Trade liberalization

and the demand for natural resources

Yvan Decreux (ITC, UNCTAD-WTO) & Lionel Fontagné (PSE-Paris1 and CEPII)

Work in progress, do not quote

Abstract

Is free trade harming the environment? This general concern has received particular attention in the case of energy use and emissions. But to what extent would “Buy local” save energy at the global level? Addressing this issue in general equilibrium and at the global level makes it possible to take into account the multifaceted impacts of trade on energy consumption. While transport is energy intensive, international specialisation concentrates production in the most economically efficient producers which can be, or not, more efficient in terms of energy use. Depending on the direction of trade specialisation and on the relative energy efficiency of exporters, more trade can lead to increased or reduced global energy efficiency. We examine this issue using MIRAGE-e and modelling two scenarios of trade liberalisation (Doha-like and full liberalisation). Results validate the hypothesis of enhanced global energy efficiency as trade increases.

JEL Codes: F18, Q4

Introduction

Is free trade good for the environment? This question has been generally addressed in the perspective of pollution, since the seminal paper by Antweiler, Copeland and Taylor (2001). Scale, technique and composition effects have since then structured our understanding of the related mechanisms and combined in net positive effect for the environment.[1] Much less attention has been paid to the impact of trade on energy consumption however.

Thanks to international trade, countries have different factor contents in their consumption and production. This difference, combined with variety gains and possibly competitive effects, is the source of overall gains. On the other hand, goods have to be shipped from the producer to the final consumer, as specialisation of countries on goods or segments of value chains calls for international transport. Shipping goods is energy intensive, and the carbon footprint of final consumption can be adversely affected.

Accordingly, proximity between producer and consumer has become a matter of concerns for the civil society in several developed countries, on the grounds of incomplete information on energy used in shipping goods or on production processes. To what extent does "Buy local" save energy at the global level?[2] While transport is energy intensive, international specialisation concentrates production in the most economically efficient producers which can be, or not, more efficient in terms of energy use. For instance, growing roses in East Africa requires much less energy than in the Netherlands, which has to be put in balance with the energy used by air-transport between Africa and Europe. In the same spirit, we could ask "which apple is the greenest": locally grown or imported.[3]

Adding to such concerns of the civil society, around year 2008, new questions emerged into the debate. While a positive outcome of multilateral trade liberalisation was a possible increase in world food prices favouring exporters in the developing world, the 2008 food crisis raised the concern that high food prices may actually be the problem. At the same moment, oil prices were reaching record levels, after 6 years of rapid growth, while climate change and the role of greenhouse gases in its generation gathered only very few sceptics. More generally, the pressure exerted on world prices of

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[1] The distinction between scale effect (overall activity level), composition effects (types of economic activity), and technique effect (environmental efficiency of production) has been instrumental in the analysis of trade effects on environment since Grossman and Krueger (1993) and Copeland and Taylor (2004).

[2] Local purchasing, short-cut as the "buy local" movement is a form of ethical consumerism invoking environmental as well as social benefits.

[3] See Miersh M., "Der Apfel aus der Heimat ist nicht immer der günstigste", Die Welt, 1st July 2008.

energy and commodities by emerging countries, and firstly China, became a concern, despite the still predominant impact of real activity growth shocks in the US on these markets (Roache, 2012).

The purpose of this paper is to quantitatively **assess to which extent trade is implying a higher demand for energy and more generally how it is affecting the demand for resource-based commodities**.

Instead of opposing the current situation with a hypothetical de-globalized world envisaged by the proponents of the "buy local", we examine the consequences of a further trade liberalisation. This is done by considering the impact of two scenarios; the last existing proposals of the DDA, as well as a free trade in goods scenario. Simulations are run on the last version of the MIRAGE-e model developed by the CEPII (Fontagné et al., 2013). In this version of MIRAGE, the modelling of energy demand has been improved. Data come from the GTAP 8 database. Resorting to a global and sectoral analysis in general equilibrium makes it possible to encompass the manifold aspects of the question. While international trade is praised for permitting a more efficient use of capital and labour, whether trade also allows a more efficient use of natural resources as well – including energy – is questionable.

The favourable mechanism channels through efficiency effects. In the agricultural sector, production is often energy-intensive in advanced countries, contrasting with labour intensive production functions in developing economies. The opposite is true for industry: high-technology industry is often less energy-intensive in advanced countries than it is in less-developed countries. As one of the expected outcomes of further trade liberalisation is for developing countries to increasing their production of agricultural products while developed countries would increase their specialisation in industrial sectors and services, an overall gain in energy used by these production sectors should be observed. Similarly, Cole and Elliott (2003) rightly stress that polluting and energy intensive industries are often also capital intensive industries for which advanced countries should keep a comparative advantage. On the negative side, beyond increasing the needs for international transport, with easier trade many energy intensive and highly polluting activities may find in developing countries pollution havens, where energy efficiency is neglected (Copeland and Taylor, 2004). We aim at identifying the net effect of specialisation, as well as the net effect of specialisation and additional transport. Interestingly, the design of the DDA is such that the efficiency gains in agriculture should be important. We expect such agreement to have more favourable effects in terms of energy use than the (hypothetical) free trade agreement.

Our approach contrasts with previous studies assessing the impact of trade liberalisation on greenhouse-gas emissions through the channels of specialisation of countries in presence of carbon leakages (Kuik and Gerlagh, 2007), or international transport related emissions Hummels (2009). Our choice to address the demand of energy is motivated not only by our focus on possible impact on world energy and other natural resources prices, but also by methodological challenges raised by emissions.

We perform a general equilibrium analysis considering the world economy aggregated in relevant regions and sectors. Energy demand is modelled with a nested structure distinguishing between fossil and non-fossil energies. Energy demand, per unit of value produced, is sector and country specific. This will allow us to capture the country level composition effects and the international differences in energy efficiency for a given sector. We adopt a dynamic perspective relying on a reference trajectory of the world economy in the long-run derived from Fouré et al. (2012) and Fontagné et al. (2013). This reference trajectory is shocked with a reduction in tariffs that is modelled at the product level. We finally examine the net effect on energy demand. Notice that relying on such model allows taking into account endogenous adjustment of demand for energy and other primary resources to changing prices.

What we find refutes the simple analysis associating trade and increased environmental footprint of the consumption or production. A modest trade liberalisation leading countries to better specialise according to their advantages (a Doha-like scenario) is having a positive impact on world GDP with no significant impact on world energy consumption. Part of the efficiency gain (increased GDP with rather constant energy use) is due to such international specialisation and reallocation of production towards more efficient producers. Interestingly, part of this effect is also channelled through price effects: reducing distortions in certain agricultural sectors will lead to a world price increase, thus reducing consumption (and the associated energy content). Similarly, the scale effect (the increase in the GDP) turns into higher energy prices reducing its usage per dollar of value added. A full liberalisation, though not realistic, helps better understanding the impact of trade: the efficiency gain already mentioned is still present (more GDP per unit of energy) but there is overall an increase in energy consumption worldwide. These effects are not limited to energy use. Turning to other natural resources, we observe a decrease in the volume of other primary products consumed at the global level (other minerals, fishery, and forestry).

The rest of the paper is organised as follows. Section 1 surveys the related literature. The model and data are presented in Section 2, and our assumptions regarding trade liberalisation as well. Results are presented in Section 3. The last Section concludes.

Literature survey

A first question arises when it comes to considering the recent advances related to the trade-environment nexus. Should one address the trade-related emissions or the trade-related use of energy? We see advantages in tackling contributions related to energy use rather than to emissions, for at least two reasons.

Firstly, specialisation following trade liberalisation is impacting gas emissions through the change in the product mix of exporters, the scale of their output, the energy efficiency of these productions, as well as through the energy mix of the producing countries. Consequently, the carbon intensity of the export mix and the actual total carbon intensity of exports differ.[4] European specialisation contains more carbon-intensive products, however relying on an energy that is less intensive in carbon emissions (due to a different energy mix): European energy intensive sectors emit relatively less carbon due to hydraulic or nuclear electricity capacities (Delgado, 2007). All in all, there is much more variance in the energy mix than in the total energy content of exports across (developed) countries. Focusing on emissions mixes two issues: the sectoral orientation of the production and the energy mix. Also, it implies relying on the questionable assumption that the marginal energy mix would be the same as the current one, while some resources, like hydroelectricity, present little possibility of expansion in some regions.

Secondly, transport-related emissions, which are part of the overall picture, are only partially an economic issue. Regulations (or the absence of regulation) are at stake, more than economics rationale. Hummels (2009) clearly shows that the future contribution of air transport to the simulated growth of world trade will be a driver of emissions. However, the shipping industry is also contributing as it is relying on a heavy polluting fuel, bunker fuel, which is a residual of crude oil distillation. The use of this fuel has been progressively limited in power stations by regulations (e.g. in the US) but is still hardly regulated for vessels. Environmental activists claim that the shipping industry (less than 100,000 ships) is emitting yearly as much CO2 as the UK.[5] Global regulation is loose and recent: the International Convention on the Pollution from Ships considered shipping emissions in 1997, but went into effect only in 2005 for the most recent vessels only. So far, bunker fuel CO2 emissions are not subject to the limitation and reduction commitments contained in Annex

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[4] The total carbon intensity of exports is the direct and indirect amount of carbon dioxide emitted per dollar exported, as computed by inverting the input-output table and multiplying by the vector of sectoral carbon dioxide air emissions. The carbon intensity of the export mix proceeds from a composition effect, identified by imposing a common energy mix to all countries and a common input-output structure to all countries.

[5] Other related emissions are sulfur, nitrogen oxides and fine particle.

I Parties under the UN Framework Convention on Climate Change and the Kyoto Protocol. The UN specialized agency (International Maritime Organization) in charge of preventing marine pollution by vessels estimates that 2.7% of global C02 emissions were related to maritime shipping (IMO, 2009). These emissions should increase mechanically with additional international trade, notwithstanding the optimization of maritime routes – including via the Northern Route opened by global warming – or the slow steaming. However, we should refrain to draw any conclusions from energy consumption regarding emissions in this sector: IMO considers that up to 75% of CO2 emissions could be cut in this sector just by "using known technology and practices" (IMO, 2009, p.74). Accordingly emissions related to maritime transport are ultimately a regulatory issue, while energy consumption is not.[6]

A first strand of literature aims at computing the energy content of export using input-output tables. We already mentioned Delgado (2007). Similarly, Amador (2012) computes the energy content of 17 manufacturing sectors in 30 advanced and emerging economies, between 1995 and 2005, based on an input-output analysis. However, only domestic input-output coefficients are considered and if inputs are imported, their energy content will be computed as if they were sourced locally. Importantly, energy coefficients are considered in nominal terms, limiting the possibility to analyse longitudinal evolution of energy content and efficiency. Amador decomposes the global energy intensity as compared to the world average between an export structure effect (exporter' energy coefficients, differences in export structures), an efficiency effect (difference in energy coefficients, exporting country export structure) and a combined effect. The main result is that developed economies appear as more efficient in terms of energy use than emerging ones.

Notwithstanding the fact that Hummels (2009) is considering emissions related to trade rather than energy or other natural resources use, the way he addresses the issue is close to ours. Hummels considers the world economy split into 40 regions and 29 sectors. Relying on the GTAP 6 database and on the standard GTAP CGE model, all tariffs, export taxes and subsidies are removed. Impacts on trade flows are translated into quantity terms. The distribution of transport by mode is unchanged for a given triplet (product, exporter, market). No economy of scale in the transportation business is assumed. A central mechanism at play is that due to existing regional agreements, trade between

[6] Though very slow, regulation is making progress: IMO's Maritime Environment Committee has pushed for regulation for years, with some success. In 2009 it proposed a set of technical measures; in 2011 these measures were adopted for new ships (irrespective of their flag). The regulation applies to ships over 400 gross tonnage and entered into force in January 2013.

distant countries increases more than trade between countries close to each other. As a result, trade creation can mostly be associated to air and maritime freight.

Our paper is related to this work in the sense that we use a global perspective and consider trade liberalisation at the region and sector level. However, we compute the impact of trade liberalisation on energy demand instead of CO2 emissions. Like Hummels, we do not assume any efficiency gain as a result of a change in the magnitude of trade flows, but some substitutability between energy and other inputs is possible if relative prices change. This absence of endogenous technical progress might be seen as a limitation of the analysis. However, a large part of the energy efficiency gains are coming through compositional effects (Huntington, 2010).[7] In contrast with Hummels, who uses an original dataset on international transportation by mode, we rely on GTAP data.

Roson and Van der Mensbrugghe (2010) tackle energy demand in a CGE framework, but adopt a different perspective. They start from climate change and look at how this shock is channelling through the economy, including through energy demand. They combine a CGE model and a climate model. Climate change affects a number of variables, like arable land, water supply, energy demand, health and labour productivity. It is first assumed that climate parameters don't change. Then, climate change is introduced, leading to changes of GDP.

Focusing on energy demand or energy use and the impact on trade, the literature is scarce. Egger and Nigai (2012), use a general equilibrium model to examine what is preferable: a tax on energy production versus a tax on the energy resource. They build a 3-sector model (final good, intermediate good, energy), calibrated for 31 OECD countries and the Rest of the World. Intermediate goods are a continuum of varieties produced by firms characterised by an exponential productivity distribution function. These intermediate goods are aggregated through a Spence-Dixit-Stiglitz (SDS) function. Energy is similar to intermediate goods, plus a tax on the natural resource needed to produce energy and another one on energy itself. The final good is perfectly competitive. Then comes the choice of imposing a tax on energy production or on energy resource (CO2 emissions are assumed to be proportional to energy production). Taxing the resource tends to reduce demand thus reduce the price in other countries. Taxing energy production has a smaller impact on the price of energy resource, leading to less CO2 emissions overall.

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[7] According to Huntington (2010) changes in the US sector structure explain 40% of the reduction of US energy intensity between 1997 and 2006 (54% if the transportation sector is excluded). Moreover, working at a fine level of sector detail leads to more being explained by changes in the sector structure than if using a broader decomposition.

Model, data and assumptions

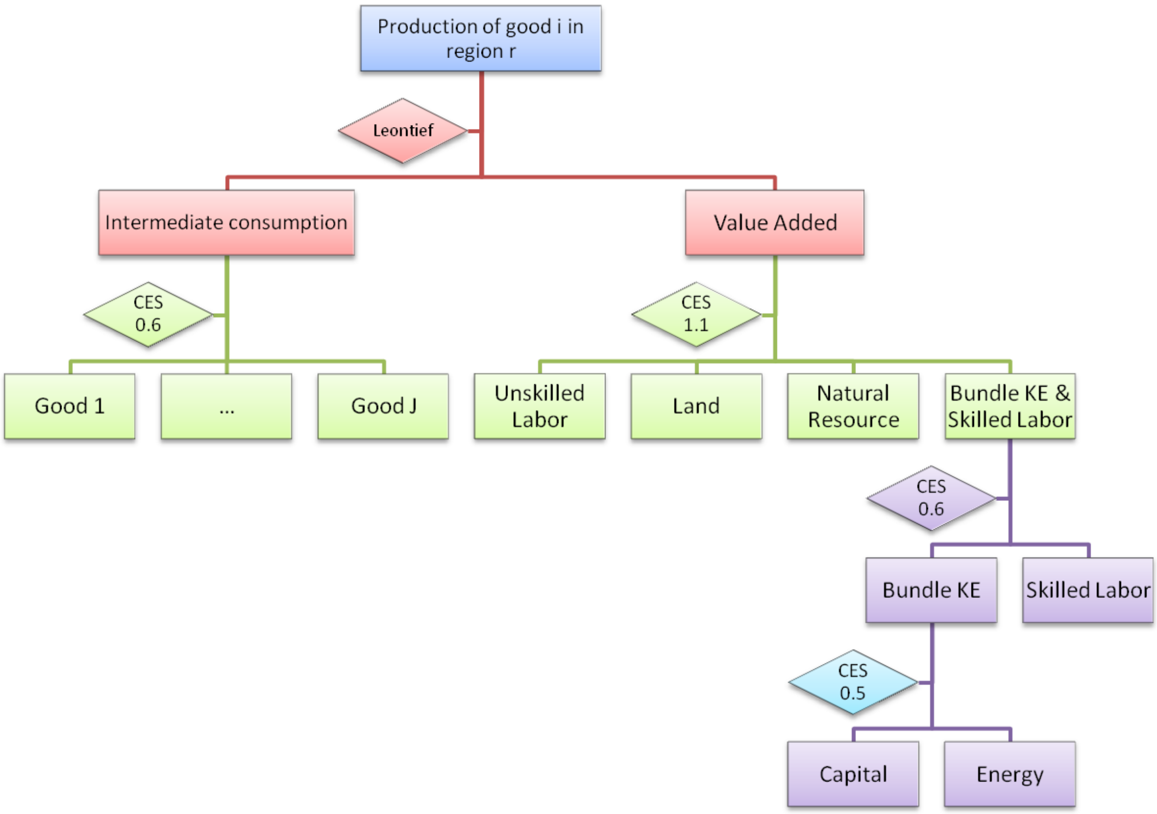
The focus of this study on how the world demand for energy and other primary resources is reshaped by increasing trade, the specialization of countries and the induced demand for additional transport. We use a new version of the multi-sectoral and multi-regional CGE model MIRAGE (Bchir et al., 2002; Decreux and Valin, 2007). We use the version of the model fitting perfect competition for sake of simplicity. MIRAGE-e version of the model proposes a different modelling of energy use, and introduces the modelling of CO2 emissions. On the supply side, in this perfect competition version of MIRAGE, each sector is modelled as a representative firm, which combines value-added and intermediate consumption in fixed shares. Value-added is a bundle of imperfectly substitutable primary factors (capital, skilled and unskilled labour, land and natural resources) and energy.

One assumes full employment of primary factors, which growth rates are set exogenously from the MaGE projections (Fouré et al., 2012). Installed capital is assumed to be immobile (sector-specific), while investment is allocated across sectors according to their rate of return. The overall stock of capital evolves by combining investment and a constant depreciation rate of capital (0.06). Land is assumed to be imperfectly mobile between agricultural sectors. Natural resources are sector-specific. Their stock is assumed as constant. In the case of energy resources, it implies an evolution of world prices in line with the projections of the International Energy Agency. Skilled and unskilled labour is perfectly mobile across sectors within each region, but there is neither migration from one category to the other, nor across regions.[8]

Firms' energy consumption comprises five energy goods (Electricity, Coal, Oil, Gas and Refined petroleum) that are aggregated in a single bundle which mainly substitutes with capital. The extent to which capital and energy are substitutable is not subject to consensus in the literature. It can vary according to the vintage of capital (for instance from 0.12 to 1 in the GREEN model), or be fixed between 0.5 (GTAP-E model) and 0.8 (PACE model). Since energy consumption is very sensitive to this elasticity of substitution, its calibration is of utmost importance. Fontagné et al. (2013) choose to reproduce stylized energy consumption trends as in International Energy Agency projections to 2025 (IEA, 2011), which led to calibrate this elasticity like in GTAP-E. We adopt the same strategy.

Figure 1: Production tree in MIRAGE-e

[8] This assumption does not imply that employees would actually move from their sector to another, as the annual variations in labour demand by sectors remains below the replacement rate of labour force by new generations as a consequence of entry and exit from the labour market.



Source: Fontagné et al. (2013)

The architecture of the energy bundle defines three levels of substitution (Figure 1). Energy used can be delivered by electricity or fossil fuels. Fossil fuels can be coal and otherwise either oil, gas or refined oil. As a consequence, oil, gas and refined oil are more inter-substitutable than with coal and finally with electricity. Values of the elasticities of substitutions used in MIRAGE-e are in line with the literature: electricity-fossil fuels substitution is based on Paltsev et al. (2005), the two other elasticities come from Burniaux and Truong (2002). Finally, the value of the energy aggregate is subject to efficiency improvements, as projected by the growth model. As stressed above, a challenging issue for CGE models is about CO2 emissions and energy consumption in physical quantities, as opposed to other variables measured in dollars at constant prices. In practice, using CES functional forms with variables in monetary units leads to inconsistencies when trying to retrieve physical quantities. In addition to the accounting relations in constant dollars, MIRAGE-e integrates a parallel accounting in energy physical quantities (in million tons of oil-equivalent), in order to provide results expressed in terms of actual energy demand.

MIRAGE-e's production function is a Leontief of intermediate consumption of the different varieties of goods, and value added. Value added is a Constant Elasticity of Substitution (CES) aggregation of land, natural resources, unskilled labour and a bundle of the remaining factors. The latter is a CES aggregation of skilled labour, and another bundle of capital and energy. Lastly, energy itself is an aggregation of energy sources as defined above.

On the demand side, a representative consumer from each region maximizes its intra-temporal utility function under its budget constraint. This agent, which includes households and government, saves a part of his income. This behaviour is here determined by the savings rate projected by the growth model on the basis of the combination of individual countries demographic profiles with a life-cycle hypothesis. Expenditure is allocated to commodities and services according to a LES-CES (Linear Expenditure System - Constant Elasticity of Substitution) function. According to the latter assumption, above a minimum consumption at sectoral level, consumption choices between sectors are done according to a constant elasticity of substitution. This assumption is a tractable representation of preferences in countries at different level of development. It is accordingly well designed for our purpose.

Then, within each sector, goods are differentiated according to their origin. A nested CES function allows for a particular status for domestic products, together with a product differentiation according to their geographical sources, according to the usual Armington hypothesis (Armington, 1969). Elasticities are those provided by the GTAP database and were estimated by Beckman et al. (2011). Total demand is built from final consumption, intermediate consumption and investment in capital goods.

The dynamic baseline of the model is provided by Fouré et al. (2012) and we consider results at the 2025 horizon. A pre-experiment with MIRAGE-e provides with the endogenously determined TFP thereafter used as exogenous in the simulations. Demography is as in the central scenario of the UN.

In order to capture potential efficiency gains or losses in energy use as a consequence of changes in the production mix and avoid differences in energy intensities being evened by aggregation, it was important to use a rather detailed structure of the world economy. The model distinguishes 29 regions and 32 sectors, listed in Appendix. The choice of sectors and regions was made so as to preserve as much as possible of the heterogeneity of energy intensities by the different regions.

We consider in this exercise two scenarios, tackling only tariffs, domestic support in agriculture, and export subsidies in agriculture. We neither address non-tariff measures in the goods sector, nor a reduction in the obstacles to trade in services. Our aim is to focus on the impact of an increase in trade in goods on energy demand, and not to simulate any outcome of a multilateral negotiation covering a large number of topics. The first scenario is inspired by the state of the play in the Doha Round, regarding tariffs in the NAMA and the negotiation in agriculture. This is an excellent experience to uncover the mechanisms we are interested in, as liberalising trade in agricultural products will have an impact on countries' specialisation and potentially re-allocate production across producers with different energy efficiency. Also, such scenario should impact world prices for certain agricultural goods, and prices are a channel of adjustment of energy consumption we are interested in. The second scenario is even more unrealistic as tariffs and support for goods are all phased out, but aims at tackling the validity of our argument.

The source information concerning the first scenario to be modelled for the negotiation on the Non Agricultural Market Access (NAMA) is the "Fourth revision of draft modalities for Non-Agricultural Market Access" published in December 2008, updated the 21 April 2011, and augmented by updated information regarding the actual percentage to be applied to the modalities as well as information collected on the option chosen by the main negotiating developing countries. Sectoral initiatives concerning chemicals, machinery and electronic products and a similar initiative concerning environmental products are also taken on board.

For agricultural goods we have similar sources: the draft modalities and the report of the Chairman to the Trade Negotiations Committee dated April 21th 2011.[9] Each scenario on tariff reductions is quantified at the country, product and year level in a first step. Then it is aggregated in the GTAP classification and introduced in a Computable General Equilibrium (CGE) model of the global economy. One important issue in agriculture is tariff rate quotas (TRQs). A reduced tariff is conceded for many lines within quotas (inside tariff), the outside tariff being much more protective. This is related to the selection of exceptions. When tariff lines are chosen as sensitive, an additional tariff quota must be open. Industrial countries have the possibility of limiting the tariff cut to the 2/3 of what it should be based on the simple use of tiered formulas, and to compensate this by a small quota. Or they can keep half of the cut and open a larger quota. Or keep only one third of the cut and open a large quota. In order to avoid explicitly modelling the quotas, one will use the outside tariff under the assumption that the quota will anyway be quickly filled as a result of the growth of world demand. We also assume that countries choose the last option (1/3 of the cut).

[9] While one relies here on HS6 tariffs, list of exceptions are defined at the tariff line level. A higher level of detail allows making a more efficient use of flexibilities. This is accounted for in the proposals, which grants 2 additional percents of HS6 products as sensitive for countries defining their protection at HS6 level. This is in tune with previous estimations based on an actual list of elected products in the EU among the 2,200 CN8 agricultural codes (out of 677 HS6 positions). We thus added this 2 percents to all countries taking advantage of sensitive products in agriculture.

The second scenario is a full tariff liberalisation across the world. Tariffs are eliminated linearly within 5 years, along with domestic subsidies in the agricultural sectors. Export subsidies in agricultural sectors are eliminated on the first year of implementation of the policy.

Results

The two simulations provide powerful insight in the mechanisms at play. We firstly observe that a Doha-like cut in tariffs has very little impact overall. This confirms previous studies (Decreux and Fontagné, 2011). More interestingly, the increase in world GDP takes place with no significant increase in energy consumption.

Table 1: Macroeconomic results at the 2025 horizon (percentage change from baseline)

Variable	Doha	Full
World exports (volume)	1.39	10.56
World GDP (volume)	0.11	0.75
World welfare	0.09	0.64
World demand for transport	0.25	2.04
World energy demand (MTOE)	0.02	0.25

Source: Authors calculation, MIRAGE-e, GTAP 8

Demand for energy

Overall, trade liberalisation results in increased energy efficiency, as measured by the ratio of energy demand over GDP. Overall, over the past twenty years, energy intensity has been reduced by approximately 1% per year while energy demand was increasing by more than 2% per year. In other words, a 1% GDP growth is usually associated to an increase in energy demand that is more than 2/3 of that gain. Our simulation show that trade liberalisation can lead to GDP gains for a significantly smaller cost in terms of energy demand. GDP growth includes the production of transportation services, and thus does not fully reflect the increase of the purchasing power by households. However this result still holds if we consider world welfare instead of GDP.

To better understand the mechanisms at play, it is useful to decompose world energy demand between various components such as energy demand for international transport of merchandises, energy demand by other sectors, and final demand for energy by households and governments. Our results confirm that energy demand by the transportation industry would significantly increase, in a proportion that would even be larger than the increase in trade volume itself. This is due to the fact that increases occur mostly in the agro-food sector, for which transport costs are large. By contrast, energy demand by other sectors would increase less than production by those sectors in the full scenario and would remain stable in the Doha scenario. Final consumption would adjust through the channel of increasing prices: the decrease in final energy consumption is striking in the full scenario. Intermediate consumption is less affected because it is less sensitive to prices. Notice that the mechanism at play does not assume any economy of scale in the transportation industry: introducing such economies would magnify our conclusion.

Table 2: Decomposition of energy demand (percentage change from baseline, 2025)

Variable	Doha	Full
Intermediate demand of the transport sector (MTOE)	2.11	17.76
Intermediate demand by other sectors (MTOE)	0.00	0.31
Final consumption (MTOE)	0.04	-0.27

Source: Authors calculation, MIRAGE-e, GTAP 8

Changes in world prices are shown in Table 3 for broad sectors. The direct effect of prices channels through the price of energy: the moderate 0.3% increase under the Doha scenario is large enough to keep the demand of energy constant – with the exception of transport – under the Doha scenario, despite the increase in production and income. Under the full tariff liberalisation, the demand of energy in the transport sector is large enough to push prices 3.5% up, which limits the intermediate demand of energy in other sectors by 0.3%, while the decrease in final consumption of energy is of similar magnitude in absolute terms. On the top of this direct effect, a second mechanism is at play: the prices increase in the agro-food sector, which is an outcome of the reduction of internal farm support as well as border protection for food products. This change in relative prices in especially visible under the Doha scenario, where the 0.7% increase in the food prices worldwide, contrasting with rather stable prices for manufacturing and services, leads to a substitution effect. There will be ultimately a substitution effect detrimental to agro-food products intensive in energy. These price increases are the largest for Animal agriculture (+1.8%), Wheat or Vegetables Fruits & Nuts (+1.6%), Other cereals (+1.4%) and Other crops (+1.3%). All in all, the world production of Agrofood will decrease by -0.3%.

Table 3: Change in prices for broad sectors (percentage change from baseline, 2025)

Variable	Doha	Full
Agro-food	0.69	1.12
Other primary	-0.06	0.53
Energy	0.31	3.49
Manufacturing	0.07	0.52
Transportation	0.18	1.07
Other services	0.08	0.76

Source: Authors calculation, MIRAGE-e, GTAP 8

Demand for other primary commodities

Similar efficiency gains can be observed if we consider the use of primary commodities. Adjustment to price increases should lead to substitution everywhere, and as primary resources other than energy are not particularly needed as an input of the transportation industry, the efficiency effect will clearly dominate the scale effect overall. We expect accordingly the demand for primary commodities such as Forestry, Fisheries and Minerals (ores and other extracted commodities) to be reduced as a consequence of trade liberalisation. We observe in Table 4 that this mechanism is at play. All sectors are affected in similar proportions in the Doha scenario, but impact on Fisheries and Forestry becomes much stronger when a full liberalisation is considered.

Table 4: impact on other primary commodities (percentage change from baseline, 2025)

Variable	Doha	Full
Forestry	-0.09	-0.47
Fishing	-0.05	-0.30
Minerals	-0.07	-0.03
All primary products	-0.07	-0.16

Source: Authors calculation, MIRAGE-e, GTAP 8

Regional patterns

These overall changes, leading to a worldwide increase in the efficiency of energy use, result however from contrasted evolutions at the regional level, illustrated in Table 5 for the Doha scenario. While demand of energy for transport is a systematic outcome, with an increase of about 2% in all regions, the final demand of energy and the intermediate demand of energy by sectors other than transport exhibit different evolutions across regions. The substitution effect leading final consumers to demand less energy is present only in developed countries. In contrast, this demand increases significantly in East Asia, while remaining unchanged in Latin America and Caribbean, and Eastern Europe and Western Asia. In the latter regions the intermediate demand of energy declines, while it is stable in East Asia.

Table 5: Changes in energy demand at the regional level under the Doha scenario (percentage change from baseline, 2025, MTOE)

Region	Final consumption	Intermediate demand of Transport sector	Intermediate demand by Other sectors
Developed countries	-0.10	2.17	0.10
South & East Asia	0.54	1.88	0.03
Latin America & Caribbean	-0.00	2.09	-0.21
Eastern Europe & Western Asia	0.03	2.18	-0.12

Source: Authors calculation, MIRAGE-e, GTAP 8

Conclusion

While trade liberalisation had long been opposed mostly because of concerns about possible adverse social consequences, new concerns have emerged in the recent years. International transportation of merchandises is liable for a significant share of energy demand and carbon emission. As trade liberalisation increases the volume of trade flows, it could also increase the overall demand for energy and eventually harm the environment.

While this concern is legitimate and the risk of an increase in the demand for transportation services is real, it is however not the only consequence of a trade liberalisation. Our simulations show that trade liberalisation actually reduces the overall energy intensity at world level through a better allocation of activities across world regions.

While the issue of harmful effects of merchandise transportation remains of prime importance, it is not the only phenomenon that should be considered. Locating activities according to countries' comparative advantages measured on the basis of environmental costs may actually be beneficial to the environment. Changes in energy and food prices worldwide are an important channel for this mechanism.

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Appendix 1: Region and sector aggregations

Mirage regions	Description	Large regions (for result display)
European Union		Developed countries
United States of America		
Canada		
Japan		
EFTA		
Oceania	Australia, New Zealand, Rest of Oceania	
Korea		
Taiwan		
China	Includes Hong-Kong	South & East Asia
ASEAN1	Cambodia, Laos, Vietnam	
ASEAN2	Indonesia, Malaysia, Myanmar, Brunei, East Timor	
ASEAN3	Thailand, Philippines, Singapore	
India		
Rest of South Asia		
Rest of Asia	Mongolia, North Korea, Macau	
Mexico		Latin America & Caribbean
Argentina		
Brazil		
Chile		
Colombia		
Rest of South America		
Caribbean		
Rest of Europe		Eastern Europe & Western Asia
Western Asia		
Middle East		
Turkey		
North Africa		Africa
SACU		
Rest of Africa		

Mirage sectors	Description	Large sectors (for result display)
Paddy rice Wheat Other cereals Vegetables Fruits & Nuts Other crops Animal agriculture Rice Sugar Dairy Meat Other food & Tobacco	Oil seeds, Plant-based fibers and Other crops	Agro-food
Forestry Fishing Minerals		Other primary
Coal Oil Gas Petroleum & Coal products Electricity	Includes gas distribution	Energy
Textile Clothing & Leather Wood Paper & Publishing Chemistry Iron & Steel Other metals Cars & Trucks Planes Ships Bikes Trains Electronic Equipment Machinery & Equipment Other manufacturing		Manufacturing
Transport		Transportation
Other services		Other services