

Camilla Jensen*

International Trade in Infant Industries: A Dynamic Analysis of Different Trade Policy Instruments and Their Implications for Sustainable Consumption**

Infant industries have come to be associated with behind the frontier technologies in developing countries. This paper takes a fresh look at the infant industry problem and in the more contemporary perspective of developed-emerging economy competition in lead markets such as for example the global solar panel industry. Different policy scenarios are considered under two different trading regimes. First one where all firms learn symmetrically in cost. Then one where learning paths and preference about sustainable consumption partly could be conforming with prevailing institutions in each country. The paper demonstrates that NTBs or standards can be welfare improving in ways that ordinary instruments such as tariffs and subsidies cannot.

Key words: Learning-by-doing, sustainable consumption, international trade policy, standards, lead markets, emerging economies (JEL: D02, D22, F18, O24, P48)

1. Introduction

This paper seeks to connect the problem concerning infant industries to that of new product markets (lead markets) in international trade. Arguing this is really the place where the infant industry problem belongs (Hansen et al, 2003). In such lead markets the central problem is one of supporting the best dominant design or optimal learning path from the outset. For the policy-maker it is important to understand all aspects of the product market and in particular when sustainability is involved. This topic as the paper shows may be of increasing importance in a global economy where it is expected that the new market economies such as Brazil, Russia, India and China (BRIC) will become major or even dominant players in lead markets. Already now BRIC countries are major spenders of government R&D funds. It must be expected that it is here the rivalry between foreign and domestic producers and innovators increasingly will be played out.

Past research has more often focused on infant industry protection under a scenario of an already established industry or technology (Young, 1991, Head, 1994, Luzio and Greenstein, 1995). The problem of the developing country policy-maker is

* Camilla Jensen, Department of Business and Economics, Faculty of Business and Social Sciences, University of Southern Denmark, Campusvej 55, DK-5230 Odense M

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then how to best support the industry (e.g. using a tariff, quota or subsidy – see also Melitz, 2005) given the assumption of learning being a localized process that takes time even when a standardized product is new to a market.

The underlying problem in the infant industry literature is to ascertain that the country with the optimal learning path (e.g. innate ability or comparative advantage for producing the specific product in question) gets selected. Often it is then assumed that countries are symmetric in every other respect, except how fast they learn in terms of realizing economies of time (Leahy and Neary, 1994).

In the model developed here consumers' preferences for durability and thereby indirectly quality (Waldman, 2003, Murthy and Djameludin, 2002) is shaped both by short-run economic decision-making such as price signals and their deeper habits. Where habits may be shaped by a combination of culture, political-economic and policy environment (formal institutions) and geography (especially climate). For example, if consumers expect the good to be of lower durability due to climate factors it may lead them to give overtly preference to less durable goods. Another similar channeling impact factor on consumers' preference for quality and durability may run through their income and/or level of education.

For the developed country in particular the present research results suggest that it is important to increasingly focus on standards and rules orientations in international trade negotiations. Once learning starts to take a particular path it may be difficult to reverse through policy intervention. Hence it is important for the international trade policy maker to establish priorities that are considered vital for long-run growth and sustainability as early as possible.

Section 2 gives a short introduction to the general problem of goods' durability and discusses how it may apply to particular industries such as solar panels which served as a major inspirational case during the early phases of this research. Section 3 offers a simple dynamic model with two goods that are perfect substitutes and subject to differential rates of learning across countries. This model is used throughout the paper to understand one particular type of situation – e.g. where the home country is lagging behind but has innate comparative advantage due to a faster rate of learning over time. This is first modeled as a very simple race between two countries on their learning cost function. However, the more realistic or perhaps critical model (the real world could fall in between the two models perhaps) is presented in Section 5 where firms in each country follow entirely different learning objectives and paths. Sections 4 and 6 make the two models subject to different policy scenarios of applying ordinary instruments such as tariffs and subsidies and more contemporary instruments such as R&D subsidies. In section 6 other alternative instruments are also considered, such as standards combined with R&D subsidies or subsidies that target consumers rather than producers. A short discussion and conclusion follows in the last section.

2. The relationship between the durability of goods and more sustainable consumption futures

The case for supporting infant industries via protective trade policies is one of the oldest accepted cases for using classical trade instruments such as tariffs and quotas (Young, 1991). Most of the cases that have been investigated in the past take the perspective of an already established industry in one country and then looks at it from the perspective of a lesser developed economy to understand whether trade protectionism is (or was as often the perspective is historical) a good idea (see e.g. Head, 1994, Chang, 2003). Past research suggests that for infant industry intervention to be successful it requires that the country that adopts a protectionist stance has an innate ability for learning, that it eventually catches up and that furthermore the short run cost of interventionism in terms of consumption and production distortion losses eventually will be dwarfed by the additional dynamic gains from learning and trade (Head, 1994, Luzio and Greenstein, 1995, Chang, 2003, Hansen et al, 2003, Melitz, 2005, Saure, 2007). Rarely has it been possible to fully identify such a case with empirical data, perhaps in part because it has proven difficult for researchers to get separate data on cost and prices and thereby be able to infer much about the competitive regime that separates cost from price. Or perhaps because interventionism on average does not pay off or at least not in the way that the infant industry literature claims (see e.g. Westphal, 1990 and Lee, 1996 for critical appraisals related to the case of South Korea.)

In the perspective of new technologies or industries the case for infant industry protection has been investigated much less. Hansen et al. (2003) ventured one of the first papers on this particular issue, using data for the Danish windmill industry. In that paper we reckoned that it was not an ordinary but rather an extraordinary case of infant industry protection as it was starting to export almost from the outset and did not face any import competition. Protection or incubation was therefore also taking place much more commonly via subsidies and institution building rather than tariffs. (Tariffs which there were no immediate need for - nor would they have been possible as Denmark does not decide over its tariff policy within the EU.) This type of scenario or problem of the need for supporting emerging technologies that are considered vital for global welfare may become more and more common.

In hindsight and from the present day perspective the Danish windmill industry must be considered quite successful as learning was sustained via different types of policies that targeted both the demand and supply side and bottlenecks in the market for delivery of electricity. We therefore also concluded that despite the smallness of the national platform, intervention in the market both via subsidies for R&D, stimulation of demand via consumption subsidies and creation of a market for electricity generated by wind energy has been decisive all together in building export capacity. Possibly the industry would not have emerged later with the force that it did, had it not been prioritized at that time by the Danish government. Today two

of the main firms that have been leading in setting technology standards and continue to supply more than 10% of the global market still operate out of Denmark (e.g. Vestas and Siemens (formerly Bonus Wind Energy)). Where the 'national' market share is miniscule and has been almost from the inception (Ren21, 2012). However, given their early success these firms have been able to withstand competition from lower cost emerging market players.

This success case seems to stand in somewhat contrast to the solar panel industry. Clear lead players have been slow to emerge from the OECD countries despite the large emphasis placed on the industry by several EU governments. There have been attempts to invest in the technology on behalf of developing countries (e.g. private and public benefactors from countries such as Turkey, Israel and Malaysia). Given that such countries have high solar irradiance means that they should hold natural comparative advantage in this industry. However, the rate of technology adoption has been slow and there have been reports of high failure rates in these type of projects (Martinot et al, 2002). In the midst of these disappointments have emerging markets and mainly China gradually taken over the supply of the technology and thereby also increasingly the command over standards (Ren21, 2012). This has stirred cause for action in terms of anti-dumping proceedings among American firms. Several Silicon Valley firms have been in financial difficulties due to among other overpromising on their warranties or the durability of their panels - promises they might not even have benefited from very much in terms of increasing sales. Sector specialists warn about the pitfalls of the technology in terms of durability and sustainability. For example, research shows that the solar panel technology has a negative CO₂ impact if the expected lifetime is 3 years or less (Ftenakis et al, 2008). Consumer rights organizations suggest that if consumers buy the cheapest panels from the assembly type companies, they may very well face the issue that the firms are out of business long before the warranties run out (Pike Research, 2010).

One long recognized problem in sustainable consumption is the issue about the degradability of goods and how it affects waste management (vertical dimension in Exhibit 1). A less researched but closely related question concerns the turnover rates of many goods or in other words the durability of goods (horizontal dimension in Exhibit 1). The focus in this paper is on the durability aspect of consumption and how this aspect may affect commonly held views in the international trade policy debate surrounding such technologies. The multi-dimensional aspect of solar panels make it a highly complex case since it has in this way both potential positive and negative impacts on the environment. Most research focuses on the positive impacts of supporting these technologies, where here the focus is more on the potential dimensions that can lead to negative impacts through the channel of trade. In fact many of the most traded goods (e.g. in particular electrical and electronic goods as identified in Exhibit 1) involve such additional considerations about the dimensions of degradability and durability for more sustainable consumption futures. The most important goods to consider are those that are slow to degrade and at the same time

suffer in present consumption patterns from overtly high turnover rates or in other words where the durability is put at stake due to the workings of the market mechanism, marketing and lifestyle. Referring to Exhibit 1 the problem of the policy-maker becomes to incentivize production that secures either more lasting goods and goods with a high environmental grade and ideally goods that encompass improvements on both aspects at the same time (e.g. organic durable solar panels would be the case in point). Hence the focus on durability for sustainable consumption is only one of several to consider but perhaps a very important one that has been ignored by past research and current trade policy debates. The paper offers a simple model construct, one approach or perspective suggesting how this issue can be included into the toolbox of the international trade policy analyst.

Exhibit 1. Product dimensions of high importance for sustainable consumption.

Environmental grade G (e.g. does the product regrade or degrade the environment)	Product durability or product life V			
	Batteries	Laptops Telephones	Houses	The pyramids →
	Copies	Books	Cars Machines	
	Ice-cream	Solar Panels		
		Rain forest		Bristlecone Pine
			Sustainability	

3. A simple model of an infant industry race

This section develops a simple model to investigate an infant industry race between two countries in a lead market (e.g. a new technology where there are significant economies of time (dynamic economies of scale) to be realized in both countries).

On the demand side it is assumed as in Head (1994) that the consumption of the particular good under investigation enters into overall consumption with a Cobb Douglas preference so that the income share, e.g. income devoted to this particular good is constant in both countries. For sake of simplicity it is also assumed that the countries are symmetrical and devote an equal share of total expenditure on this good in the size of 2m. (The discussion will address how alleviating some of these assumptions might potentially change some of the obtained results in the paper.)

It is assumed that the good in question is produced in both countries even though there is not necessarily any production for consumers or world markets taking

place, e.g. producers in the country maintain a small platform such as for example a government procurement programme would facilitate. This is necessary as otherwise the absence of production could make the potential infant industry racer fall into oblivion, e.g. if there are very large differences in the initial cost advantage (see further below).

The static optimization problem for consumers in the two countries, assuming that the good is a perfect substitute whether produced in Country 1 or Country 2, takes outset in the following utility maximization problem (where m is income, p is price and x is quantity):

$$\begin{aligned} \max! \quad & U = x_1 + x_2 \quad (1) \\ \text{st.} \quad & m = p_1x_1 + p_2x_2 \end{aligned}$$

Trade cost are assumed away in the model as in most of the simple general equilibrium models that study the consequences of introducing different policy instruments on country level and global welfare. Including trade cost would give a similar effect as a tariff, however, without the offsetting benefit of the tariff revenue on the country that collects it (see also Section 4). Hence trade cost would eat up part of the benefits of trade as in the models that assume iceberg trade cost (see for example Krugman, 1980).

Following the infant industry literature it is assumed that the supply curve is perfectly elastic, supranormal profits will be competed away and all the cost of taxes and benefits of subsidies fall on consumers given these assumptions (see Varian, 2010, Page 302-304). This assumption of a flat supply curve therefore also has the implication that there is no producers' surplus and hence consumers' surplus (CS) becomes the sole barometer of welfare in the model assuming that each instrument is neutral on welfare (as it turns out this is not the case as discussed and investigated further in Section 4).

The solution to the utility maximizing problem gives that:

$$\begin{aligned} x_1 = 0 \quad & \text{if} \quad \frac{p_1}{p_2} > 1 \quad (2.i) \\ x_1 = \left\{ 0, \frac{2m}{p_2} \right\} \quad & \text{if} \quad \frac{p_1}{p_2} = 1 \quad (2.ii) \\ x_1 = \frac{2m}{p_1} \quad & \text{if} \quad \frac{p_1}{p_2} < 1 \quad (2.iii) \end{aligned}$$

Where in situation i. Country 2 serves both markets and Country 1 is an importer. In situation ii. both countries serve both markets. In situation iii. Country 1 serves both markets and is thus an exporter.

Now when substituting into Equations (2) that in each period in equilibrium relative prices equal relative cost in the two countries (since cost are the sole determinants of prices in the model) we get:

$$x_1^t = 0 \quad \text{if} \quad \frac{c_1}{c_2} > 1 \quad (3.i)$$

$$x_1^t = \left\{0, \frac{2m}{c_2}\right\} \quad \text{if} \quad \frac{c_1}{c_2} = 1 \quad (3.i)$$

$$x_1^t = \frac{2m}{c_1} \quad \text{if} \quad \frac{c_1}{c_2} < 1 \quad (3.i)$$

To solve the general equilibrium under free trade in the two countries we need to know what determines the cost structure in the two countries at any particular point in time. This is where the infant industry problem enters into the model. With outset in the infant industry engineering literature (see Mishina, 1999) it is assumed that learning over time facilitates a reduction in the labour input requirement per unit of output (e.g. $b < 0$) following the discovery in the Boeing factories of this type of exponential learning process (where l is labour requirement and Y is output):

$$l_t = aY_t^b \quad < = > \quad (4)$$

$$\log l_t = a + b \log Y_t$$

Given that we are interested in the cost function rather than the labour input requirement, this may translate into a cost function in semi-log form (for example, assuming that the learning process also entails a gradual introduction of more capital-intensive devices such as robots and more skill-intensive labour such as engineers and designers). This implies that cost will decline with less than the reduction in labour cost over time which could make the cost function take the following form in the two countries (where c is cost and T is discrete time):

$$c_1 = a_1 - b_1 \log T \quad (5)$$

$$c_2 = a_2 - b_2 \log T$$

With Equation 5 it is assumed that cost decline automatically with the passing of time, whereas the standard assumption would be that cost decline in cumulative output (see e.g. Hansen et al, 2003). Such learning-by-doing or via experience is one of the central tenets of the infant industry argument. However, modelling the effect as solely a function of T does simplify among other the calculation of consumers' surplus. Under the assumption of a constant income devoted to this product over time, the effect in cumulative output would also be directly proportional in time T . Hence the implications of this assumption are minor as long as the income is constant and the countries are symmetric (e.g. equally sized in terms of income

devoted to this product). See also Section 7 for a continuation of the general discussion of alleviating some of these simplifying assumptions.

To find the solution to the optimization problem of consumers in each country in each period, we can insert the cost functions in Equations 5 into the relative cost curve ($CC=c1/c2$):

$$CC = \frac{a_1 - b_1 \log T}{a_2 - b_2 \log T} \quad (6)$$

As long as the relative cost of production CC in Country 1 is greater than 1 (or above the relative price line where prices equate defined as PP) Country 2 will serve the market in both countries and conversely when the relative cost of production CC in Country 1 is smaller than 1 (or smaller than PP). The solution from the perspective of Country 2 is the same (e.g. using $1/PP$ and $1/CC$) as long as there are no trade cost. See also the static equilibrium panels that are derived in the Appendix for the next section which further inquires into these issues.

Only at one moment in time T' do both countries serve both markets and any potential spell without trade is thus short-lived when there are no cost of engaging in trade. With trade cost (which are similar to tariffs) there will be longer spells without trade in the model as discussed in Section 4.

4. Simulations and estimation of the welfare effects of free trade in the model

Now the model can be solved using simulations. For example, baseline values are inserted for each parameter in the model with outset in a particular situation or baseline scenario. The baseline scenario used throughout the paper is that Country 2 initially is the cost leader ($a1 > a2$), but that Country 1 holds dynamic comparative advantage as the faster learner ($b1 > b2$). An example of this situation is depicted with the respective cost functions drawn in Figures 1A and 1B.

Figures 1A and 1B. Production cost in Country 1 and Country 2.

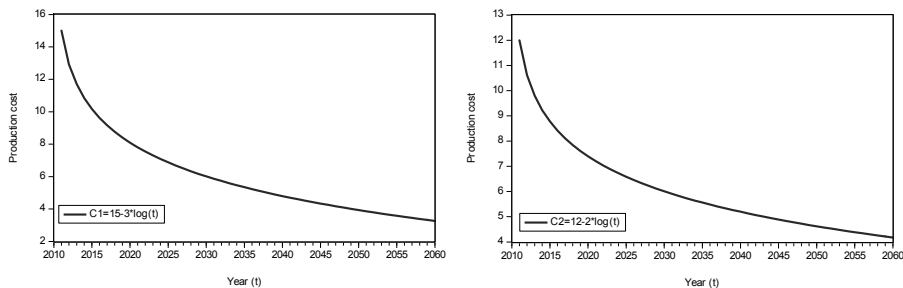


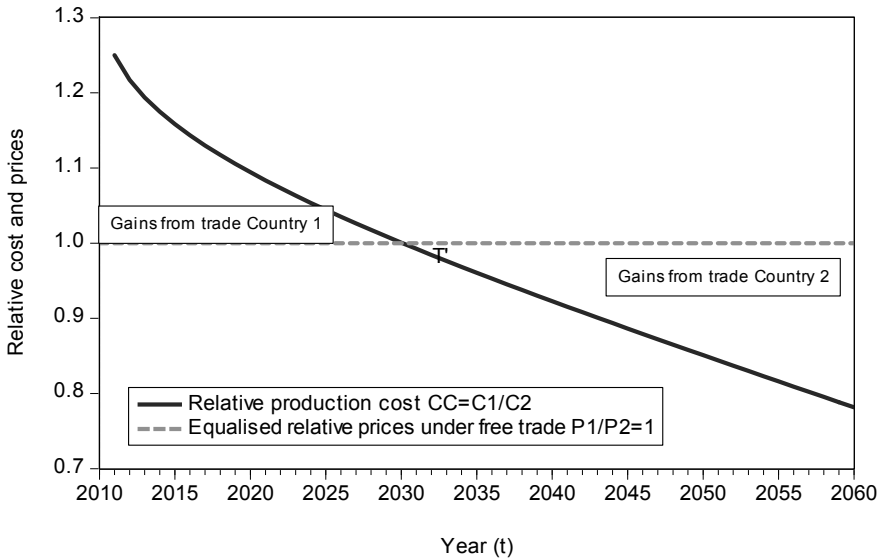
Figure 2. Gains from trade (Consumers' Surplus) in the dynamic trade model.

Figure 2 shows the solution to the infant industry race over time, where the CC line represents the relative cost (and the relative prices in the two countries if there is no trade). The PP line represents the situation where the prices in the two countries are equal (hence relative prices or $PP = 1$). The latter will be the case when there is free trade between the countries. Hence the difference between the two lines shows the difference in prices under autarky and free trade.

This simple model of an infant industry race (e.g. the race is represented by the CC line) can be used to investigate the welfare implications of trade and the welfare implications of applying different policy scenarios. It is a dynamic representation of the general equilibrium comparative statistics in continuous time under some simplified assumptions. Where the area between the CC line and the PP line represents an approximation to consumers' surplus (CS) when there is trade taking place between the two countries. The area between the two curves will capture an approximation to CS over time. For example, the CC curve measures Country 1's cost disadvantage or advantage relative to Country 2. Therefore as long as the CC line is above the $PP = 1$ line, Country 1 will import from Country 2 and thereby enjoy lower prices. The difference between the relative cost and the relative value difference (the latter being 1 since X_1 and X_2 are perfect substitutes) is a measure that approximates consumers' surplus. Assuming that price changes are marginal in T and that income is constant over time, the approximation is quite exact. The approximation is based on a continuous time concept in Figure 1 and is compared

with an exact calculation based on discrete time as derived in Appendix 1. The comparison shows that the discrepancy between the two measures is less than 4%.

This simple model suggests that it is mainly consumers in the importing country that enjoy gains from trade. This is because of the model assumptions and since there is no additional consumers' and no producers' surplus at all in the model construct.

5. Policy scenarios applied to the base model

In this section it is considered how *CS* is affected in the base model by implementing different policy instruments. The instruments considered are tariffs, ordinary production subsidies and R&D subsidies. The benchmark is the *CS* that results from free trade as calculated already in Section 3.2. Then the *CS* under each policy scenario is calculated and compared to welfare under free trade. Again the results from using the approximation to *CS* in continuous time are checked by going back to the more ordinary comparative statics in a general equilibrium type of situation to benchmark the exactness of the results in a discrete time context.

Ideally the general *CS* could be found by using variable parameters (as derived for discrete time in the Appendix). In such a case the *CS* could be calculated using Equation 7:

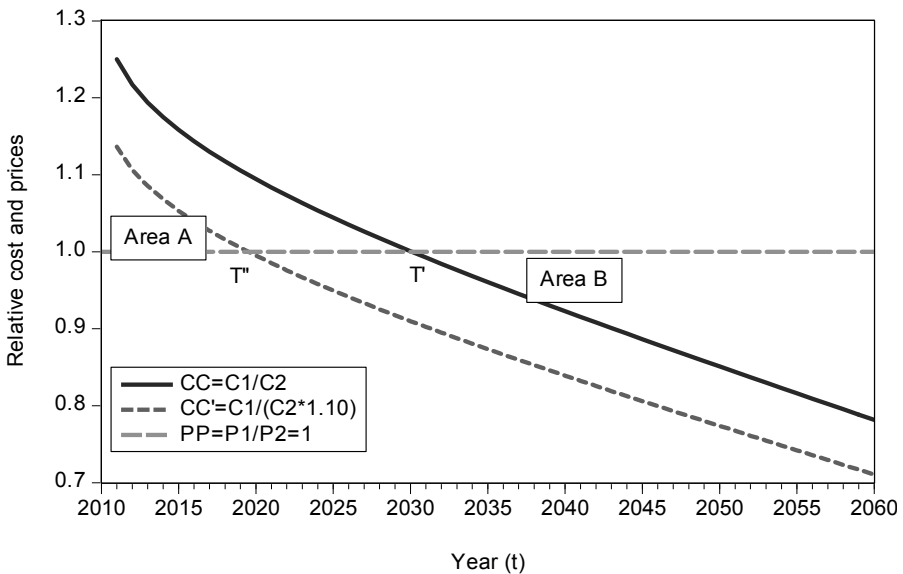
$$CS = \int_0^{T'} \frac{a_1 - b_1 \log T}{a_2 - b_2 \log T} - \int_0^{T'} 1 + \int_{T'}^T 1 - \int_{T'}^T \frac{a_1 - b_1 \log T}{a_2 - b_2 \log T} \quad (7)$$

However, this does not result in a finite numerical result even starting from time $T = 1$. Therefore specific estimates for *CS* in a simulation must be found and these estimates are then compared back to the benchmark under free trade in absolute numbers and percentages. Note that these numbers do not contain any relevant information besides being ordinal measures of *CS* and are therefore useful only for comparative purposes.

The first instrument investigated is an ordinary ad valorem tariff. Specifically it is assumed that Country 1 adopts a 10% ad valorem tariff on imports from Country 2. Hence this will increase the price (cost) of the product from Country 2. This scenario is shown in Figure 3A where the *CC* curve due to the tariff shifts inwards to the left. The result of the tariff as can be seen is that the cutting point T'' where comparative advantage shifts from one country to the other occurs earlier (e.g. around 2020 rather than around 2038). However, the interim period between the original T' without the tariff and the new T'' with the tariff will create a prolonged period of possibly no trade or some two-way trade between the two countries. The gains from trade therefore shrink considerably due to the tariff as now it must be calculated as the area under the new *CC* curve up until T'' (marked as area A in Figure 3A) and thereafter as the area under the *PP* curve at T' to the original *CC* curve (marked as area B in Figure 3A). This is because the tariff is only temporarily

relevant or in force up until time T'' . After that time the tariff will be prohibitive and the rest of the new CC curve ceases to be relevant. The calculations of the CS areas suggest that a tariff reduces the gains from free trade with 27%. The exact measure calculated in the appendix moderates the negative result of the tariff (to only 11% when comparing back to free trade) from the viewpoint that the Government in Country 1 recuperates most of the lost CS due to the tariff in the form of tax revenue (hence wiping out most of the offsetting effect of the instrument). The real cost of the tariff is therefore mainly the period where it prevents trade from taking place.

Figure 3A. Country 1 levies a tariff of 10% on imports from Country 2.



The second instrument considered is an ordinary production subsidy given to producers in Country 1. This scenario is drawn in Figure 3B – where now the price and cost are reduced in Country 1 equivalently with a 10% production subsidy. Seemingly the effect is similar to a tariff and it also turns out that this is very much the case in this particular model. However, it also depends on when the subsidy is cut off. The timing issue becomes quite important to the exact assessment of the welfare effect of the production subsidy. As shown in the Figure (3B) it is assumed that the subsidy is discontinued at the time when Country 1 is able to export to Country 2 independent of receiving a subsidy. This would be the ordinary infant industry reasoning. Hence the CS from using this instrument can be calculated as the sum of the three areas as marked on Figure 3B (note the subsidy will not be effective until at the time $CC' = PP$). According to the specific simulation example used the subsidy will hardly change global welfare. But in the more exact discrete

time analysis there is a negative net effect on welfare with 18%. It is mainly due to the instrument cost of the subsidy as the subsidy is not fully recovered by an equal sized increase in CS in Country 2 owing to a production distortion loss. The subsidy becomes again as the tariff a net-liability for welfare. But here because it leads to an interim period where it replaces more efficient producers abroad with less efficient producers at home (in Country 1 where the subsidy is given). However, compared to the tariff the subsidy does not lead to a prolonged period without any trade.

Figure 3B. Country 1 gives a 10% production subsidy to its own producers.

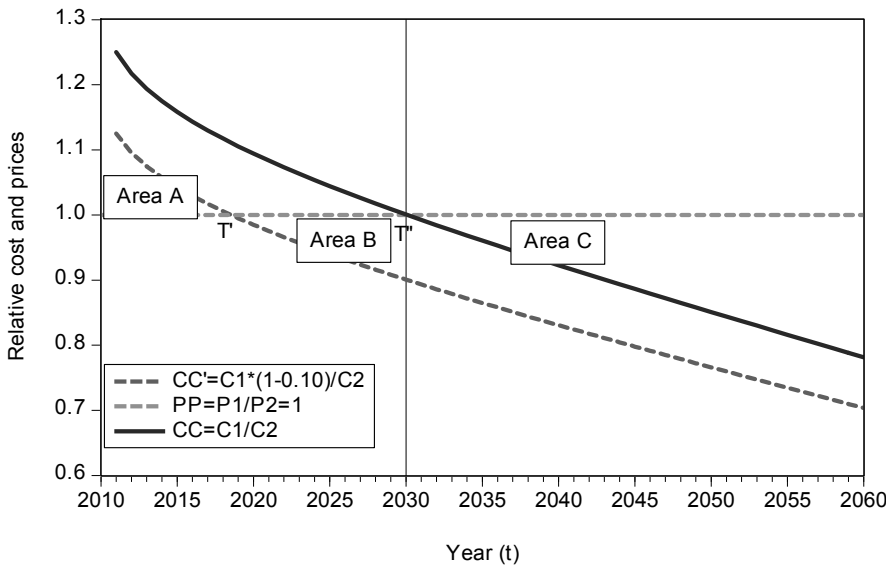
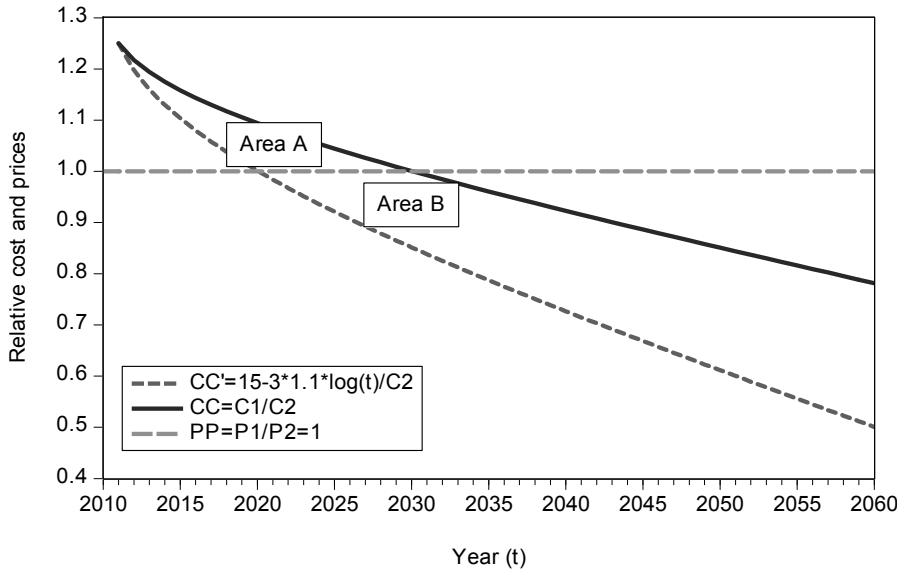


Figure 3C. Country 1 gives a 10% R&D subsidy to its own producers which makes them learn 10% faster.



The last policy scenario considered using the base model is an R&D subsidy. This policy is different from the previous instruments. Both a tariff and a subsidy works to twist the balance between the relative cost of producing the product in the two countries. Furthermore, as direct instruments on prices both have a cost-benefit ratio of 1:1 (assuming away administration cost). However, the R&D subsidy is assumed to affect the learning rate and may potentially be more effective as it could involve a cost-benefit ratio greater than 1. If the government in Country 1 gives an R&D subsidy it could affect the learning rate of firms in Country 1. Here it is assumed that the learning rate improves with 10% as a result of the subsidy¹. This situation is depicted in Figure 3C applying this scenario to the simulations. The result is that the CC curve becomes steeper. Not surprisingly therefore the welfare improves mainly because consumers in the other country enjoy much greater gains

1 There is a rich literature documenting the positive effect of tax credits on R&D spending (see e.g. European Commission, 2014). However, evidence demonstrating the linkage between R&D spending and innovation is still weak. A recent microeconomic study of Canadian firms by Czarnitzki et al (2011) showed that subsidized firms were twice as innovative (in terms of counts but not necessarily sales) as non-subsidized firms. Another recent study estimated the social welfare of R&D subsidies for Finnish firms and found using an economic model and standard assumptions that the benefits somewhat exceed the cost. However, due to the impact such subsidies can have both on the extensive (hurdle type of effect which is more likely to lead to radical innovation) and intensive (more likely to lead to a speed up in learning or incremental innovation) margins of innovation it is difficult empirically to estimate their exact social welfare impact.

from trade (it goes up with area B less area A as marked in Figure 3C). Compared to free trade it is estimated that welfare goes up with 118% under this scenario. In the exact model where the welfare effect is only 77% the main difference is that the cost of the instrument is accounted for. This reduces the welfare effect (and with exactly how much would depend on the exact cost-benefit ratio of the instrument which is unknown).

Table 1 summarizes the findings from the policy analysis applied to the base model. In the base model many of the classical results of trade policy analysis are confirmed and here mainly focusing on the global welfare perspective, e.g. tariffs are associated with a deadweight loss whereas production subsidies can lead to production distortion losses and substantial income transfers and involve typically only minor additional benefits. The R&D subsidy could in an infant industry perspective be the superior policy, however, the empirical evidence in support of the effectiveness of using R&D subsidies to incentivize innovation or learning remains weak. Hence the exact cost-benefit ratio of this particular instrument is an unknown factor. Overall it is concluded that the welfare analysis in the continuous model is only somewhat consistent in the perspective of correctly assigning rank to policy instruments referring back to the ordinary welfare analytical tool kit of trade policy. The main problem would be that the CS in continuous time gives too low a rank to the tariff relative to the subsidy and that the lack of empirical evidence on the effectiveness of R&D subsidies makes the relative ranking highly susceptible to model assumptions. The welfare effects as approximated here with CS need adjustments due to the cost-benefit structure of each instrument and the smaller areas of the indirect cost and benefits that are lost when moving from the discrete to the continuous time concept. The deviations between the CS in continuous time and CS and total welfare in discrete time are summarized in Table 1. A full explanation of the areas and the calculations are given in the Appendix.

Table 1. Policy scenarios in the base model, comparing the continuous time (ct) and discrete time (dt) models

Policy	CS	Δ CS (ct model)	Δ CS (dt model)	Δ Welfare (dt model)	Discrepance in using Δ CS in ct for Δ W in dt
Free trade	5,46	-	-	-	-4% Area b
Tariff, 10%	4,01	-27%	-24%	-11%	-27% Areas b+d+e and Instrument
Subsidy, 10%	5.51	≈ 0	+24%	-18%	+16% Triangles b+d and Instrument
R&D Sub., 10%	11,94	+118%	+165%	+77%	+16% Instrument

6. An extended model with differential learning paths

This section extends the base model discussed in Section 3 to include the durability V of the product into the analysis. The product in the two countries can now be characterized in terms of cost C_i and durability V_i (or sustainability even though the dimension of environmental grade is not accounted for here). It is assumed that consumers do not internalize the characteristic V . Preference for the characteristic V is only reflected through the learning paths on the supply side. In real terms preference for durability will often run through habit rather than rational calculation. Whereas the actual or true cost of the product is C_i/V_i - and $1/V_i$ is the implicit depreciation rate. If a product endures longer it is better for economic welfare which should be obvious but may often not be at the time of consumption. The longer things endure the less frequently they have to be repurchased which frees resources for more consumption possibilities now and in the future.

More specifically it is assumed that the institutions (here defined as rules and norms guiding social behavior resulting over time from a composite or coevolution of formal rules, physical environment and culture or habit²) in Country 1 favor durability whereas oppositely in Country 2 producers (and indirectly also consumers even though this is not modelled directly but only through learning paths of firms) place less importance on this aspect of the good. This comes to be reflected in the model through the supply side or learning priorities of producers in each country. Producers in Country 1 only learn about V over time, whereas firms in Country 2 learn about C . Consumers could also be reinforcing this pattern because of their preferences which are really habits formed by the same institutions that form the habits or priorities of the firms.

At time T it is again assumed that $a_1 > a_2$ (Country 2 has the initial cost advantage). But instead now it is assumed that $b_1 = 0$ whereas still $b_2 < 0$. At the beginning of the period it is furthermore assumed that the durability of the product is the same in both countries e.g. $V_1 = V_2$. However, as producers in Country 1 learn about durability of their product, V goes up over time with the following function:

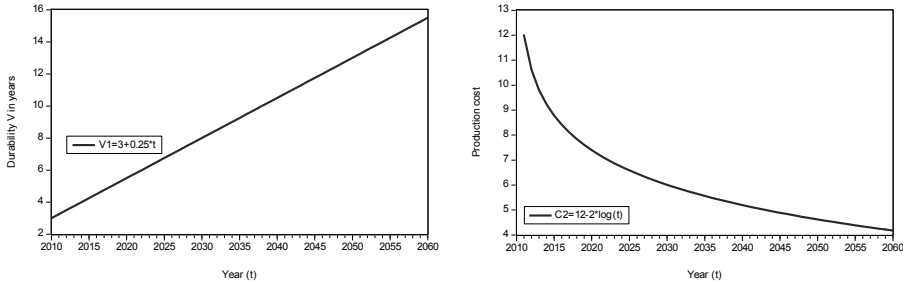
$$V_1^t = V_0^t + d_1 T \quad (8)$$

Whereas for Country 2 firms they continue to follow their learning path:

$$C_2 = a_2 - b_2 \log T \quad (9)$$

2 For example, Rojas (2013) defines institutions theoretically as the rules that connect an individual or organisation to a larger social environment.

Figure 4A. Different learning paths in Country 1 (durability V) and Country 2 (cost C) in the extended model.



This situation is also depicted with Figure 4, where learning follows different paths in the two countries. The economies of time in terms of cost are exhausted whereas it is assumed that the economies of time in terms of better more durable products are never exhausted (at least not within the time interval included in the simulations).

Inserting the above assumptions into the CC function it now becomes:

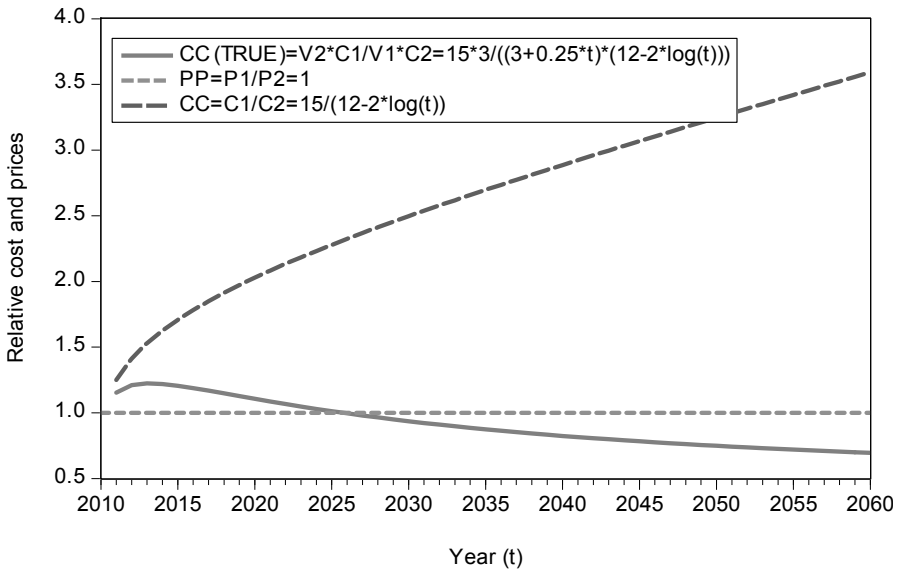
$$CC = \frac{a_1}{a_2 - b_2 \log T} \quad (10)$$

Whereas the real or true CC function looks as follows:

$$CC_{true} = \frac{c_1^t / V_1^t}{c_2^t / V_2^t} = \frac{V_2 c_1}{(V_0 + d_1 T) (a_2 - b_2 \log T)} \quad (11)$$

Equations 10 and 11 are drawn for the particular parameter values as used previously in the simulations, additionally assuming that V in both countries is 3 years and that every year Country 1 discovers a new product with a quarter of a year longer life. Since people do not internalize the durability dimension of the good into their optimization behavior, the product variant from Country 2 looks more attractive than it is. A specific simulation of this situation with the above mentioned parameter values is shown with Figure 5. Country 1's product is relatively expensive compared to Country 2's. However, taking into account the learning taking place on durability in Country 1, in fact product 2 is the more expensive one and increasingly so over time. However, in international trade as before consumers trade comparing the CC with the PP line – hence throughout the period depicted Country 2 enjoys comparative advantage. Incorporating the true welfare - the situation should be the reverse and Country 1 has again the long run comparative advantage. However, in this situation that potential is never realized.

Figure 5. The cost of free trade when durability is added as a dimension to the base model.



7. Policy scenarios for the extended model

In this section the implications of the same policy scenarios as discussed in Section 4 are briefly touched upon in relation to the extended model in Section 5. However, it should be immediately quite obvious that most of the traditional policy instruments will be futile and have little effect in reversing the situation as just described.

Table 2. Policy scenarios in the extended continuous time model

Policy	CS	ΔCS (ct model)
Free trade	-86.88	-
Tariff, 10%	-74.88	+14%
Subsidy, 10%	-73.70	+15%
R&D Subsidy	-89.36	-3%
R&D Subsidy tied to NTBs/standards	5.17	+106%
Policy that target demand-side (consumers fully internalize V)	0	+100%

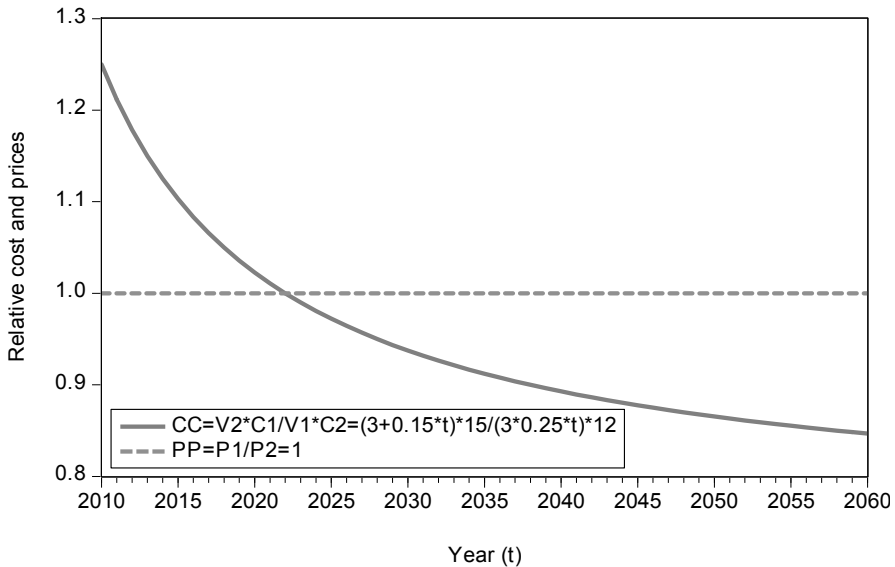
Table 2 summarizes the results³. Free trade is now harmful for global welfare and the cost are born by the consumers in Country 1 since they would be better off without trade. The costs are sizeable according to these calculations although again could we not attach much importance to the absolute size of these numbers. However, compared to the more conventional gains from trade captured in Section 4 and working with outset in similar and not unreasonable parameter values the results do suggest that trade is quite harmful in this particular situation.

The next three rows in the table repeat the exercises of applying the 10% tariff, the 10% subsidy and the 10% improvement in the learning rate over time. Again is the situation analyzed from the perspective of Country 1. These instruments only have a small impact, the welfare improvements of using the tariff or ordinary production subsidy are minor and in the order of 14 – 15% (underestimated in the case of the tariff and vice versa for the subsidy as explained in Section 4). The R&D subsidy is counter-productive as it only impacts the implicit or true CC curve thereby increasing the loss from trade with a small factor of around 3%.

To correct the problem of durability other instruments are instead considered. One of the suggested policies is for Country 1 to exercise standards in trade negotiations with Country 2. For example, Country 1 can try to make Country 2's government use R&D subsidies that give firms incentives to develop more durable products and thereby also help make consumers internalize the problem (even though only very indirectly in this case). This particular scenario is depicted in Figure 6A.

3 Note that Table 2 only summarises the welfare effects using the approximation previously introduced of relying on Consumers' Surplus as the main barometer of welfare (hence ignoring the social cost-benefit aspects of each instrument and also ignoring production and consumption distortion losses identified in traditional trade policy analysis).

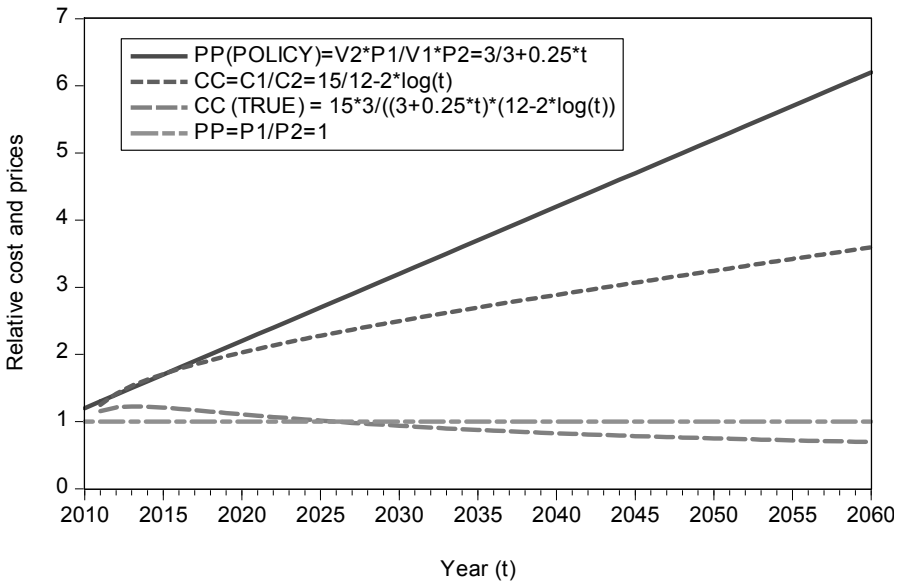
Figure 6A. Policy Scenario 1: Country 1 imposes a standard on Country 2 that make firms in Country 2 start learning on durability via an R&D government subsidy.



The simulations here assume again that $a_1 > a_2$ so that country 2 has comparative advantage on cost throughout the period. Country 1 is initially importing the good as the two countries start out with a product of the same durability (e.g. $V_0 = 3$), hence Country 2 has initial comparative advantage due to lower production cost. However, this advantage gradually erodes given the assumption that Country 1 again has innate comparative advantage, but now learning quicker on durability, whereas Country 2 also learns on this aspect of the product due to the R&D subsidy, but at a slower rate than in Country 1. Hence eventually comparative advantage shifts to Country 1. Many different parameter values would render similar results and it is not important which country has comparative advantage. The most important assumption in this scenario is that it is possible indirectly to affect consumption priorities about durable products in both countries by incentivizing a different learning path in Country 2. In this situation as shown with the simulation of CS in Table 2 are there significant positive gains from trade and the improvement in welfare compared to the original free trade situation is 106%. Aiming to affect the standards of Country 2 as a condition for engaging in trade is the best policy if other issues besides cost are at stake. This paper is just one example of such other issues that are taken for given in one country but not necessarily in another country. (And it is compared also with the next policy scenario, the only policy considered here with a positive welfare outcome for consumers in both countries.)

An alternative policy is also considered in Country 1 – which instead aims at making consumers in Country 1 fully internalize the problem about durability into their preferences (for example by giving them a consumption subsidy that dictates certain standards and requirements to the products purchased or by implementing legislation that dictates certain formal requirements when advertising products⁴). This alternative policy scenario is shown with Figure 6B. As consumers are made to internalize on their preferences the difference in durability, the *PP* curve is upward sloping over time. In this particular situation all trade would cease and welfare will improve – e.g. the CS from trade is 0 whereby compared to the baseline scenario in the model with durability there is a 100% recovery of the loss from free trade.

Figure 6B. Policy scenario 2: Country 1 makes consumers fully internalize the problem of durability hence their PP curve (reference for trading along CC curve) becomes upward sloping over time.



8. Discussion and conclusions

The paper develops a simple dynamic model to investigate the infant industry problem in the perspective of a lead market or new to the world technology. The research is driven by the question whether and how such markets or technologies can be best incentivized for global welfare, when other issues besides price or cost are at

⁴ A case in point are the legal requirements in the EU to advertise along with price and other product specifications full information to the consumer about the energy efficiency of white goods at the point of purchase.

stake. The particular concern for the non-tariff barrier or standard investigated in this paper, is one of the dimensions of sustainability, namely the durability of goods.

The base model is developed and used to investigate the accuracy of using solely consumers' surplus in continuous time as a barometer for welfare. It is shown that this welfare measure is only an approximation to the true welfare measures developed for the general equilibrium model in discrete time. Here it is adopted as a fair approximation that can be used to compare welfare aspects of different policy instruments and especially on the consumers' side of welfare.

The classical instruments of tariffs and subsidies are compared with the more recent R&D instrument in the base model. In the base model where firms only learn and compete in cost, it is shown that the R&D subsidy could be a superior instrument as it incentivizes learning compared to the traditional instruments that mainly work to twist prices and shift rents across countries. The classical instruments therefore have none or few beneficial effects in a global welfare perspective. While the global welfare benefits of the R&D instrument hinges also on the cost-benefit ratio of the instrument itself which is an unknown factor in the model framework provided and empirical evidence in this area is largely absent.

With outset in the developed base model the paper has set up the necessary analytical framework to investigate the research question of interest, being what the best trade policy instrument would be in the presence of other dimensions of sustainable consumption such as the durability of goods. At the early stages of research this question was identified through highly relevant and recent trade policy cases such as the international trade disputes in solar panels involving stakeholders and producer firms in the US, Germany and China among several other. However, the problem is perhaps even more relevant within one of the most R&D intensive and traded goods sectors today which is electrical and electronic goods. The simple model is extended to include a dimension of durability of goods in terms of the longevity of their life. This has been an ignored factor in the literature when the cost and prices of goods are evaluated and may be more important to include especially when goods are compared across large distances due to differences in factors that affect preference and learning for durability such a climate, political-economy or institutional factors including differences in consumer cultures.

This simple set-up is used to investigate what happens to welfare adopting the same policy instruments in the base model. It is shown that under the new and extended model assumptions trade does in itself lead to high cost for consumers. Instruments such as tariffs and subsidies only have very minor effects on altering this situation. Surprisingly the ordinary R&D subsidy is counterproductive as it only works to increase the gap in the learning priorities of the two countries. All these effects arise due to the assumption that consumers fail to internalize the characteristic of dura-

bility when making their consumption choices. Hence they will rather import apparently cheaper goods from abroad than buy domestic goods with a longer life.

Finally it is shown that in this set-up and under these assumptions the best policy will either be to make consumers internalize the characteristic by using other non-trade related instruments such as setting domestic standards in combination with incentives such as subsidies. A much superior trade policy in this case is to make standards a precondition for international trade. This is shown with a practical example in the model where the government in the home country (Country 1) induces the government in the other country to use instruments that make their firms shift or change their learning priorities. Assuming the other country will catch up and learn quickly on this new aspect of the good, the positive benefits on global welfare of including such standards into trade negotiations can be substantial according to the specific simulation results.

The research has a number of limitations given the assumptions of the modeling framework. For example, the results obtained may be determined by the specific values applied with the simulations. However, the conclusions will not be altered by changing the parameter values as long as the main assumptions of the situation or policy scenarios investigated are the same. But if the assumptions about the relative size of the parameters in the two countries change different results could be obtained. One way to see this would be to investigate the consequences of implementing the same policies in the other country. The conclusions here would not be entirely the same as Country 1 is the faster learner whereas Country 2 has the initial advantage. Future research could investigate this issue and compare a wider range of issues than was possible given the necessary limitations of investigating in a short research paper what must be considered a relatively novel area of research in international trade policy.

Exhibit 2 draws up what would be some of the main assumptions in the present model framework that could reduce the external validity of the research. In future research it would be desirable to make the results applicable to a broader range of cases and industries and perhaps more realistic real world circumstances. A major problem of the assumptions is that the absence of firms, profits and market power removes from the model the potential significance hereof on global welfare developments over time. The assumptions as listed in Exhibit 2 also together corroborate to prevent the increasing returns associated with such market power that are likely involved in learning in lead markets to take full impact in this model (e.g. creating winner-takes-all type of markets).

Alleviating these assumptions would make the race a much more finite race among a limited number of countries and producers as is often the case in real world industries. Lead players will very quickly outrun laggards and this as the paper shows would be the cause of major and additional welfare problems. The results obtained here are almost entirely dependent on the assumption that there continues to be a

small production platform present in the other country with at least one producing firm during lapses of time when there is no market demand for the product in question from that country. In combination with the fact that it is assumed that firms learn automatically in time rather than through cumulative output (thereby downsizing the importance of economies of scale within each time period) also corroborates to produce this result. Alleviating these assumptions would favour the outcompeting of potential producers and especially from countries or firms without immediate access to economies of scale and thereby also dynamic economies of scale (as are termed economies of time in this paper not to confuse up with static economies of scale). This only shows the importance of the size of the initial market; or in the case of small countries the initial market access in terms of global outreach for lead market products.

Exhibit 2. Main model assumptions.

Model aspect	Assumptions	More plausible	Consequences
A - Economies of scale	None	Increasing returns	Market power Long term rents
B - Country size	Symmetric	Asymmetric	Shifts natural comparative advantage in combination with A and C away from small countries
C – Learning-by-doing	Automatic in time	Cumulative in output	Attenuates A

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Appendix

1. The case of free trade in discrete time

Figure A1.

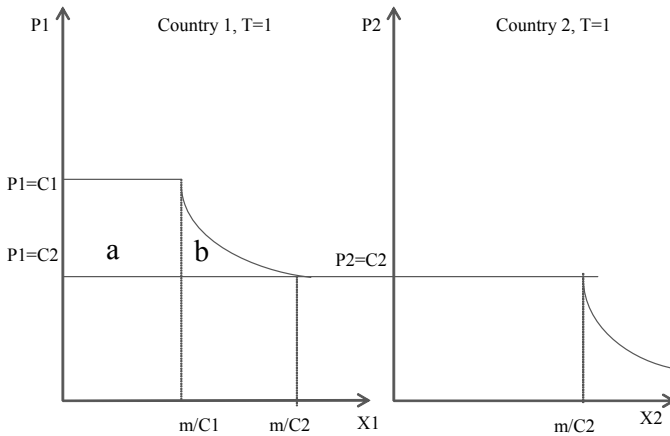


Figure A1 shows the situation in discrete time at time $T = 1$ in Country 1 and Country 2 under the Scenario depicted with Figure 2 (continuous time). The demand curves take the usual form under the assumptions of perfect substitutes (see Varian, 2010, Page 99). At this point in time Country 2 has comparative advantage as $C_2 < C_1$ and hence Country 1 is an importer. The general equilibrium analysis of the gains from trade is highly simplified due to these assumptions. The welfare gain from free trade is captured in Country 1 with the increase in consumers' surplus (CS) represented with the areas *a* and *b*. The assumptions about perfect substitutes and perfectly elastic supply simplifies the calculations of the gains from trade, in fact there is only a CS arising in this simple model because there is the possibility to trade. Without trade there would be no CS at all. As time passes in the model (re. Figure 2) C_1 will be decreasing at a faster rate than C_2 until the learning functions cross and relative prices become 1. Hereafter the gains from trade will start to accrue to Country 2. Here in the Appendix it is shown how to calculate the exact size of the CS in each period (discrete time). This exact measure is compared with the approximation using the areas in Figure 2 as explained in Section 4. The main difference is that the approximation only accounts for the area *a* whereas the exact measures account for both areas *a* and *b*. In the absence of trade both areas would be similar to the ordinary dead weight loss of a prohibitive tariff.

$$\text{Area } a: 1 - \frac{c_2}{c_1}$$

$$\text{Area } b: \frac{1}{2} \frac{c_1}{c_2} + \frac{1}{2} \frac{c_2}{c_1} - 1$$

$$\text{Areas } a + b: \frac{1}{2} \frac{c_1}{c_2} - \frac{1}{2} \frac{c_2}{c_1}$$

$$\text{Total gains from trade: } \sum_{2010}^{2060} \left[\frac{1}{2} \frac{c_1}{c_2} - \frac{1}{2} \frac{c_2}{c_1} \right]$$

2. The case of Country 1 levying a tariff on imports from Country 2

Figure A2.

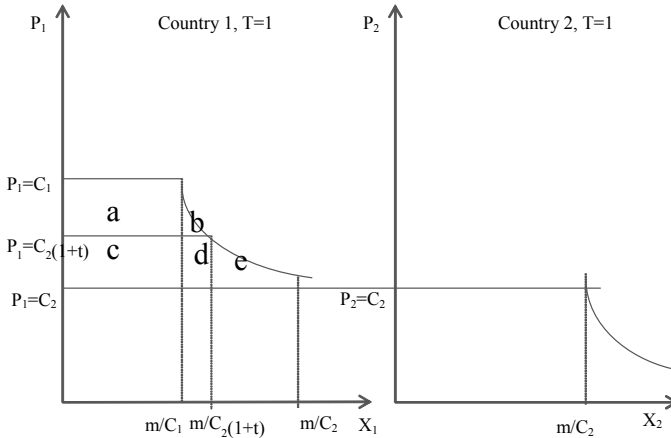


Figure A2 shows the situation when Country 1 levies a tariff t on imports from Country 2. CS goes down with the areas c , d and e . However, areas c and d are recovered by the instrument. Hence the area e represents in this case the dead-weight loss of the tariff.

$$\text{Areas } a + b: \frac{1}{2} \frac{c_1}{c_2(1+t)} - \frac{1}{2} \frac{c_2(1+t)}{c_1}$$

$$\text{Areas } c + d: \frac{t}{(1+t)}$$

$$\text{Area } e: \frac{1}{2}t - \frac{1}{2} \frac{t}{(1+t)}$$

$$\begin{aligned} \text{Total welfare with tariff: } & \sum_{2010}^{2019} \left[\frac{1}{2} \frac{c_1}{c_2(1+t)} - \frac{1}{2} \frac{c_2(1+t)}{c_1} + \frac{t}{(1+t)} \right] \\ & + \sum_{2031}^{2060} \left[\frac{1}{2} \frac{c_1}{c_2} - \frac{1}{2} \frac{c_2}{c_1} \right] \end{aligned}$$

3. The case of Country 1 paying a subsidy to its producers

Figure A3.

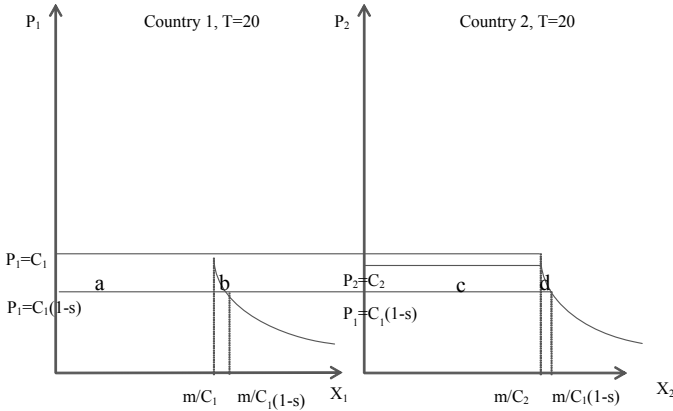


Figure A3 shows the case of the production subsidy. The subsidy (given to producers in Country 1 by Government 1) will only start to take effect for private production once the subsidized price in Country 1 falls under the price level in Country 2 (exactly at the point where Country 1’s dynamic comparative advantage is realized and with the subsidy a bit quicker than in the absence of the subsidy). CS in the two countries is increased with the areas *a*, *b*, *c* and *d*. Areas *a* and *c* will be used up by the cost of the instrument. (In fact Area *c* will be smaller than the subsidy most of the time due to a production distortion loss.) The net welfare benefit of the subsidy will be represented by the two triangles *b* and *d* minus the production distortion loss on *c*. Effectively there will be a transfer of income from Country 1 to Country 2.

Area *a*: s

Area *c*: $1 - \frac{c_1(1-s)}{c_2}$

Area *b*: $\frac{s}{(1-s)} - s$

Area *d*: $\frac{1}{2} \frac{c_2}{c_1(1-s)} + \frac{1}{2} \frac{c_1(1-s)}{c_2} - 1$

Total welfare with subsidy: $\sum_{2010}^{2018} \left[\frac{1}{2} \frac{c_1}{c_2} - \frac{1}{2} \frac{c_2}{c_1} \right]$

$+ \sum_{2019}^{2030} \left[s + 1 - \frac{c_1(1-s)}{c_2} + \frac{s}{(1-s)} - s + \frac{1}{2} \frac{c_2}{c_1(1-s)} + \frac{1}{2} \frac{c_1(1-s)}{c_2} - 1 - 2s \right]$

$+ \sum_{2031}^{2060} \left[\frac{1}{2} \frac{c_1}{c_2} - \frac{1}{2} \frac{c_2}{c_1} \right]$

4. The case of Country 1 paying an R&D subsidy to its producers

In this case welfare can be assessed as in the case of free trade since the R&D instrument does not affect relative prices directly as in the case of the tariff and the production subsidy. It is assumed that the cost of the R&D subsidy is equivalent to its learning impact, e.g. if the learning rate improves with rds , the cost of the instrument is $rds\%$ of income spent on the good per year.

$$\textit{Total welfare with R\&D subsidy} \sum_{2010}^{2060} \left[\frac{1}{2} \frac{c'_1}{c_2} - \frac{1}{2} \frac{c_2}{c'_1} - rds \right]$$