

Trade and the Environment: could the technique effect be the missing piece in environmental assessment of trade liberalisation?

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Introduction

International trade has a key role in promoting global prosperity through the exchange of goods, services, and ideas across international borders. That trade can promote global prosperity is generally well understood, but a key challenge for trade economists will be understanding the role that trade can play to meet new challenges like climate change, which will continue to affect analytical demands as further understanding is needed of the channels and impacts of trade on the environment.

Trade has an important role to play in stimulating environmental action by facilitating access to technology and innovation embodied in goods and services and by promoting environmental action across countries. According to OECD data, international trade in environmentally related goods more than doubled between 2003 and 2016, increasing its share in global trade from 7.2% to 8.1%. Preliminary results from the OECD (2019) illustrate that, if the appropriate domestic environmental policies are in place, opening markets to trade in environmental goods and services could improve access to new technologies leading to more efficient local production processes which would reduce the use of inputs such as energy, water and other environmentally harmful substances.

Meanwhile, trade has its own impacts on the environment, affecting Greenhouse Gas (GHG) emissions, biodiversity, and water use, for example. Trade liberalisation impacts GHG emissions through various channels. Antweiler *et al.* (2001) developed a well-respected framework which splits the impact of trade on the environment into three effects: scale, composition, and technique. The scale effect is the impact on GHG emissions from increased economic activity resulting from freer trade and, all else equal, will lead to an increase in GHG emissions. The composition effect is the change in the mix of products that a country produces as a result of moving production towards those products where it has a comparative advantage. The composition effect can increase or decrease GHG emissions depending on which sectors a country specialises in and the GHG intensity of each sector within that country.

What is the technique effect?

There's not one clear definition of the technique effect. It has been described as the improvements in energy efficiency as a result of trade opening, which can lead to lower GHG emissions from the production of goods and services. Other definitions include the replacement of environmentally harmful goods and services with environmentally friendly goods and services. However, the idea is always the same: trade opening leads to better, more efficient production techniques which can reduce emissions. The technique effect is often considered an indirect effect from trade as it stems mostly from domestic environmental policies, such as a Net Zero target, but can be enhanced by FTAs. For example, freer trade will increase the availability and lower the cost of environmentally-friendly goods, services and technologies ([WTO](#)). This will also lower abatement costs by increasing flows of technical information and by increasing competition in the market for environmental services.

There are two key drivers of the technique effect (Copeland, 2009). First, is the technical change, or technology spillover angle, where trade opening contributes to improvements in energy efficiency. Innovation and the accumulation of knowledge plays a key role in long-term economic growth and international technology spillover is playing a major role in ensuring the latest green and energy efficient technology filters around the world. The second driver is the increase in environmental

regulation as incomes increase. There is strong evidence for this effect, however, given the limited impact of trade agreements on overall incomes, there is limited scope for FTAs to play a massive role. The focus here, therefore, is on the first driver, where trade opening contributes to improvements in energy efficiency and capital productivity. See Table 1 below for a summary of the key channels through which trade can impact upon GHG emissions.

Table 1: Summary of the key channels through which trade can impact GHG emissions, based off Antweiler et al. (2001).

Channel/effect	Impact on GHG emissions	Is it generally captured by CGE modelling?
Scale effect	Generally, an increase. Trade opening increases economic activity which, all else equal, leads to an increase in emissions	Yes
Composition effect	Can lead to either an increase or decrease in emissions, depending on changes in sectoral output and the emissions intensity of those sectors.	Yes
Technique effect	Generally, a decrease. Trade opening leads to improvements in energy efficiency and the replacement of environmentally harmful goods with more environmentally friendly ones which leads to a fall in emissions.	No, which this paper aims to resolve.

This project therefore aims to incorporate the technique effect, through technology spillover which leads to increases in energy efficiency, into a CGE model. To incorporate this endogenous technical change, the rest of the paper is set out as follows. Section 2 critically evaluates the current literature and available methodologies, with the most appropriate method carried through into the methodology section (section 3). The methodology section then clearly sets out the options to integrate the technique effect into a CGE model for the assessment of trade liberalisation and further detail on how the selected approach has been applied. The results (section 4) from the analysis are then discussed before setting out the conclusions and potential future work (section 5).

Literature Review

Due to the increasing urgency around climate change, there is more literature on trade and the environment than ever before, however there are few papers that quantify the technique effect. This is, in part, due to technology effects being harder to assess quantitatively and therefore these effects are typically analysed qualitatively (Moise and Rubinova, 2021). This has been DIT's approach in previous impact and scoping assessments, see for example the 'Opportunities for increased trade in environmental goods' section in the UK-GCC Scoping Assessment **Error! Bookmark not defined.** This analysis shows the number of environmental goods and services which have tariffs imposed on them and the proportion of total trade which they make up between trading partners. As is suggested in the scoping assessment, increasing trade in environmental goods and services can increase their application and speed up the diffusion and take up of more environmentally friendly production techniques. This would result in positive environmental outcomes from increased trade.

Despite being harder to assess quantitatively, technology effects are not impossible to quantify. There is significant theoretical and empirical work to lay the foundations for incorporating a technique effect into trade policy analysis. Innovation, technology improvement and knowledge accumulation have long been understood to drive long-term economic growth, with much of the endogenous growth literature in the 1990s focusing on this topic. Take, for example, the Schumpeterian models of growth, which focus on quality-improving innovations that render old products obsolete i.e., they rely upon 'creative destruction' (Schumpeter, 1942). One implication of these innovation-based theories is that to grow rapidly a country should devote a large fraction of output to research and development. However, productivity gains don't just arise from domestic R&D as innovations are likely to spill over international borders.

Therefore, Computable General Equilibrium (CGE) models are often used to estimate changes in trade in environmental goods, which embody clean technology, and these environmental goods and services are likely to provide the destination country with better access to innovation and technology improvement. Francois *et al.* (2020) use a CGE model to assess the impact of the EFTA-Mercosur FTA on the environment. Analysis of the technique effect is done qualitatively using changes in trade of environmental goods, rather than attempting to quantify the impacts. This is an important first step, however, unlike Francois *et al.* (2020), this paper focuses solely on the technique effect, rather than trying to comprehensively assess the environmental impacts of an FTA. This provides the opportunity to explore it further.

The Schumpeterian model of Howitt (2000) incorporates technology transfer, where productivity in one country is improved by innovation in other countries. Grossman and Helpman (1991) also present a model of endogenous growth with international trade. Their findings suggest that promoting international trade increases innovation through the international spillover of technology, which drives economic growth. This is backed up empirically by Coe and Helpman (1995) whose seminal empirical work supports the existence of international spillovers. Therefore, there is significant theoretical and empirical evidence for the existence of a technique effect but also a clear evidence gap in the need to quantify it. With a narrower scope compared to most environmental analyses of trade liberalisation, this paper has the opportunity to adjust the modelling approach taken to incorporate it.

Shu and Steinwender (2019) review the empirical literature on the impact of trade liberalisation on innovation-related outcomes for firms. They define and examine four types of shocks to trade flows: import competition where innovative is driven by domestic firms having to compete with imports, export opportunities as firms have larger markets to target, access to imported intermediates, and foreign input competition. Their work reveals that in developed countries, export opportunities and access to imported intermediates are the key shocks which tend to encourage innovation. Therefore, with a focus on a developed economy like the UK, this paper will focus on access to imported intermediates, which can spur improvements in energy and resource efficiency in firms, leading to better environmental outcomes.

International technology spillover, particularly through importing intermediate goods, is a key driver of the technique effect and there are several approaches in the literature to incorporating this effect into CGE analysis. Van Meijl and van Tongeren (1999) specify a transmission mechanism for technical knowledge assuming that knowledge is embodied in traded commodities, both final products and intermediate inputs. Perrado and De Cian (2014) assume that knowledge is embodied only in machinery and equipment imports which is supported empirically by Carraro and De Cian (2013) who estimated a positive relationship between machinery and equipment imports and energy and capital productivity. Building on this estimated relationship is one of the key strengths of their approach. In a slightly different approach, Gerlagh and Kuik (2014) focus on international technology diffusion, not through goods, but rather through knowledge where each region has a propensity to contribute to international knowledge and a propensity to absorb innovations.

All three papers assume that this knowledge spillover can improve productivity in the domestic economy, including in the energy sectors, which may lead to lower emissions. In van Meijl and van Tongeren (1999), the transmission of knowledge is controlled by the volume of trade between two countries, the local absorptive capacity of the importer¹ and structural differences between the two countries. This will be important when considering the realistic magnitude of any technique effects. Similarly, Perrado and De Cian (2014) capture a country's absorptive capacity, but at a more detailed sector level, through the inclusion of coefficients which are a function of three measures of the propensity of a sector in a region to benefit from spillovers. In terms of approach, Gerlagh and Kuik (2014) include induced technical change in an energy-environmental CGE model by transforming the technical change parameter, which is normally an exogenous parameter, into an endogenous variable and relating it to the relative, price-induced change in the demand for energy. Instead, Perrado and De Cian (2014) focus on trade-driven technology spillovers and analyse the interaction of climate and trade policies in the presence of such spillovers within a dynamic recursive CGE model.

In terms of results, Perrado and De Cian (2014) find that the aggregated net effects of spillovers are small but that international and intersectoral redistribution effects can be significant. Similarly, Gerlagh and Kuik (2014) find that technological spillovers have a limited effect on production and trade in the energy-intensive sectors, but have a substantial impact on carbon leakage, even reducing it to zero. Therefore, it appears from the literature that although aggregate effects can be limited, there can be important distributive impacts from the inclusion of international technology spillovers, or the technique effect.

¹ Which is determined by the knowledge infrastructure and human capital of that country.

Research methodology

In this paper a Computable General Equilibrium (CGE) model is modified to include the technique effect. In this paper, an energy environmental CGE model, GTAP-E², is used which is based on the well-known GTAP model³ and is extended to include a relatively detailed specification of energy inputs and associated carbon emissions, additional to capturing the intersectoral and international linkages, as in the standard model. GTAP-E is used to evaluate the costs of abatement, to assess the spillover effects of GHG abatement policies and to understand the environmental impacts of trade and economic policies. GTAP-E uses a ‘top-down’ approach to environmental modelling, which starts with a detailed description of the macro (and international) economy and then derives from there the demand for energy inputs in terms of the demand for various sectors’ outputs through highly aggregated production or cost functions. GTAP-E then incorporates carbon emissions from the combustion of fossil fuels as well as a mechanism to trade these emissions internationally. The GTAP-E database provides carbon dioxide (CO₂) emissions data distinguished by fuel and by user for each of the countries/regions in the database. The data used is based on the standard GTAP database and extended energy balances compiled by the International Energy Agency (IEA).

The analysis in this paper follows the approach of Perrado and De Cian (2014). Their paper assesses the impacts of trade liberalisation and trade driven spillovers. Other approaches, such as Gerlagh and Kuik (2014), are similar, but more focused on climate policy and the spillover of knowledge not necessarily through trade. *Further work will be undertaken to test the sensitivity of results to the approach used.* Therefore, in this paper, GTAP-E is modified to include endogenous productivity (or technological progress or technical change – these terms are used interchangeably here) of capital and energy, which is then determined by the change in the intermediate imports of machinery and equipment. R&D and expenditure on education are also significant determinants of factor-biased technical change but these are not considered here as: i. they are not explicitly specified in GTAP-E, and ii. They are both domestic policy issues, and therefore not as relevant as trade driven technology spillovers to DIT policy. Therefore, it is important to note that this is a partial interpretation of endogenous technical change.

As in Perrado and De Cian (2014), the first step of this approach introduces a new equation into the model, which links capital and energy technical change with imports of machinery and equipment. The additional equation is set out below:

$$afall_{c,a,r} = gamma_{c,a,r} \times qfm_{ome,a,r}$$

Where $afall$ is the input⁴ c augmenting technical change for activity a in region r , $gamma$ is the spillover coefficient linking the change in machinery and equipment imports and the input c augmenting technical change for activity a in region r and qfm is the change in intermediate imports of machinery and equipment by activity a in region r . Therefore, if as a result of trade liberalisation, a sector in a country imports more machinery and equipment, this will lead to an increase in the energy and capital productivity in that sector. For example, if the UK chemicals sector imports 1% more machinery and

² Version 7 which was developed by Corong et al., 2020.

³ Developed by (Hertel, 1997; Corong et al., 2017).

⁴ Inputs here refers to endowments and all intermediate inputs, but only capital and energy productivity is allowed to adjust.

equipment as a result of an FTA, then the productivity of energy and capital in the UK chemicals sector will increase by $(1 \times \gamma_{c,a,r})\%$.

A simple approach would be to assume that the spillover coefficient $\gamma_{c,a,r}$ is equal to one and that the productivity of capital and energy have a one to one relationship with machinery and equipment imports. However, this seems unrealistic and from Carraro and De Cian (2013) we know this not to be true⁵. Following Perrado and De Cian (2014), the sector- and region-specific spill-over coefficient (γ) is therefore calibrated to Carraro and De Cian (2013) and by three variables which determine the propensity of a sector in a region to benefit from trade-driven spillovers, as shown below:

$$\gamma_{c,a,r} = \gamma_0 \times MS_r \times CR_r \times CS_{a,r}$$

Where γ_0 is the global calibration coefficient for capital and energy, MS is region r share of global machinery and equipment output, CR is region r machinery and equipment imports from OECD countries over total imports from OECD countries and CS is sector a machinery and equipment imports over total region r machinery and equipment imports.

MS , CR and CS capture the most important determinants of the potential for spillovers. MS represents an indicator of absorptive capacity by assuming that a region's share of global machinery and equipment output represents its ability to reverse engineer capital goods. It acts as an indicator of the knowledge level in that region in the production of machinery and equipment which is essential for being able to understand new innovations and technology embodied in machinery and equipment imports. The shares of global machinery and equipment output in 2014 for the regions in the aggregation is shown in Table 2 below. Machinery and equipment output is dominated by the US, China, and the EU. In total, OECD countries accounted for roughly 53% of all machinery and equipment output globally.

Table 2. Share of global machinery and equipment output, by region, in 2014 (Source: author's calculations from GTAP-E database).

Region	India	UK	US	China	Korea	Japan	Australia	NZL	Canada	Chile	Pakistan	Bangladesh	Sri Lanka	EU	RoW
% share	0.02	0.02	0.17	0.31	0.03	0.08	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.21	0.13

CR and CS measure the regional and sectoral propensity to import machinery and equipment. CR represents a measure of the flow of imports of machinery and equipment from OECD countries, which are assumed to be the countries at the technology frontier (and hence the source of innovation and technology). CS is used as a tool to distribute spillover effects among sectors within a region according to its machinery and equipment imports.

⁵ Carraro and De Cian (2013) find that the world average of the spillover coefficient should be 0.09 for energy and 0.02 for capital, both much less than one.

Model setup

To understand the impact of trade driven spillovers, this paper compares: GTAP-E with endogenous productivity/technology spillover against GTAP-E without endogenous productivity (the default model). By comparing the results from the two models, it's possible to extract the marginal impact of endogenous productivity on the economic and environmental impacts of policy changes. The model uses the GTAP10.1 database with 2014 as a reference year (Aguilar et al., 2019) – *to be updated to GTAP11 and a 2017 reference year*. The region and sector aggregation are selected to ensure there is an appropriate level of detail necessary to achieve the required output without over working the model. In terms of regional aggregation, a balance is struck between ensuring there is sufficient country coverage, e.g., inclusion of OECD countries and potential UK FTA partners, and disaggregating too many regions which would increase complexity and run time of the model. In terms of sector coverage, the maximum disaggregation is used to ensure that analysis is consistent with other DIT CGE modelling and to ensure that there is sufficient sectoral detail available. The final aggregation includes 15 regions and 64 sectors and is provided in full in Appendix B.

To test this approach, this paper presents three trade policy scenarios: a UK-US FTA, a UK-India FTA and a UK-Australia FTA. The scenarios are set out in more detail below:

- i. A UK-US FTA: full tariff liberalisation, no reductions in non-tariff measures.
- ii. A UK-India FTA: full tariff liberalisation, no reductions in non-tariff measures.
- iii. A UK-Australia FTA: full tariff liberalisation, no reductions in non-tariff measures.

The findings from this analysis are presented in the next section. However, before moving onto results, it is important to clearly set out the key assumptions and uncertainties in the analysis, especially the key assumptions made relating to the international transfer of technology and innovation.

First, the analysis assumes that clean technology and knowledge is embodied *only* in machinery and equipment imports. This is reasonable as machinery and equipment covers the manufacture of general purpose and special-purpose machinery so covers the majority of capital goods. It is capital goods, such as engines, ovens, and factory machinery etc., which will embody the innovation and new knowledge which can be used to become more energy efficient and hence environmentally friendly. According to Probst et al (2021), around 25% of all high-value climate change mitigation technologies are manufactured goods such as these. However, it could be argued that this definition is too narrow, for example motor vehicles and other transport equipment may be goods which have clean technology and knowledge embodied in them which might spillover or replace environmentally harmful technology.

A second key assumption is that a region's share of global machinery and equipment output is a good proxy for absorptive capacity in that region. It assumes that the higher the value of machinery and equipment output, the higher the knowledge in that region. For example, a country with little or no machinery and equipment production would find it difficult to understand the imported technology. However, this is clearly not the only determinant of absorptive capacity. For example, a country with high levels of human capital may be able to adopt and reverse engineer novel capital inputs just as

well as a country with high levels of machinery and equipment output. This assumption is appropriate as it acts as a reasonable proxy of an extremely complex and multi-faceted issue.

Also related to the transfer of technology, it is assumed that OECD countries are at the technology frontier. This has been assumed as the OECD has for decades led in producing new technology and innovation. Although this has been the case in the past, looking ahead it may be the case that other countries, such as China, become the technology frontier and this will likely have significant impacts on the analysis. The findings presented here may change if we assumed a different technology frontier.

DRAFT

Research and findings – *to be added*

Conclusions and next steps – *to be added*

DRAFT

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