, it can be argued that rise in energy costs lead to greater degree of production fragmentation. A possible explanation for this may be that rising energy prices disproportionately affect larger firms, which in turn erodes their profitability. The rising fuel costs may compel larger firms to cut back on other costs of production such as labour costs, interest charges, abatement costs, etc. On the other hand, the smaller firms face lower input costs because of lenient labour laws and are also often exempted from carrying out certain abatement activities because these are less monitored and outside the radar of enforcement. The formal firms fail to substitute energy input with other inputs; thus, they take the channel of outsourcing to save on other input costs. The relocation of certain production processes may lead to generation of more pollution due to the fact that the smaller firms are equipped with inferior abatement technologies. Apart from the relation between energy price and outsourcing intensity, we delve into the relation between other covariates and the dependent variable. For example, we find that wages, sales, profit after tax, dividend rate, forex earnings and welfare expenses in most of the alternative empirical specifications are positive and statistically significant.

Finally, the interaction term addresses a very important issue. The negative interaction term suggests that for a given value of energy price, with rise in foreign exchange earnings, firms tend to outsource less since increased integration to world market demands compliance and certificates from environmental authorities. Thus, outsourcing to smaller firms which do not follow environmental standards would restrict the larger firms to meet the desired environmental standards and participate in international market. So, the firms which witnesses larger foreign exchange earnings, should produce major portion of production process in-house and hence the negative and statistically significant interaction effect. The government of such developing countries needs to understand this issue and take attempt in order to solve the rising environmental problems. It is advisable to enforce stricter environmental regulations and supervise both the larger and smaller firms as well as the informal firms so that they receive environmentally friendly FDI and does not involve in dirty stages of production. Enforcing stricter environmental regulations only on the large firms will not help the cause since the large firms can easily find a way out by outsourcing the pollution-intensive production processes. This reorganization of production and fragmentation in production processes really negates the attempts made by the environmental authorities to reduce overall emissions. The global pollution will reduce only if countries across the world take initiative in adopting cleaner technology while producing environmental-intensive commodities.

Chapter 4

Relationship between Trade in Intermediate Goods and Pollution in South Asia

This chapter addresses a broad research question "How does trade in intermediate commodities affect the emission levels in South Asian countries?" In order to investigate this research question, this chapter focuses on empirically testing the link between international production fragmentation induced-international trade in intermediate goods and pollution. The prevailing literature has engaged with production fragmentation and trade in middle products for a long time, but the environmental impact of this exponentially growing practice is less understood. This chapter deals with eight south Asian countries between 1998 and 2018 to estimate if export and import of intermediate products affect the emission of CO_2 in these countries. The empirical analysis uses a number of covariates including trade taxes, trade with rich countries and interaction with degree of industrialization in these countries. The main results indicate that greater fragmentation indeed leads to more emission, although deepening industrial base moderates the overall impact. Static and dynamic panel estimates with a variety of robustness analyses supports the main conjectures. This chapter starts with the discussion of the growing importance of fragmentation induced-trade in intermediate goods. It then moves on to describe the methodology and the data set and finally concludes with the empirical results and its interpretations.

4.1 Trade in Intermediate Goods and Environment

The phenomenal increase in the volume of international trade in the last four decades is significantly associated with environmental degradation (Copeland and Taylor, 2001; 2004; Antweiler and Trefler, 2002; Johnson and Noguera, 2012; etc). Human actions not only led to increased volume of greenhouse gas emissions (leading to environmental pollution) but also played a significant role in climate change across the globe (Vitousek, et al., 1997). Due to severe consequences[13]of such environmental damage, there have been growing interest among the researchers to address the issue regarding the impact of globalization and international trade on environment. Grossman and Krueger (1991) empirically investigated the impact of North American Free Trade Agreement (NAFTA) on environment. The authors segregated the effect of trade on environment into scale, composition and technique effects. Scale effects refer to the increase in pollution due to expansion by economic activities (increase in scale of production) caused by international trade. Composition effect highlights the change in the composition of the trading basket due to liberalization of economy which may lead to a higher level of pollution. Finally, the technique effect indicates that countries participating in international trade may witness improvement in their production techniques or technology due to global integration and technology transfer through foreign investments. Technique effect generally refers to the positive side of international trade claiming that such technology transfer may decrease the level of pollution per unit of output. Several theoretical and empirical papers have studied different aspects of these effects (Frankel and Rose, 2005; Grether and Mathys, 2010, etc).

Apart from these three effects, the impact of trade on the environment has been studied in different dimensions (which include the Pollution Haven Hypothesis (PHH) and the Factor Endowment Hypothesis (FEH)) in the existing trade-environment literature. As already discussed in the previous chapter, PHH emphasizes the importance of environmental regulation in determining the pattern of specialization of different countries. The PHH argues that with liberalization, the developing countries tend to specialize in pollution intensive commodities. The reason behind the above argument is that, the developed countries generally have more

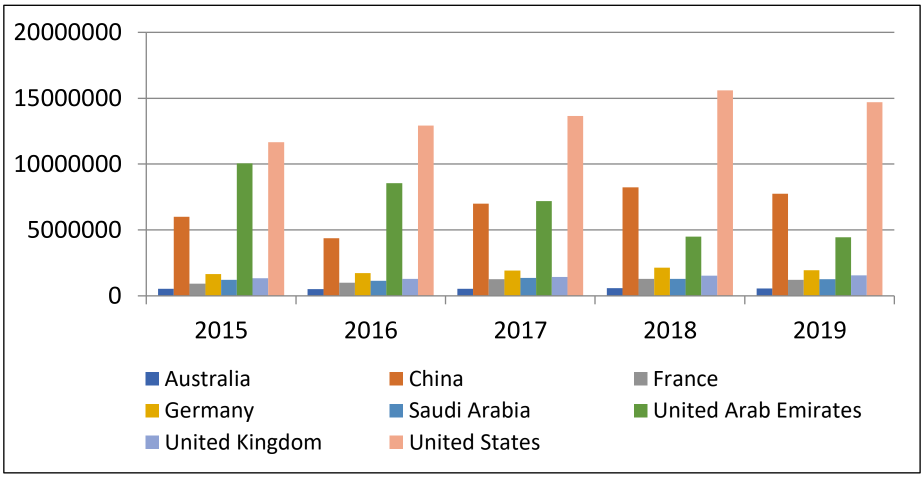
[13] It may include extreme weather due to climate change which is detrimental to both human health and property. For example, the rising incidences of natural hazards like the bushfires in Australia which have a devastating effect on several communities and properties. The magnitude of such hazards is more in developing countries like China where the level of air pollution has risen to a hazardous level in recent years.

stringent environmental regulations compared to their developing counterparts. Thus, the pollution intensive industries migrate from the developed to the developing countries in order to save cost of production for dirty commodities. (Copeland and Taylor, 2003; Cole, 2004; Xing and Kolstad, 2001; Eskeland and Harrison, 2003). The factor endowment hypothesis (FEH), on the contrary, asserts that it is not the differences in pollution policy, but the differences in endowments or technology that determine trade. It predicts that the capital abundant country will specialize in capital intensive goods while the labour abundant country will specialize in labour intensive goods. Since the pollution intensive goods are generally capital intensive, then by the FEH it is the developed countries which will specialize in the dirty goods. The FEH predicts just the opposite to the PHH. However, the impact of trade on environment depends on selection of country for study, time period of analysis and the choice of variable to capture environmental degradation.

The rapid growth in trade in intermediate goods further fuelled the growth of world merchandise trade. Intermediate goods are considered as the component parts which are used to produce finished consumer goods. Intermediate goods trade and international production fragmentation are closely connected to each other. Athukorala and Yamashita (2006) defined international fragmentation production as "cross-border dispersion of component production/assembly within vertically integrated production processes, with each country specializing in a particular stage of the production sequence". So, it can be noted that trade in intermediate goods and international production fragmentation are closely related concepts. The phenomenon of production fragmentation includes industries which are vertically integrated and witnesses a geographically split production processes into various stages and inputs. In this process, different entities across the world takes part in the production of various product components. Basically, firms tend to produce different parts and components of a product rather than producing a finished product. With increase in the pace of globalization such fragmentation extended beyond domestic boundaries. Different parts and components are produced at different regions across the globe compelling countries to take part in cross boundary trade in intermediate inputs. The splitting up of the global value chain and trade liberalization in intermediate goods both makes vertical international specialization possible due to cost advantages.

While the effects of trade in final goods on the environment offer extensive evidence, the extant literature says fairly little about the estimates of damage due to trade in 'middle products' (*a' la* Sanyal and Jones, 1982). Indeed, for a long time the importance of middle products or intermediate goods has been widely discussed in the international trade literature, although the implications have remained confined to production reorganization, factor prices and income distribution, and generally economic development. Importantly, over the last few decades the share of trade in intermediate goods rose at a rapid pace across the world and this need to be duly addressed while dealing with issues in trade and environment. As of recent statistics (2019), an emerging economy like India recorded a share of intermediate exports out of total exports at 31.09% and the import share at 31.12%. Figure 1 shows selective country-wise patterns in export of intermediate goods from India.

Figure 4.1 Export of Intermediate Goods (US$ '000) from India



Source: WITS, World Bank

In the previous decade also, the global share of intermediate inputs in world trade accounted for about 55 percent for most years (WTO, 2013) and for OECD countries only, it represented more than 50 percent of their total trade between 1995 and 2007 (Miroudot *et al*., 2009). In fact, the average growth rate of intermediate goods trade has been higher than the growth rate of world output. To reiterate, despite a growing literature on the relationship between trade and environment, the role played by fragmentation in production and trade in intermediate goods, on the environmental quality has not been addressed adequately, however.

The present chapter examines how trade in intermediate goods affects total emission of carbon dioxide for South Asian countries. Since, South Asian countries account for a significant share of world trade in intermediate goods and also suffer from relatively high pollution levels, estimating this relationship should be policy relevant. In this regard, it is useful to mention that our paper is one among the scant attempts at linking intermediate goods and pollution, such as that in Xu *et al*. (2020). It shows that trade in intermediate goods have been responsible for significant environmental damages in the US. For developing countries, the effect seems reversed as trade in fragments lead to greater local pollution for low-technology countries. It is well-known that the developed countries delegate more pollution-intensive components offshore and transfer the burden of environmental pollution (Zhang, 2020). This is one of the most crucial relations between trade in intermediate goods and carbon emission. There is allied evidence on East Asian countries (Zhang, 2015) where trade in intermediate goods actually moderates out the pollution effects of direct energy consumption in these countries.

Given this perspective, section 4.2 discusses the scope and the literature in further details. Section 4.3 offers the data and methods used while section 4.4 presents the benchmark results. Section 4.5 deals with advances on the static results by introducing dynamic estimates and section 4.6 concludes.

4.2 Brief Literature Review on Fragmentation and Pollution

It is duly documented that firm level optimization often results in cross-border fragmentation of production which subsequently influences the growth of trade in intermediate goods worldwide. While some effects of international production fragmentation have been dealt with in the existing literature, such as that on productivity, wages, investment patterns, and generally production reorganization at the firm level, very few studies considered its impact on environment. As a rare piece, Dietzenbacher *et al*. (2012) show that when intermediate trade is accounted for, the perception that exports raise pollution in China appears to be overestimates. The predominant emphasis has thus far been on trade in final goods and the impact on environment, which goes back a long way. For example, Grossman and Krueger (1991) empirically investigated the impact of North American Free Trade Agreement (NAFTA) on environment. Subsequently, a number of studies further investigated the technology upgrade-to-pollution, or scale-to-pollution effects as mentioned in this paper to theoretical and empirical extensions (see, Frankel and Rose, 2005; Grether, Mathys and de Melo, 2010, etc). The extensive literature on pollution haven and factor endowment hypotheses also provides direct evidence in favor of how resource abundant developing countries record high emission due to outsourcing (see Copeland and Taylor, 2003; Cole, 2004; Xing and Kolstad, 2002; Eskeland and Harrison, 2003 for early evidence). Since, most of the outsourced production activities bring foreign capital and technology with it, the foreign direct investments are likely to have certain impact on pollution levels also. Dean and Lovely (2010) found that an increase in foreign direct investment (FDI) influenced by international production fragmentation led to a decline in pollution intensity of China's trading basket. This seems to corroborate the prediction in Benarroch and Weder (2006) which argues that owing to increasing returns in the production of the final good which uses a pollutant intermediate, more trade should lead to a fall in the total pollution or that in one country at least. It is also possible that countries with low trade share face higher pollution level as in Swart (2013). The evidence for South Asian countries we offer here might display positive or negative impact of intermediate trade on emission of pollutants depending on threshold levels of crucial covariates. This and above conjectures for South Asian countries are candidates for empirical verifications that we carry out, shortly.

South Asia is a geographical sub-region of Asia that consists of the Indo-Gangetic plain and peninsular India. It includes eight countries namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. This region accounts for approximately 21 percent of the world's population and hosts fast growing economies. Trade in intermediate goods has also increased rapidly in recent years for most of the South Asian countries. Given that the intermediate goods produced by emerging economies are found to be more pollution intensive, we expect that more trade should lead to greater pollution in this region controlled for country-level variations. The carbon emissions for this region have been rising at an alarming rate and it remains one of the most affected and vulnerable regions in terms of environmental degradation and climate change.

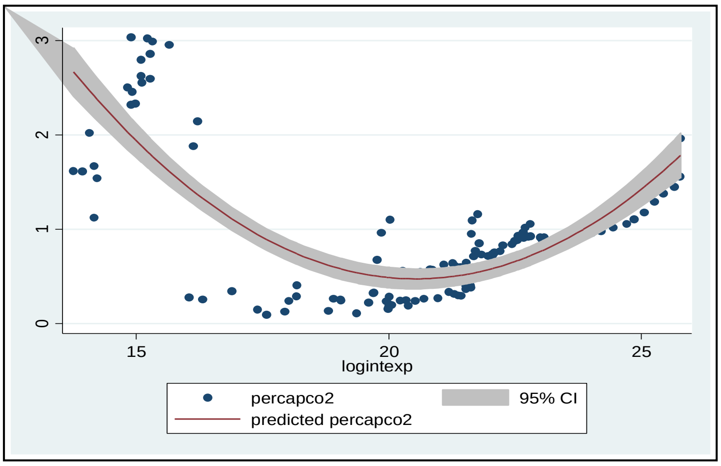
Out of the eight countries in South Asia, six countries (which include Afghanistan, Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka) are members of the Vulnerable Twenty (V20) group in terms of climate change. Since trade liberalization increases pollution for high, medium and low-income countries at varying rates (viz. Rafiq *et al*., 2016), South Asian countries have gone through such episodes around the middle of 1990s. Importantly, there has also been moderating episodes, since the economic reforms in South Asia also allowed foreign direct investments (FDI) in industry and agriculture such that the more efficient technologies might have tempered the rate of emission (see, Kastratović, 2019 for a panel of 62 developing countries). In addition, firms often have to adopt environmental standards in order to remain competitive internationally[14] with favorable reduction on the level of pollution (also see, Arora and De, 2020 for similar experiences in Latin America). As far as intermediate goods or raw materials are concerned, the advanced know-how that comes with FDI and technology transfers might even help to reduce pollution from lot more sensitive sources like mining (viz. Katz and Pietrobelli, 2018). So, how do south Asian countries cope with more trade, environmentally speaking? From a review of existing literature there is reason to believe that trade and environmental impact is still an open empirical question for South Asian countries -- one that remains even less explored with regard to trade in intermediate commodities.

In terms of theoretical underpinnings, the Environmental Kuznets Curve (EKC) has been considered in hundreds of analyses and requires mention in view of the panel of South Asian countries that we construct. In similar panels and using EKC framework, Farhan, Shahbaz and Arouri (2013) show that trade, GDP and energy consumption tend to have detrimental effect on the environment, one which is further aggravated by urbanization. Note that, in more recent avatars the EKC model is augmented via inclusion of other variables along with per-capita income, while also accommodating second cycle of environmental degradation due to even higher levels of consumption from very high levels of per capita income (Shafik, 1994; Cole, 2004). The present paper improvises on the augmented version by including industrial and agricultural share to predict the effects of trade on emission levels. Most importantly, we learn from Frankel (2009) regarding potential effects of trade (final goods and not intermediate, however). Frankel (2009) enquires about the effects of trade that do not operate via economic growth. He suggests that the effects can be classified into three categories, (i) system-wide effects that are adverse, (ii) system-wide effects that are beneficial, and (iii) effects that vary across countries depending on local comparative advantage. The first

[14] The tea producers in India have to acquire 19 different licenses in order to qualify as an exporter (of green tea, viz.) to Japan (Tea Board of India). However, evidence (see Cole *et al*. 2014) suggests that Japan also outsources environmentally 'sensitive' middle products to developing countries.

one is largely about the race-to-the-bottom, while the second one is about how trade openness benefits environment -- a relation not too commonly observed. Indeed, Frankel (2009) asks, how does openness generate a positive effect on environmental quality, especially when the possibility of accelerating progress along the falling segment of EKC is set aside? It is argued that technological and managerial innovation could be a factor, because openness encourages ongoing innovation and that too often brought about by multinational investments and ownerships. A second possibility is an international ratcheting up of environmental standards.[15] The present paper deals with intermediate goods only and the primary scatter (Figure 1) shows U-shaped relation between exports of intermediate goods and emission for the South Asian countries implying that more trade leads to a fall in emission until a point where it starts rising although never reaching the same level as under low volumes of trade. The plot suggests that the countries exist in the rising part of the U-shaped relation. The evidence for intermediate imports is offered subsequently.

Figure 4.2 Per Capita CO_2 and ln (Intermediate Export)



Source: Authors' Calculation

[15] Based on results as in Vogel (1995), Braithwaite and Drahos (2000), etc. The ratchet effects may be more relevant for product standards than for standards regarding processes and production methods.

4.3 Data and Methodology

Basically, the issue discussed in the previous section revolves around a central research question which is: Does fragmentation-induced trade in intermediate goods lead to environmental degradation? To address and answer the above research question, the following hypothesis has been tested.

Hypothesis: Rise in the trade in intermediate goods leads to environmental degradation.

The presence of a statistically significant relationship between intermediate goods trade and environment has been empirically tested for South Asian countries in the following sections using an augmented Environmental Kuznets Curve (EKC) Model. Broadly speaking of environmental degradation, it can be captured or measured by a wide variety of indicators including consumption of natural resources, forest coverage, air and water quality, different types of pollution, etc. In this study, we will consider environmental pollution (specifically pollution created by carbon dioxide emissions) to capture the intensity of environmental degradation.

4.3.1 Data Selection and Data Cleaning

It follows from the existing empirical literature that intermediate goods trade can be measured by two approaches namely input-output (I-O) analysis and trade flow analysis. The trade flow analysis requires data which focuses on the flow of products while the I-O analysis consists of data based on flow of products (values) across borders. Presently, we consider the trade flow analysis for South Asian countries. For this, the trade data on intermediate goods is collected from the United Nations (UN) COMTRADE database according to the Broad Economic Categories (BEC) classification. [16] However, measuring intermediate goods trade

[16] BEC classification system is an international three digit product classification system. This is not an independent system since it is based on the Standard International Trade Classification (SITC) system. It was first published in 1971 and revised in 1976, 1986 and 1988. Presently, the BEC classification system has revision version 3.

via trade flow analysis is not an easy task. In this connection the flow of goods is considered rather than the flow of value in the empirical analysis. The data on trade according to BEC classification system is segregated by end use into different groups in the System of National Accounts (SNA). Apart from the classified goods, the other goods are included in SNA classifications under three categories, namely, intermediate goods, consumption goods and capital goods. The product groups along with the product codes are provided in Table A1 in the appendix. The trade data in the UN COMTRADE database is reported country-wise at the industrial level. The data includes both aggregate trade with the rest of the world and country pair-wise trade for each country. In this empirical analysis, however, we consider only the aggregate trade data for intermediate goods. As shown in Table 4.3, the intermediate goods categories are represented by the following codes in the COMTRADE database according to BEC classification: 111, 121, 21, 22, 31, 322, 42, and 53.

The intermediate goods data is collected for eight South Asian countries, namely, Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. The period of this empirical analysis ranges from 1998 to 2018.

To capture the negative impact on environmental quality we use the most commonly used measure – emission of harmful gases. In the existing literature, emission data of many harmful gases has been used, including, sulfur dioxide, nitrogen dioxide, carbon dioxide (CO_2), etc. We chose CO_2 as a measure of environmental pollution since according to a recent inventory report (2021) by the United States Environmental Protection Agency (EPA), almost 80% of all greenhouse gas emissions in the US for 2019 can be attributed to CO_2. The statistics seems similar for developing countries also. The country-level data on annual per-capita carbon dioxide emission (*in tons*) has been collected from *Global Change Data Lab.*[17]

[17] This is an UK-based non-profit organization under the leadership of Wendy Carlin, Sir David Hendry and Stefano Caria.

Table 4.3: Product categories (BEC Classification)

Level 1	Level 2	Level 3	Classification
	11– Primary	111-Mainly for industry	Intermediate
		112-Mainly for	Consumption
	12- Process	121-Mainly for industry	Intermediate
		122-Mainly for	Consumption
2-Industrial supplies not elsewhere	21-Primary		Intermediate
	22-Processed		Intermediate
3-Fuels and lubricants	31-Primary		Intermediate
	32- Process	321-Motorspirit	Not classified
		322-Other	Intermediate
4- Capital goods (except transport equipment), and parts and accessories thereof	41- Capital	goods (except transport	Capital goods
	42-Partsandaccessories		Intermediate
5- Transport equipment and parts and accessories thereof	51- Passenger motor cars		Not classified
	52 -	521 - Industrial	Capital goods
		522 - non-industrial	Consumption
	53 - Parts and accessories		Intermediate
6 - Consumer goods not elsewhere	61 - Durable		Consumption
	62 - Semi-durable		Consumption
	63 - non-durable		Consumption
7 - Goods not elsewhere specified			Not classified

Source: United Nations Statistical Database

4.3.2 Methodology

To find out the direction and magnitude of the impact of economic activities on environment, the augmented Environmental Kuznets Curve (EKC) Model has been adopted. The original EKC model has been introduced by Grossman and Krueger in 1991. The model is named after Simon Kuznets who hypothesized an inverted U-shaped relation between income inequality and economic development (i.e. initially higher economic development leads to higher levels of inequality but after a certain stage of development, inequality diminishes as development proceeds. EKC on the other hand proposes an inverted U-shaped relationship between economic development (or economic growth generally represented by per-capita income) and pollution (or various indicators of environmental degradation). According to the hypothesis, in the early stages of development, with growth in per capita income, emissions increase and environmental quality declines. This may be due to the fact that initially government is reluctant to put emphasis on environment at lower levels of income. Thus, at lower income levels countries are expected to witness laxer environmental regulation and hence greater degree of environmental degradation (or higher levels of pollution). As income increases beyond a threshold level, policy makers put more emphasis on environmental quality which in turn results in declining pollution level with higher per capita income. A significant number of empirical papers tested the EKC hypothesis. The EKC is an empirical phenomenon and some of the empirical literature on EKC are econometrically weak. Also, the results are not robust. Depending on the choice of pollutants, the empirical studies found different results. Empirical evidence has shown that some pollutants indeed follow the EKC-shape whereas others do not. The fit of data with theory is well among local traditional air pollutants (e.g. sulphur, nitrogen oxides and particulate matter). In fact, the turning points of EKC varies across countries and the period of analysis.

While the main focus of the EKC literature is the relationship between growth and environment, some of the studies also plugged in trade intensity variables in the empirical analysis to observe the changes in the pattern. Studies by Grossman and Krueger (1991), Stern (1996), Rothman (1998), Panayotou (2003), etc used trade as one of their explanatory variables and found that it significantly affects the pollutant emissions. Cole (2003) conducted a cross-sectional analysis to study the impact of both growth and trade on the emissions of several pollutants. He found that the turning points of the EKC increased with the introduction of the trade variable, i.e. with more trade the environment degraded. More recently, Farhani, Shahbaz and Arouri (2013, MENA countries) found that apart from income, other factors such as trade, urbanization and energy consumption also affect the quality of a country's environment.

As discussed above, a modified version of the EKC model has been used in order to consider trade in *intermediate goods as one the main independent variable* ($Intermediate_{it}$) for the i^{th} country and t^{th} year while controlling for per capita income and other country-specific variables ($\underline{X}$).

We frame up our regression model as:

$$pollution_{it} = f\left(Intermediate_{it}, \underline{X_{it}}, \varepsilon_{it}\right) \qquad (1)$$

where, $pollution_{it}$ is measured by *CO_2 emission per capita* at the country level serving as the *dependent variable*.

For the empirical estimates we break up trade in intermediate goods for the eight South Asian countries into exports and imports and conduct two separate, but identical, set of exercises. The classification of intermediate trade into two components should allow us greater precision with regard to the source and magnitude of emission due to trade fragmentation. Therefore, equation (1) yields to the following two sub-specifications:

$$CO_{2it} = \alpha_{Ei} + \overline{\beta}_E * InterExports_{it} + \beta_{iE} * \underline{X}_{it} + \theta_{Et} + \gamma_{Ei} + \varepsilon_{it} \qquad (2)$$

and $$CO_{2it} = \alpha_{Ii} + \overline{\beta}_I * InterImports_{it} + \beta_{iI} * \underline{X}_{it} + \theta_{It} + \gamma_{Ii} + \varepsilon_{it} \qquad (3)$$

The intermediate trade variable, in two parts (equation 2 and 3), includes data on total intermediate exports and imports for country 'i' in year 't', while $\underline{X}_{it}$ includes the set of control variables, namely *gdp per capita*, *agricultural share (as percentage of gdp)*, *industrial share (as percentage of gdp)*, *net foreign direct investment inflows for each country for a given year*, *exports to high income economies* (percentage of total exports, equation 2), *imports from high income economies* (percentage of total imports, equation 3), and *taxes on trade* (as percentage of revenue). To conduct panel regression, we have tested for panel unit roots and found that the variables are stationary at levels. θ_{Et} and θ_{It} represent country fixed effects for the two specifications, respectively, while γ_{Ei} and γ_{Ii} represents time fixed effects. The error terms are given as ε_{it}. The separation of intermediate trade into components also helps to lessen concerns about endogeneity in composite models because even for developed countries it has been convincingly argued (see Bas and Strauss-Kahn, 2014 for recent evidence on France; and Görg, 2000 for US-EU trade) that imported intermediates affect exports by raising productivity at the firm level, by creating varieties and greater opportunities for trade. This is largely the story for developing countries also.

Further, it is important to report the functional nature of the empirical relation and therefore, the *identification* is of concern, which performs best under strict exogeneity of factors affecting the dependent variable. Indeed, one of the foremost challenges that an empirical study with panel data can potentially face is that of presenting a clear identification strategy with regard to the empirical analysis. Identification issues can arise due to reverse causality, or omitted variable bias, or both. For equation (2) one can argue that intermediate exports from the choice of industrial classifications affect emission of CO_2 rather than exports been driven by presence of higher pollution in the country. In addition, it is well established in the literature on international trade that per capita income, agricultural share, industrial share, etc are not the drivers of exports, but may affect pollution level in the country. In this regard, commodities with low economic benefits generate less pollution, while those with high benefits are rather pollution-intensive as in case of China or USA (see, Wang *et al*., 2020, and Xu *et al*., 2020). Still, we offer results from dynamic panel regressions to rule out possible endogeneity biases.

In standard applications, the identification strategy uses multiple estimation methods with greater emphasis on the panel fixed effects. It is well-known that time invariant factors like geographical location, stock of natural resources, cultural and social capital, etc. can affect production and trade. Fixed effect estimates can take into account these (slow-moving) time invariant factors and can ensure that our estimates are only capturing the variation across countries. Besides, considering the right-hand side variables only, especially the potentially endogenous ones in contemporaneous terms will not solve the endogeneity problem. Lagged explanatory variables are less likely to be influenced by or correlated with the error term. So, in the dynamic models we offer for both equation (2) and (3) accommodate this specification. We show that the lagged structure retains the estimates under fixed effects.[18] Difference or System GMM analysis takes care of robustness for our benchmark model. The dynamic panel estimators, as adopted subsequently, use internal instruments generated via moment conditions employing several lags of the endogenous covariates. Generally, this reduces the sample size in the process. However, at the cross-country level, the model functions well given the available data points.

[18]For recent applications, see, Dutta and Mallick, 2018; Dutta and Williamson, 2016; Dutta and Sobel, 2016; Asiedu and Lin, 2011; Dollar and Kray, 2002, to mention a few.

4.3.3 Description of Variables

Before moving on to the empirical exercises and its results, a brief summary of all the variables that has been used in this study are discussed below.[19]

Intermediate Exports and Imports

This includes the constant values (in US$) intermediate trade of individual countries with the rest of the world. The trade in intermediate goods includes both intermediate exports and intermediate imports which has been studied separately in two fixed effects model. The intermediate goods trade is driven by production fragmentation. This variable is our key independent variable which will help us to test the hypothesis that international production fragmentation induced trade in intermediate goods affects the environment.

Gross Domestic Product (GDP) per capita

This variable is used as a proxy for income or level of economic development. This measure breaks down a country's total annual output per person which helps us to understand how the value generated by productive activities in an economy can be attributed to each individual economic agents in a country. The data on GDP values in current US$ is collected from World Bank database and the variable GDP per capita is constructed by dividing the GDP values with total population figures for each year. The data on total country-wise population has been also collected from World Bank database.

Agriculture Share (as percentage of GDP)

This variable captures the role played by agricultural activities in determining the pollution level of a country. This variable consists of data on agriculture, forestry and fishing, value added as percentage of GDP. The data is collected from World Bank database. This

[19] The selection of the control variables in our study is motivated from Zhang (2015) and Zhang (2020).

variable is expected to carry a positive sign since a rise in any kind of economic activities results in environmental damage caused by rise in pollution.

Industry Share (Percentage of GDP)

This variable has been considered to control for industrial activities. It includes total industrial value (including construction) as a percentage of a country's GDP. This data is also collected from World Bank database. The coefficient for this variable is similarly expected to have a positive sign since a rise in activities or production in the industrial sector is associated with a greater levels of pollution. Also, it has been witnessed that the industrial sector mostly performs pollution intensive activities which is expected to aggravate the environmental problems of any particular country. South Asia consisting of emerging economies like India, Malaysia and Pakistan also depends on their industry's for economic growth and since the environmental regulations are not so strong in these economies, a rise in industrial activities is expected to lead to a rise in the pollution.

Foreign Direct Investment Inflows

This variable consists of country-wise data on net inflows of foreign direct investment. In the past few decades, globalization led to surge in capital transfers across countries especially in the developing economies which increased their participation in world trade and global competition. The emerging economies like India, Malaysia and Pakistan witnessed huge inflows of foreign capital in the form of FDI through several MNCs. These FDIs are distributed and allocated across several sectors for the purpose of development and stay competitive in world economy. Now the question arises regarding the nature of FDI and the destination of these capital flows. Whether FDI flows in the pollution-intensive sectors in developing country's or not. As it has been discussed in the existing literature that with increased global integration through trade, developing countries often specializes in the production of pollution intensive goods which in turn aggravates the environmental problems of such countries. To answer this question, we consider FDI as one of the control variables and try to find out whether the inflows of such capital in South Asian countries lead to more pollution or less. Since the South Asian region consists of emerging and developing nations, it is expected that FDI inflows are mainly attracted to the dirty industries and thus we expect a positive sign for the coefficient associated with this variable.

Exports to high income economies (as percentage of total exports)

This variable consists of data on total merchandise exports (as percentage of total merchandise exports) to high income economies. This captures how much the South Asian countries are exporting to the developed nations. According to the PHH, the developing countries are expected to specialize in the production of pollution intensive goods since these countries have relatively laxer environmental regulations. If we go by this concept, then we can say that with rise in the production of exportable goods that finally reaches the developed countries should lead to greater pollution since the production of those goods are pollution intensive. Thus, if the existing trade-environment debate is followed then a positive sign is expected for the coefficient of this variable.

Imports from high income economies (as percentage of total imports)

This represents the total merchandise imports (as percentage of total imports) by the South Asian countries from the developed nations. Again, the rise in imports can lead to greater pollution since most of the end-use commodities is associated with a higher amount of pollution. Thus, in this case also the coefficient is expected to bear a positive sign.

Taxes on trade (as percentage of revenue)

These variable measures the total percentage of revenue earned by a country's government by imposing tax on international trade. According to the existing trade environment debate, with liberalization in international trade, a rise in the trade volume is often associated with a rise in pollution especially in developing countries. Now with imposition of taxes on trade it acts as a deterrent to trade and with rise in taxes, the trade volume should diminish. Thus, a higher tax implies lower volumes of trade which may lead to lower levels of pollution. So, we expect a negative sign for the coefficient of trade taxes.

4.4 Empirical Results

4.4.1 Estimates for Intermediate Exports

The empirical results for the fixed effects regression analysis on intermediate exports is presented in Table 4.4 (a).[20] In all the seven regressions presented here, we see that the coefficient associated with intermediate exports is (a small) positive but highly significant statistically. This indicates that the South Asian countries with growing emphasis on trade in intermediate commodities are expected to witness higher levels of (per capita) carbon dioxide emissions in the process. In view of Figure 4.4 the results indicate that the countries are on the upward sloping segment of the relation. Obviously, we need to include the sources of cross-country variations and revalidate the impact of rising intermediate exports on CO_2 emission. Therefore, between regression 2 and regression 7 we add important covariates such as GDP per capita, industry share in total output, agriculture's share in total output, net inflow of foreign capital, export share to high income destinations and trade taxes (viz. export duties and other restrictions). In column 2, the rise in GDP per capita buttresses the impact of intermediate exports. In column 3, the rise in industry's share in GDP neutralizes the impact of GDP by bringing down the emission. This implies that as long as the intermediate goods are industrial output from the south Asian countries these do not exacerbate emission level in the region. This is also true for agricultural share in GDP which does not raise emission. The coefficient of *agrishare* is positive but not significant. The level of emission rises with net capital inflow

[20] To make a choice between fixed effects model and random effects model, the Hausman test (Hausman, 1978) has been conducted and it supports FE.

into these countries, although the magnitude is very small (but, statistically significant at 1% level, column 5-7). This can possibly be attributed to the fact that south Asian countries are not too selective about the kind of FDI that flows in, ending up with investments mainly to the pollution intensive sectors. The variable 'export to high income economies' as in column 7 is positive and strongly significant (1% level) in the presence of all of the above variables, except *agrishare*. Notably, column 7 also includes the trade taxes variable which dampens the emission level significantly. The evidence suggests that despite environmental pressure on developing countries to deliver cleaner products to rich countries, the reality is starkly different. While it cannot be tested empirically in this attempt, but it seems that in order to remain competitive the South Asian countries continue to remain pollution-intensive. Overall, trade in intermediate goods (exports, here) leads to more pollution following rise in the volume of trade for eight south Asian countries. Importantly, we have followed up the results in Table 4.4 (a) with those in Table 4.4 (b) as part of robustness analysis. Column 1 in Table 4.4 (b) considers robust standard errors while column 2 considers clustering of standard errors by country. The results are identical and preserve those obtained under FE. In section 4.1 we conduct similar exercises for intermediate imports and in section 5 we conduct dynamic analysis for both.

In order to explore the mechanism which helps to reduce emission, we chose to *interact* intermediate exports with industrial share in the country. The interaction term in this structure should help to identify if the main explanatory variable. i.e., intermediate export (or import) jointly with one of the controls supports or reverses the hypothesis. The industrial share in the country interacted with (components of) intermediate trade can identify whether pollution is generated in the industrial belts of south Asian countries or not. In our analysis using the FE (table 4.4 (a), column 6) we do find that if intermediate exports originate more and more from the industrial base it actually lowers emission. We do not find a significant effect of agricultural production of intermediate exports (although negative) on emission, and do not report here.

Technically, the coefficient of the interaction term captures the joint effect of industrial share and intermediate exports on emission. It is possible that the overall impact is neutralized or even reversed under interaction effects, because structurally it comes from the following relation (4), where the variable *Interaction* is a product of [$(InterExports)_{it} * (Industryshare)_{it}$] determining the marginal impact of a one unit rise in one variable on the level of per capita emission at a given value of the other variable:

$$CO_{2it} = \alpha_{Ei} + \overline{\beta}_E * InterExports_{it} + \beta_{iE} * \underline{X}_{it} + \beta_{jE} * Interaction + \theta_{Et} + \gamma_{Ei} + \varepsilon_{it} \quad (4)$$

$$\frac{\partial CO_{2it}}{\partial (InterExports)_{it}} = \bar{\beta}_E + \beta_{jE} * (Industryshare)_{it} \quad (4a)$$

$$\frac{\partial CO_{2it}}{\partial (Industryshare)_{it}} = \beta_{jE} * (InterExports)_{it} + \beta_{kE} \quad (4b)$$

where $k \in i = 1,2 \ldots n$ and $j \neq i$.

The variable on the right-hand-side of equations (4a) and (4b) are estimated at the mean value given the aggregative nature of the problem and determines the overall impact of own effect and the effect of the other variable. For example, using equation (4a) and the empirical estimates in Table 4.4 (a) column 6 we find that the marginal impact of a rise in intermediate export on CO_2 emission has an own effect ($\bar{\beta}_E$ =1.11e-11) and an interaction effect (β_{jE} = -3.07e-13) at the mean value of $(Industryshare)_{it}$, for each year across the set of countries. The emission may therefore rise, fall or remain constant depending on the relative strength of these terms. In other words, for a unit rise in intermediate exports channelled through greater production at the industrial level the overall emission may even fall for the group of south Asian countries. But more importantly, we find a threshold level of $(Industryshare)_{it}$ from equation (4a) at which per capita emission remains constant even when intermediate export rises:

$$\frac{\partial CO_{2it}}{\partial (InterExports)_{it}} = \bar{\beta}_E + \beta_{jE} * (Industryshare)_{it} = 0$$

$$\Rightarrow (Industryshare)_{it}^{Threshold} = (-\bar{\beta}_E/\beta_{jE}) = 36.15 \qquad (4c)$$

In table 4.4 (b), the robustness analyses with robust standard errors and errors clustered at the country level, the threshold level of industry share across countries and averaged over the years stand at 41.49%. This should leave the emission level in South Asian countries unchanged even when exports rise. When the industry share is below these levels, intermediate exports raise emission. The threshold level for intermediate exports for a change in the share of industry can similarly be estimated from equation (4b). The same procedure and results hold for the effects of intermediate imports on CO_2 emission as shown in the next section.

Table 4.4 (a): Fixed Effects (Intermediate Exports)

Dependent variable: per-capita carbon dioxide emissions							
Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)	Regression (7)
Intexp	6.46e-12 *** (1.13e-12)	4.40e-12*** (4.72e-13)	4.51e-12 *** (4.41e-13)	4.53e-12 *** (4.54e-13)	2.63e-12*** (8.51e-13)	1.11e-11*** (3.77e-12)	2.60e-12 *** (9.07e-13)
gdppercap_current		0.000191*** (7.84e-06)	0.000185*** (7.44e-06)	0.000186*** (8.46e-06)	0.000184*** (7.41e-06)	.0001887*** (8.02e-06)	0.000215*** (1.74e-05)
Indshare			-0.0180*** (0.00417)	-0.0178*** (0.00432)	-0.0192*** (0.00447)	-.01599*** (.005202)	-0.0214*** (0.00583)
Agrishare				0.000654 (0.00363)			
FDI					6.83e-12 ** (2.66e-12)	7.32e-12** (2.63e-12)	5.38e-12* (2.88e-12)
exp_highincome						.0013582 (.00122)	0.00489*** (0.00180)
taxes_trade							-0.00980** (0.00434)
Industry-Interaction						-3.07e-13** (1.35e-13)	
Constant	0.862*** (0.0284)	0.529*** (0.0179)	0.950*** (0.0990)	0.932*** (0.141)	0.980*** (0.106)	.81877*** (.1280)	0.842*** (0.154)
Observations	130	130	130	130	129	128	96
R-squared	0.213	0.868	0.886	0.886	0.892	0.865	0.849
Number of groups	8	8	8	8	8	8	7

Standard errors in parentheses.

Chi-square test statistic (Hausman test) in favor of fixed effects model is governed by a low value of $\chi 2 < 0.05$. This is true for the above results.

*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level. Source: Own calculations.*

Table 4.4 (b) Robustness Check (Intermediate Exports)

Independent Variables	Regression 1 Robust SE	Regression 2 FE VCE Cluster
Intexp	7.76e-12 ***	7.76e-12***
	(2.46e-12)	(2.46e-12)
gdppercap_current	.0002112***	.000211***
	(.0000423)	(4.10e-05)
Indshare	-.0180722**	-.01807**
	(.0062052)	(0. 0062)
FDI	5.78e-12***	5.78e-12***
	(6.27e-13)	(6.27e-13)
exp_highincome	.0041416***	.004142***
	(.0010318)	(.001032)
taxes_trade	-.008233***	-.00823***
	(.0019653)	(.00196)
Industry-Interaction	-1.87e-13**	-1.87e-13**
	(8.10e-14)	(8.10e-14)
Constant	.7822***	.7822***
	(0.1399)	(.1399)
Observations	96	96
R-squared	0.7752	0.7752
Number of groups	7	7

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We summarize the regression results in the following table which includes the expected sign of the independent variables taken in our study and the actual signs from the regression analysis.

Table 4.4 (c): Summary table for the empirical results including the expected signs and the actual signs of the independent variables

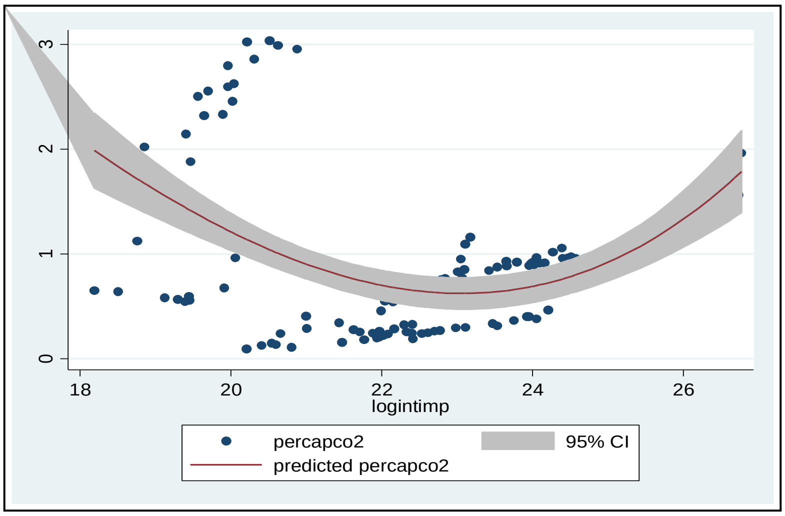
Independent Variables	**Expected Signs**	**Actual Signs**
Intermediate Exports/Imports **(Intexp/Intimp)**	**+ ve**	**+ ve***
GDP per capita_currrent price **(gdppercap_current)**	**+ ve**	**+ ve***
Industry share (% of GDP) **(Indshare)**	**- ve**	**+ ve***
Agriculture share (% of GDP) **(Agrishare)**	**+ ve**	**+ ve**
Foreign Direct Investment inflows **(FDI)**	**+ ve**	**+ ve***
Exports to high income economies **(exp_highincome)**/ Imports from high income economies **(imp_highincome)**	**+ ve**	**+ ve***
Taxes on Trade **(taxes_trade)**	**- ve**	**+ ve****
Interaction Term **(Industry-Interaction)**	**- ve**	**- ve****

*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level.*
Source: Own calculations.

4.4.2 Estimates for Intermediate Imports

In this sub-section, the relationship between intermediate imports and emission has been tested in a way similar to that in the previous section, except for the inclusion of imported commodities from high-income countries in place of exports made to these. The reason behind this inclusion is a characteristic that most developing countries are heavily dependent on imports in order to produce both traded and non-traded goods and services at home. Indeed, reduction in cost of imported inputs owing to trade liberalization in India and other South Asian countries around the same time has helped both exporters and importers to expand (see, Bas and Ledzema, 2020). In the extant literature there is however, little evidence on how it has affected the pollution level in the developing countries. With respect to final goods, a recent report (UNEP, Nairobi, 2020) suggests that many East European, African, Asian and Latin American countries imported approximately 14 million used cars, vans and minibuses between 2015 and 2018. Most of these light vehicles did not have valid roadworthiness certificate at the time of exports. The majority of 146 countries covered in this report have weak or very weak regulations on dirty imports and there is a general appeal made to developed countries to put a self-restraint on such exports. Importantly, many such commodities imported from the developed countries are used as inputs for final service delivery or production chains. The environmental impact of trade fragmentation as described here might therefore, have several implications. In figure 4.4 (d), the per capita emission plotted against log intermediate import reports high values at low levels of imports, but the effect seems to die down as the value of imports rises, although a positive trend is clearly visible.

Figure 4.4. Per capita CO2 and ln (intermediate import)



Source: Authors' Calculation.

For fixed effects panel regression using intermediate imports, we carry out the empirical exercise using the same set of control variables and find that the rise in intermediate imports (variable *Intimp*; Table 4.4 (d)) leads to greater emission in all variations of the specification as in equation (3). As before, a larger share of industries in GDP of the countries leads to a fall in the level of per capita emission and moderate the impact of 'dirty' intermediate imports. In terms of the interaction effect as in regression 6 in 4.4 (d), the role of high-income countries is passive. Albeit the impact of import from high-income countries is positive, it is not significant. In regression 7 Table 4.4 (d), the effect is positive and weakly significant. It should be noted that for south Asian countries production fragmentation and production chain also operates between proximate countries with varying degrees of industrialization and technological capabilities (generally, fragmentation has a lot to do with cross-border proximity, see, Johnson and Noguera, 2012a). This must explain the rise in emission from intermediate imports if that flowing from high-income countries only weakly supports such outcome. Similarly, intermediate imports in the presence of FDI and per capita GDP certainly lead to higher emission. Indeed, rise in import is commonly explained by prosperity, but that applies mainly to final products. Intermediate imports are less visible in this regard and enter production process directly rather than being functionally related to income level. Therefore, when we do find the rise in per capita income to be a highly significant covariate explaining per capita emission the problem of endogeneity, if at all, should not be onerous. Note that, *agrishare* is not significant in this case. Once again, the trade tax (tariffs) is negative and significant implying that greater restrictions to trade could be beneficial for environmental quality in these countries.

Further, using the formulation as in (4d) a threshold level of industrialization (33.87) in the south Asian countries that should leave the pollution level unchanged is obtained. For the robust estimates in Table 2.1 this turns out to be 34.79.

$$\frac{\partial CO_{2it}}{\partial (Inter\,\mathrm{Im}\,ports)_{it}} = \overline{\beta}_I + \beta_{jI} * (Industryshare)_{it} = 0$$
$$\Rightarrow (Industryshare)_{it}^{Threshold} = (-\overline{\beta}_I / \beta_{jI}) = 33.87 \qquad (4d)$$

`

Table 4.4 (d): Fixed Effects (Intermediate Imports)

Dependent variable: per-capita carbon dioxide emissions

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)	Regression (7)
Intimp	2.26e-12 *** (3.93e-13)	1.52e-12 *** (1.66e-13)	1.56e-12 *** (1.55e-13)	1.57e-12 *** (1.60e-13)	8.69e-13 *** (2.74e-13)	4.98e-12*** (1.45e-12)	8.00e-13*** (3.00e-13)
gdppercap_current		0.000191*** (7.92e-06)	0.000185*** (7.51e-06)	0.000186*** (8.54e-06)	0.000184*** (7.40e-06)	0. 000187*** (7.63e-06)	0.000198*** (1.58e-05)
Indshare			-0.0183*** (0.00420)	-0.0181*** (0.00436)	-0.0196*** (0.00446)	-.01526*** (0.00503)	-0.0203*** (0.00589)
Agrishare				0.000585 (0.00366)			
FDI					7.42e-12 *** (2.45e-12)	7.36e-12*** (2.39e-12)	6.02e-12 ** (2.73e-12)
imp_highincome						.001682 (.00118)	0.00320* (0.00171)
taxes_trade							-0.00936** (0.00467)
Industry-Interaction						-1.47e-13** (5.10e-14)	
Constant	0.868*** (0.0276)	0.535*** (0.0180)	0.962*** (0.0999)	0.946*** (0.142)	0.991*** (0.106)	.80148*** (0. 127)	0.965*** (0.149)
Observations	130	130	130	130	129	128	96
R-squared	0.214	0.866	0.884	0.884	0.892	0.893	0.842
Number of countryid	8	8	8	8	8	8	7

Standard errors in parentheses

Chi-square test statistic (Hausman test) in favor of fixed effects model is governed by a low value of $\chi 2 < 0.05$. This is true for the above results.

*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level. Source: Own calculations.*

Table 4.4 (e) Robustness Check (Intermediate Imports)

Independent Variables	Regression 1 Robust SE	Regression 2 FE VCE Cluster
Intimp	4.21e-12***	4.21e-12 ***
	(8.57e-13)	(8.57e-13)
gdppercap_current	.0001967***	.000196***
	(.000035)	(.00003)
Indshare	-0.015704**	-.0157**
	(0.00597)	(0.00597)
FDI	6.21e-12***	6.21e-12 ***
	(8.17e-13)	(8.17e-13)
imp_highincome	.00303*	.003034*
	(.00155)	(.00155)
taxes_trade	-.007219*	-.007219*
	(.0037)	(.0037)
Industry-Interaction	-1.21e-13***	-1.21e-13***
	(2.78e-14)	(2.78e-14)
Constant	.8247***	.8247***
	(.1412)	(.1412)
Observations	96	96
R-squared	0.7910	0.7910
Number of groups	7	7

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.5 Dynamic Panel Estimations

We acknowledge that the level of emission generally, and for the South Asian countries in particular, may be affected by many other factors that are not part of the set of covariates in this exercise mainly owing to limitations in the availability of data. The omitted variables as well as lack of strict exogeneity among chosen variables are typically reasons behind endogeneity biases in the above regressions. Therefore, in order to rectify potential endogeneity and omitted variables bias we use a dynamic panel data (DPD) methodology. In this methodology, the lagged dependent variable is treated as one of the independent variables to solve for the omitted variable issue by acting as a proxy. But it has been observed that the lagged dependent variable may be correlated with the individual specific effects which ultimately lead to biased estimates for the parameters (Arellano and Bond, 1991). The dynamic panel estimators, as described below, use internal instruments generated via moment conditions employing several lags of the endogenous covariates. One drawback of this approach is that it reduces the sample size considerably. Nevertheless, the chief advantage of using this method in our analysis is that it takes into account the dynamic nature of trade performances for the countries. Consequently, by using the Generalized Method of Moments (GMM) technique we try to minimize potential biases arising from the endogeneity problem. This also helps us to find consistent estimators.

In fact, for the sake of clarity we briefly justify our choice below. It is well-known that there are two methods commonly applied for analyzing panel data in dynamic set up. These are: difference GMM (Arellano and Bond, 1991) and system GMM (Blundell and Bond, 1998). When OLS based estimation technique is applied to a dynamic setting, the estimates can be biased and inconsistent. The reason may be due to the existence of correlation between the lagged variables and the error term. In that case, a GMM estimation technique is the most appropriate method. In difference GMM method of estimation, the inclusion of the differenced term of the endogenous variable (which is used as an instrument to eliminate the endogeneity problem) solves the above problems and provides consistent estimators.

In the Difference GMM (DGMM) model, a system of equations is considered (one per time period) and the lagged variables are generated by the method of moments which are used as instruments and each equation consists of unique instruments. The estimator is a better estimator compared to Anderson-Hsiao estimator since according to Arellano and Bond, the DGMM estimators takes into account all potential orthogonality conditions (Baum *et al*., 2003). But it is of utmost importance to check the externality conditions of the instruments and test whether the instruments are valid or not. Therefore, the Sargan test is used for validating this exercise and the p-values from the Sargan test statistic is reported in the appendix in order to ensure that the instruments that are generated internally in the DGMM estimation process meet the over-identification restrictions. From the p-value of Sargan statistic (available in the appendix), it is observed that the null hypothesis is accepted. This implies that the instruments are valid and there are no over-identification problems with the instruments.

Finally, it is worth mentioning that one problem of the difference GMM technique is that the finite properties are poor when the sample size is small. When the time points of the analysis are less, the estimates calculated by this technique are biased downwards. Apart from this, the Arellano Bond estimates help to a great extent to solve the endogeneity problem and also check for the robustness of the findings. In the following tables (Table 4.5 (a) and Table 4.5 (b)), the results of the GMM specification are reported. The results show that the estimates obtained under FE remain valid even after accounting for correction of potential endogeneity. In other words, following incorporation of the instruments both intermediate exports and intermediate imports show positive (and statistically significant) relation with emission and that the covariates maintain direction and significance exactly as in the previous results. The trade taxes, however, loses significance while the interaction term shows more sensitivity (for exports, column 6, Table 4.4 (a)). The interaction term has similar impact for the intermediate imports (Column 6, Table 4.4 (d)) as under FE although imports from high income countries do not seem to affect emission significantly in the GM specification, and this should support the conjecture above. Overall, the dynamic panel estimations provide a resounding support to the results obtained under the static fixed effects estimates and prove that emission is significantly affected by trade in intermediate goods while controlled for a set of important covariates.

Table 4.5 (a): GMM Estimates (Intermediate Exports)

Dependent variable: per-capita carbon dioxide emissions

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)	Regression (7)
CO_{2t-1}	0.864*** (0.0508)	0.376*** (0.0924)	0.322*** (0.0907)	0.323*** (0.0910)	0.287*** (0.0896)	0.2581*** (0.0894)	0.315*** (0.105)
Intexp	1.22e-12 * (7.37e-13)	3.11e-12*** (6.41e-13)	3.35e-12*** (6.03e-13)	3.22e-12 *** (6.14e-13)	1.99e-12 ** (8.69e-13)	8.31e-12** (3.85e-12)	1.95e-12 ** (9.12e-13)
gdppercap_current		0.000110*** (.0000102)	0.000116*** (.0000131)	0.000113*** (.0000163)	0.000121*** (.0000157)	.0001321*** (.0000184)	0.000139*** (.0000172)
indshare			-0.0144** (0.00590)	-0.0152** (0.00607)	-0.0162*** (0.00584)	-.0114314* (.006113)	-0.0138** (0.00697)
agrishare				-0.00349 (0.00475)			
FDI					5.66e-12** (2.60e-12)	5.94e-12** (2.54e-12)	4.65e-12* (2.74e-12)
exp_highincome						.0019488 (.0015315)	0.00396* (0.00235)
taxes_trade							-0.00365 (0.00465)
Interaction-Industry						-2.23e-13* (1.36e-13)	
Constant	0.150*** (0.0446)	0.360*** (0.0493)	0.723*** (0.158)	0.812** (0.202)	0.786** (0.157)	.57038** (0.196)	0.491* (0.285)
Observations	111	111	111	111	111	111	83
Number of groups	8	8	8	8	8	8	7

Standard errors in parentheses

*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level. Source: Own calculations.*

Table 4.5 (b): GMM Estimates (Intermediate Imports)

Dependent variable: per-capita carbon dioxide emissions

Independent Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)	Regression (7)
percapco2$_{t-1}$	0.861*** (0.0503)	0.397*** (0.0900)	0.340*** (0.0893)	0.340*** (0.0892)	0.285*** (0.0885)	.2442** (0 .0892)	0.308*** (0.105)
intimp	4.53e-13 * (2.49e-13)	1.03e-12 *** (2.12e-13)	1.13e-12 *** (2.05e-13)	1.09e-12 *** (2.10e-13)	6.76e-13 ** (2.73e-13)	3.94e-12** (1.57e-12)	6.06e-13** (2.92e-13)
gdppercap_current		0.000106*** (.0000167)	0.000113*** (.0000179)	0.000109*** (.0000171)	0.000121*** (.0000185)	.0001319*** (.0000182)	0.000124*** (.0000178)
indshare			-0.0145** (0.00592)	-0.0155** (0.00608)	-0.0165*** (0.00580)	-.01097* (0. 00623)	-0.0160** (0.00698)
agrishare				-0.00360 (0.00475)			
fdi					6.05e-12 ** (2.41e-12)	6.00e-12** (2.37e-12)	5.03e-12* (2.60e-12)
imp_highincome						.001568 (.00159)	0.00119 (0.00207)
taxes_trade							-0.00392 (0.00481)
Interaction-Industry						-1.15e-13** (5.49e-14)	
Constant	0.153*** (0.0446)	0.354*** (0.0489)	0.723*** (0.158)	0.818*** (0.202)	0.796*** (0.156)	0.608*** (0.1961)	0.746*** (0.247)
Observations	111	111	111	111	111	111	83
Number of groups	8	8	8	8	8	8	7

Standard errors in parentheses

*Note:*** significant at 1% level; ** significant at 5% level; * significant at 10% level. Source: Own calculations.*

4.6 Conclusion

The air quality in South Asian countries is generally quite poor with very high amounts of hazardous particulate matters in some pockets being regularly reported in almost all pollution mapping sources. A number of pressing concerns including permanent health damages have been directly related to prevailing pollution levels in large and populous cities in the region. The present paper investigates the role of international trade, in particular, intermediate goods trade on emission in eight South Asian countries, namely, Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. The time period chosen is between 1998 and 2018 supporting a panel of approximately 168 observations on a variety of explanatory factors. The empirical analysis is centered on the principal question of whether fragmentation in trade, which often takes the form of contiguous cross border transactions, add to the emission levels in these countries. The extant literature does not engage substantially with the question of intermediate trade and emission. At the same time the growth of fragmentation in trade is relatively high for south Asian countries as compared to regional enclaves in Africa, South America, East Europe, etc.

Subsequently, we carried out empirical estimates of the effects of intermediate exports and imports on emission of CO_2 separately for the panel. The empirical structure subscribes to an augmented EKC model, where trade in intermediate goods is considered as an additional explanatory variable. The static fixed effects estimates subjected to stationarity conditions for the variables in the panel suggests a rise in emission due to expansion in trade of intermediate commodities. The direct relation between intermediate exports and imports and the per capita emission level is subjected to a number of control variables in conformity with influential early research. For example, we find that GDP per capita is always positive and statistically significant across a number of alternative empirical specifications. The net inflow of foreign capital also raises emission unambiguously. The share of industrial output in GDP, however, contrary to general perception does not cause higher pollution. A possible explanation is that the industrial base for South Asian countries is on average small and shrinking over time, such that the marginal increase in the share is not environmentally harmful. To explore this connection further, we estimated the marginal effects of a rise in intermediate exports and imports, separately on CO_2, and determined the threshold levels of industrial shares. Under the fixed effects estimates, we found that the threshold level of industrial share which does not increase emission level despite rise in intermediate exports is 36.15%. If robust standard errors are applied to the fixed effects the threshold rises to 41.49%. Importantly, the same threshold settles at 37.26% for the dynamic analysis that we carried out subsequently to correct for potential endogeneity related biases in the aforementioned specifications. On average this seems appropriate for South Asian countries, since greater industrialization might have harmful environmental impact following rise in export of intermediate goods. The industrialization threshold is however lower for intermediate imports all through the analysis. For the fixed effects panel regression where the main independent variable is intermediate imports the industrial threshold is 33.87%. For robust standard errors, the estimate for industrial threshold rises marginally to 34.79%. In section 5 we obtained similar estimates under the GMM specifications for intermediate imports affecting per capita CO_2 and find that the industrial threshold stays at 34.26% in between the above estimates.

Generally speaking, the covariates in this exercise may support rise in pollution due to greater fragmentation in trade in all specifications. For example, trade with high-income countries (weakly significant for exports and non-significant for imports) and trade taxes (non-significant) as in the dynamic specifications in unlikely to turn around the general outcome. Attempts to seek environment friendly FDI could be one way to reduce overall emission in this kind of specification. Subject to availability of data, the set of explanatory variables may also be expanded to factors that have negative impact on pollution levels.