LICOS Centre for Institutions and Economic Performance

Centre of Excellence

LICOS Discussion Paper Series

Discussion Paper 276/2011

On Butterflies and Frankenstein: A Dynamic Theory of Regulation

Johan F.M. Swinnen and Thijs Vandemoortele

Katholieke Universiteit Leuven

LICOS Centre for Institutions and Economic Performance
Waaistraat 6 – mailbox 3511
3000 Leuven

BELGIUM

TEL:+32-(0)16 32 65 98
FAX:+32-(0)16 32 65 99
http://www.econ.kuleuven.be/licos

On Butterflies and Frankenstein:
A Dynamic Theory of Regulation

Johan F.M. Swinnen and Thijs Vandemoortele

LICOS Centre for Institutions and Economic Performance

& Department of Economics

University of Leuven (KUL), Belgium

Abstract

There are major differences in regulation among various countries. A particular case is the difference between the EU and US in regulating biotechnology. We develop a formal and dynamic model of government decision-making on regulation. We show that minor differences in consumer preferences can lead to important and persistent regulatory differences, and that temporary shocks to preferences can have long-lasting effects. This hysteresis in regulatory differences is shown to be caused by producer protectionist motives. We argue that this model may contribute to explain the difference between EU and US biotechnology regulation.

The authors gratefully acknowledge useful comments from Rob Paarlberg, David Zilberman, Chris Gilbert, Justus Wesseler, Jo Reynaerts, and seminar participants in Ravello, Leuven, and Wageningen. This research was financially support by Research Foundation – Flanders (FWO) and the K.U.Leuven Research Fund (EF).

On Butterflies and Frankenstein:
A Dynamic Theory of Regulation

Johan F.M. Swinnen and Thijs Vandemoortele

"A small blue butterfly sits on a cherry tree in a remote province of China. As is the way of butterflies, while it sits it occasionally opens and closes its wings. It could have opened its wings twice just now; but in fact it moved them just once – and the miniscule difference in the resulting eddies of air around the butterfly makes the difference between whether, two months later, a hurricane sweeps across southern England or harmlessly dies out over the Atlantic."
Smith (1991, p247)

"If they want to sell us Frankenfood, perhaps it's time to gather the villagers, light some torches and head to the castle."
Lewis (1992)

1 Introduction

In many cases regulation and standards are introduced when preferences change (e.g. regarding social issues), environmental conditions change (e.g. climate change) or when new technologies become available (e.g. nuclear energy, genetic modification (GM)). These changes induce new policy questions to either allow (approve) new technologies or not; to try to change behavior in response of environmental and social concerns, or not.

There are major differences in technology regulation among countries, reflected in the abundance of differences in labor standards, food safety and quality standards, environmental standards, etc. A particular case is the difference in GM technology regulation between the EU and the US. Since the end of the 1990s, EU legislation has put a de facto moratorium on the approval of GM products whereas the US has chosen to rely on pre-existing laws considering GM products as substantially equivalent to conventional ones (Sheldon 2002). This difference has traditionally been attributed to either differences in consumer preferences, or to trade protectionist motives. Neither of these arguments provides a satisfactory explanation – at least not in isolation – and lacks a dynamic perspective.

The ‘different consumer preferences’ argument advances that European consumers are more risk averse and concerned with food safety, and therefore distrust biotechnology more, whereas US consumers are indifferent toward GM products (Curtis et al. 2004). However, according to Paarlberg (2008), consumers on both sides of the Atlantic tend to dislike GM technology. Additionally, this difference in EU and US consumer preferences is not evident from a historical perspective either. There has been an important shift in the difference between consumer and environmental protection policies in the EU and US, as illustrated by Vogel (2003): “*[f]rom the 1960s through the mid 1980s American regulatory standards tended to be more stringent, comprehensive and innovative than in either individual European countries or in the EU. However, since around 1990 the obverse has been true; many important EU consumer and environmental regulations are now more precautionary than their American counterparts.*” Moreover, surveys on consumer attitudes with respect to biotechnology that illustrate these differences in consumer preferences are endogenous to GM regulation. In countries where GM products are available consumer preferences may shift in favor of this technology, while inversely consumers may distrust GM technology more in countries where GM products have been banned.

A related argument is that European consumers have only limited confidence in national public bodies. Trust in regulatory authorities is significantly higher in the US than in Europe, which is said to explain why citizens’ demands for GM regulation are stronger in Europe (Gaskell et al. 1999; Nelson 2001). However, this would – somewhat paradoxically – imply that European consumers demand more regulation from authorities in which they have lower trust.

A second argument focuses on the interests of the agrochemical and seed industry, and farmers. Biotechnology regulation is said to support agrochemical companies, either by creating higher returns on investment in biotechnology or by protecting against the comparative disadvantage from not investing in biotechnology (Graff and Zilberman 2004). In this view, the European ban of GM products serves as a protectionist non-tariff barrier to trade (Lapan and Moschini 2004), and protects the European agrochemical firms who are dominant in the traditional crop-protection market (Anderson and Jackson 2006; Graff and Zilberman 2007). Additionally, Anderson et al. (2004) argue that EU farmers lobby in favor of GM regulation because farmers in countries such as the US and Brazil have a comparative advantage applying biotechnology. Therefore, it is argued, it is rational for EU farmers to support regulation that restricts the use of biotechnology. However, EU farmers were initially less opposed to GM technology according to Bernauer (2003), and US and EU GM regulations were initially moving in the same direction (Vogel 2001). These observations seem to contradict the static trade protection argument.

There exists an extensive literature on the welfare effects of biotechnology and biotechnology regulation. The effect of efficiency-enhancing biotechnology on social welfare depends crucially on the extent of consumer aversion to GM products (Moschini 2008).[1] Studies also show that the welfare effects of biotechnology regulation are complex. Lapan and Moschini (2004) and Veyssiere and Giannakas (2006) show that the welfare effects of GM regulation depend on consumer preferences, segregation

[1] The early literature ignored this potential consumer aversion and estimated the welfare impact of biotechnology innovations measuring traditional consumer and producer surpluses (Alston et al. 1995). Even when accounting for market power of innovating biotechnology companies (Moschini and Lapan 1997), studies found considerable welfare gains from the introduction of new GM products (Falck-Zepeda et al. 2000) that were shared among consumers, farmers, and agro-chemical innovators (Moschini et al. 2000). Recent studies which integrate consumer aversion to GM products find that the welfare impact of biotechnology is ambiguous (Fulton and Giannakas 2004; Lapan and Moschini 2004; Lence and Hayes 2005; Sobolevsky et al. 2005).

costs, efficiency gains by the GM technology, and the market power of the innovating companies. Fulton and Giannakas (2004) demonstrate that the introduction of GM products and the regulation of biotechnology may have different welfare effects on different groups in society – such as consumers, farmers, seed companies, and innovating life science companies. This inherent rent distribution may induce different preferences for biotechnology regulation and conflicting pressures on governments which demands a political economy analysis (Josling et al. 2003).

Therefore, building on our previous work on the political economy of standards and regulation (Swinnen and Vandemoortele 2008; 2009a; 2009b), this paper develops a general and dynamic political economy model of technology regulation. Our framework allows to combine both arguments of differences in consumer preferences and producer protectionism to provide a more nuanced explanation for the different biotechnology regulations in the EU and the US, and why this difference may persist.

First, our formal model shows that there exists a critical level of consumer preferences below which no technology regulation is imposed. Hence small variations in consumer preferences may determine whether a country imposes technology regulation or not. If consumer preferences are identical between countries and constant over time, countries adopt the same technology regulation and stick to the status quo independent of which technology regulation was initially imposed.

Second, when consumer preferences are different between countries and constant over time, different technology regulations may be imposed, and these differences may persist because of changing producer interests. If a government chooses to allow a technology, it continues to allow that technology independent of what the other government decides. If a government however chooses to ban that technology, it may continue to do so in the long run depending on the relative impacts of both regulatory options on consumers and producers, and their political power. A larger political power of producers leads to a larger range of situations where the technology is banned in the long run, even though consumers prefer allowing it. In these situations producer interests are translated into policy persistence.

Third, we show that even a temporary difference in consumer preferences between countries, a ‘butterfly’, may create a difference in technology regulation that may persist after the difference in consumer preferences has disappeared. We show that this hysteresis[2] in technology regulation is driven by producer protectionist motives.

Our work is related to several other papers on hysteresis in socio-economic behavior and policy. For example, Dixit (1989a) shows that output price uncertainty leads to investment hysteresis for certain ranges of entry and exit costs, and Dixit (1989b) and Baldwin and Krugman (1989) demonstrate that exchange rate fluctuations create similar hysteresis in firms’ export decisions. Hysteresis is also shown to exist in labor markets where firing and hiring costs lead to persistence in unemployment (e.g. Lindbeck and Snower 1986; Belke and Göcke 1999). Our model is different from these contributions, both in the source of variation (small consumer preference variations) that triggers technology investment (or not), and in the hysteresis effect (persistence in technology regulation due to producer protectionism).[3]

Our paper is structured as follows. Section 2 advances a general and dynamic political economy model of technology regulation. Sections 3, 4, and 5 apply this model to three different cases. In the first case (Section 3), consumer preferences are identical

---

[2] Hysteresis is defined as *“permanent effects of a temporary stimulus”* (Göcke 2002) and originates from physics and magnetism (Cross and Allan 1988). See Göcke (2002) for an overview of various concepts of hysteresis as applied in economics.

[3] Our paper is also linked to research on path-dependence in technical standards and technical lock-in by historical events (Arthur 1989). This type of lock-in is driven by network externalities, increasing returns to adoption, or learning by doing. See e.g. David 1985; Farrell and Saloner 1985; Cowan 1990; Puffert 2002 for some historical cases.

between countries and constant over time. In the second case (Section 4), consumer preferences are different between countries and constant over time. In the third case (Section 5 – the 'butterfly' case), consumer preferences are only temporarily different between countries. Section 6 discusses the implications of our model, and Section 7 extends the model in several directions. Section 8 concludes.

2 The Political Economy of Technology Regulation: A Dynamic Model

Assume two identical open economies $k = A, B$, with between them symmetric transportation costs (which could be small, but positive). In both countries we consider the same sector in which one product is produced and consumed. Two production technologies can be applied to create this product. The technologies differ in their cost-efficiency, and consumers have some aversion to the 'cheap' technology. All consumers rank products manufactured with the cheap technology as being of lower quality than products produced with the 'expensive' technology, but are heterogeneous in their willingness to pay for this quality difference. One example is child labor – which is cheap – but consumers object to its use. Another example is the installation of expensive catalytic converters that, as preferred by consumers, reduce carbon dioxide emissions. A last example is conventional farming that uses non-GM seed versus biotechnology that applies GM seed. Using biotechnology is cheaper (Falck-Zepeda et al. 2000; Lapan and Moschini 2007), but consumers have some aversion to GM products (Curtis et al. 2004).

Technology Regulation and Standards

In every period $t = 1, 2$, each country k's government has to decide whether to approve the cheap technology or not by setting a standard s_t^k. We assume that there are only two possible levels (high and low) of this standard, i.e. $s_t^k \in \{s_L, s_H\}$ with $s_H > s_L$, where s_L refers to a baseline safety and/or quality requirement satisfied by both technologies (see also Moschini et al. 2008). If the government sets $s_t^k = s_H$, the cheap technology is prohibited in country k at time t.

All domestic producers have to comply with the standard – whether they produce for the home or foreign market – and equally all foreign producers who export to this country.[4] We assume that only the government can guarantee consumers that a good has been produced with the expensive technology.[5] We abstract from government enforcement or credibility issues in the implementation of the regulation.

Producers

We assume that production is a function of a sector-specific input factor that is available in inelastic supply. All profits made in the sector accrue to this specific factor. There are at least two firms active in each country, and firms compete on prices. Aggregate producer profits at time t in country k are

$$\Pi_t^{p,k}\left(s_t^k\right) = \max_{p_t^k}\left\{x_t^k \cdot \left[p_t^k - c_t^k\left(s_t^k, s_{t-1}^k\right)\right] + L\right\}, \qquad (1)$$

where p_t^k is the price of the good; x_t^k is the quantity produced; $c_t^k\left(s_t^k, s_{t-1}^k\right)$ is the marginal cost; and L is the sector-specific factor owners' total labor income, realized in some other sector(s).[6] Following Amacher et al. (2004) and consistent with Spence

---

[4] These assumptions are consistent with biotechnology regulation. Regulation on domestic producers prohibits the production of GM crops, independent of whether they are eventually sold on domestic or on foreign markets.

[5] This implies that a producer who produces according to s_H is not able to market his good as a high quality product in a country where the government allows the use of the cheap technology (s_L), although the producer is allowed to sell his product on that market $(s_H > s_L)$.

[6] See also Grossman and Helpman (1994). This labor income ensures that producers' welfare is positive and their lobbying contributions credible.

(1977), Dixit (1980) and Dong and Saha (1998), we use a specific form for the cost function:

$$c_t^k\left(s_t^k, s_{t-1}^k\right) = b\left(s_t^k\right)^2 + a\left(s_t^k - s_{t-1}^k\right)^2, \tag{2}$$

where a and b are positive parameters. The first term, $b\left(s_t^k\right)^2$, represents the 'cost of quality'. As is typical in the vertical differentiation literature, it is a quadratic term: the marginal cost function is increasing and convex in the level of the standard (see e.g. Ronnen 1991; Valletti 2000). The technology allowed under s_H is more expensive than under s_L: $b\left(s_H\right)^2 > b\left(s_L\right)^2$. The second term, $a\left(s_t^k - s_{t-1}^k\right)^2$, represents the 'investment cost' which is an increasing and convex function of the difference between the standard of the current period and the standard of the previous period. If governments switch regulation between periods, producers need to adjust to the new regulation and incur a one-period increase in their marginal cost. This cost component can be interpreted as a capacity investment along the lines of Spence (1977) and Dixit (1980), which depends on the current and previous periods' regulations. All other production costs are normalized to zero.

We assume that $bs_L > a\left(s_H - s_L\right)$ to ensure that producing under the low cost technology s_L is cheaper than under the expensive technology s_H, even when producing under s_L involves an investment cost of switching from s_H to s_L.[7]

[7] Given that the expensive technology was in use before, producing with the expensive technology costs bs_H^2, whereas producing with the cheap technology requires investment and costs $bs_L^2 + a\left(s_H - s_L\right)^2$. The former costs are larger than the latter if $b\left(s_H + s_L\right) > a\left(s_H - s_L\right)$, which is true under our assumption.

Consumers

We impose a vertical differentiation representation of heterogeneous consumer preferences based on Spence (1976), Mussa and Rosen (1978) and Tirole (1988). The underlying assumption is that if products with both technologies were available at the same price, all consumers would choose the high standard product. Individuals in country k and period t consume at most one unit of the good and their preferences are described by the following utility function:

$$u_i = \begin{cases} \phi_i s_t^k - p_t^k & \text{if consumer } i \text{ buys the good with standard } s_t^k \text{ at price } p_t^k \\ 0 & \text{if consumer } i \text{ does not buy,} \end{cases} \tag{3}$$

where ϕ_i is consumer i's preference parameter.[8] Consumers with higher ϕ_i have a higher willingness to pay for a product of higher quality, i.e. with a more stringent standard s_t^k. Consumers with $\phi_i < p_t^k / s_t^k$ do not consume the product. We assume that ϕ_i is uniformly distributed over the interval $\left[\phi_t^k - 1, \phi_t^k\right]$ with $\phi_t^k \geq 1$ and $i \in \left\{1, \ldots, N_t^k\right\}$. The number of consumers N_t^k is constant over time and identical between countries, i.e. $N_t^k = N$. The aggregate demand function

$$D_t^k\left(p_t^k, s_t^k\right) = N\left(\phi_t^k - p_t^k / s_t^k\right), \tag{4}$$

is presumed to be positive at market equilibrium. Consumer surplus in country k at time t is

$$\begin{aligned} \Pi_t^{c,k}\left(s_t^k\right) &= N \int_{p_t^k / s_t^k}^{\phi_t^k} \left(\phi_i s_t^k - p_t^k\right) d\phi_i \\ &= \frac{N s_t^k}{2}\left(\phi_t^k - p_t^k / s_t^k\right)^2 . \end{aligned} \tag{5}$$

[8] Our approach of modeling standards is common in the literature on vertical differentiation and GM technology (see for example Fulton and Giannakas 2004; Moschini et al. 2008) and consistent with the standard approach in the literature on minimum quality standards (see e.g. Ronnen 1991, Jeanneret and Verdier 1996, Valletti 2000).

The Government

The government maximizes a weighted sum of contributions from interest groups and social welfare as in Grossman and Helpman (1994; 1995). Social welfare $W_t^k\left(s_t^k\right)$ is defined as the sum of producer profits and consumer surplus:

$$W_t^k\left(s_t^k\right) \equiv \Pi_t^{p,k}\left(s_t^k\right) + \Pi_t^{c,k}\left(s_t^k\right). \quad (6)$$

Interest groups offer contributions to the government conditional on the policy choices made by the government. For simplicity, we assume that only producers are politically organized, and that an interest group cannot contribute to a foreign government.[9] The government's objective function, $\Pi_t^{g,k}\left(s_t^k\right)$, is

$$\Pi_t^{g,k}\left(s_t^k\right) \equiv \alpha C_t^{p,k}\left(s_t^k\right) + W_t^k\left(s_t^k\right), \quad (7)$$

where $C_t^{p,k}\left(s_t^k\right)$ is the 'truthful'[10] contribution scheme of the producers' interest group; and α represents its relative lobbying strength. Because the government's regulatory choice is dichotomous, this 'truthful' contribution function need only to comprise two numbers (see Grossman and Helpman 1995), i.e. the contributions associated with allowing the cheap technology, $C_t^{p,k}\left(s_L\right)$, or banning it, $C_t^{p,k}\left(s_H\right)$. We therefore define the 'truthful' contribution function of the producers' interest group as $C_t^{p,k}\left(s_t^k\right) \equiv \Pi_t^{p,k}\left(s_t^k\right)$.[11]

[9] This assumption makes the derivation simpler but is not essential for the results. Consumer interests still play a role but through the social welfare function in the government's objective function.

[10] The common-agency literature (e.g. Bernheim and Whinston 1986) argues that a truthful contribution schedule must reflect the true preferences of the interest group. In our political economy model this requires that interest groups set their lobby contributions in accordance with their expected profits linked to the different levels of the public standard.

[11] Our approach is equivalent to assuming that the producers' interest group represents only a small fraction of the population since its contribution scheme does not take into account the effects of regulation on consumer surplus (see also Lopez and Matschke 2006).

Time Framework

Each period consists of several sequential moves which take place simultaneously in both countries. At the beginning of each period, agents take stock of the existing technologies. The producers' interest group then proposes its contribution scheme to the government that chooses the standard. We assume that none of the agents takes future periods into consideration when making their decisions, i.e. they have a 'myopic planning horizon' (Göcke 2002). Upon the policy selection, producers make the necessary investment if the level of the standard has been altered between periods. Finally, the product(s) are produced and sold, and the producers' interest group makes its political contribution.

A government maintains the existing standard if and only if

$$\Pi_t^{g,k}\left(s_t^k = s_{t-1}^k\right) \geq \Pi_t^{g,k}\left(s_t^k \neq s_{t-1}^k\right), \tag{8}$$

or equivalently, if

$$\alpha C_t^{p,k}\left(s_t^k = s_{t-1}^k\right) + W_t^k\left(s_t^k = s_{t-1}^k\right) \geq \alpha C_t^{p,k}\left(s_t^k \neq s_{t-1}^k\right) + W_t^k\left(s_t^k \neq s_{t-1}^k\right). \tag{9}$$

In the remainder of this paper, we assume that only the expensive technology is available before period 1, and that therefore, by default, governments set their standard to $s_0^A = s_0^B = s_H$. This resembles a situation where the expensive technology is a conventional existing technology, and the cheap technology is an innovation that becomes available in period 1.[12]

In the next sections, we analyze the governments' regulatory choices under different scenarios: (i) when consumers in both countries have identical preferences, and

[12] We focus our analysis on the default option $s_0^k = s_H$ because this resembles best the issue of biotechnology regulation. Oppositely, for issues such as child labor or carbon dioxide emissions, the expensive technology is an innovation that becomes available in period 1. In these cases the default option is to allow the cheap technology, $s_0^k = s_L$, and conditions for regulatory hysteresis can be obtained in the same analytical framework as presented here.

these preferences are constant over time; (ii) with different consumer preferences between countries and preferences constant over time; and (iii) with a temporary difference in consumer preferences (the 'butterfly').

3 Case (i): Constant and Identical Consumer Preferences between Countries

Consider the case where consumers in both countries have identical preferences, $\phi_t^A = \phi_t^B$ for $t = 1, 2$, that are constant over time, $\phi_1^k = \phi_2^k$ for $k = A, B$. Under our assumptions, both countries are identical and with Bertrand competition and positive trade costs, there is no international trade. Thus, it suffices to look at one country.

Period 1

The cheap technology becomes available in both countries. Prohibiting its use $\left(s_1^k = s_H\right)$ results in a marginal cost of $c_1^k\left(s_H\right) = b\left(s_H\right)^2$, while allowing it $\left(s_1^k = s_L\right)$ requires investment to switch between regulations and the marginal cost is $c_1^k\left(s_L\right) = b\left(s_L\right)^2 + a\Delta^2$, where $\Delta \equiv s_H - s_L$. Under the assumption of Bertrand competition with at least two producers in each country, the market price equals the marginal cost of domestic producers, $p_1^k = c_1^k$, and $\Pi_1^{p,k}\left(s_H\right) = \Pi_1^{p,k}\left(s_L\right) = L$. Hence, producers are indifferent to the level of the standard in period 1.

Since price equals marginal cost, consumer surplus $\Pi_1^{c,k}$ is equal to $\frac{Ns_H}{2}\left(\phi_1^k - bs_H\right)^2$ for $s_1^k = s_H$ and $\frac{Ns_L}{2}\left(\phi_1^k - bs_L - a\frac{\Delta^2}{s_L}\right)^2$ for $s_1^k = s_L$. Consumers prefer to ban the cheap technology if $\Pi_1^{c,k}\left(s_H\right) - \Pi_1^{c,k}\left(s_L\right) \geq 0$, or equivalently, if

$$\phi_1^k \geq \phi_1^{c,k} = \frac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right) - a\frac{\Delta^2}{\sqrt{s_L}}\right], \tag{10}$$

where $\phi_1^{c,k}$ is the consumers' critical preference value in country k and period 1.[13] In other words, the consumers' critical preference value is the level of consumer preferences below which they prefer allowing the cheap technology.

As producers are indifferent, the government follows consumers' interests and the government's critical preference value $\phi_1^{g,k}$ coincides with the consumers' one. Thus, the government prohibits the cheap technology if and only if

$$\phi_1^k \geq \phi_1^{g,k} = \frac{1}{\left(\sqrt{s_H}-\sqrt{s_L}\right)}\left[b\left(s_H^{3/2}-s_L^{3/2}\right)-a\frac{\Delta^2}{\sqrt{s_L}}\right]. \tag{11}$$

Result 1: *With* $bs_L > a\Delta$ *and* $\phi_1^A = \phi_1^B$ *for* $k = A, B$ *:*

- $\forall \phi_1^k \in \left[\phi^{\min}, \phi_1^{g,k}\right[: s_1^k = s_L$;
- $\forall \phi_1^k \in \left[\phi_1^{g,k}, \infty\right[: s_1^k = s_H$;

with $\phi_1^{g,k} = \frac{1}{\left(\sqrt{s_H}-\sqrt{s_L}\right)}\left[b\left(s_H^{3/2}-s_L^{3/2}\right)-a\frac{\Delta^2}{\sqrt{s_L}}\right]$; $\phi^{\min} = b\left(s_H+s_L\right)+a\Delta$.

Result 1 implies that, given equal consumer preferences between countries, a critical preference value $\phi_1^{g,k}$ exists such that if consumer preferences ϕ_1^k are strictly lower than $\phi_1^{g,k}$, country k's government allows the cheap technology and the politically optimal standard is $s_1^k = s_L$. If ϕ_1^k is higher than $\phi_1^{g,k}$, the politically optimal standard is $s_1^k = s_H$ and the government prohibits the cheap technology. Result 1 thus shows that a minor

[13] Consumer surplus is convex in ϕ_t^k so $\Pi_t^{c,k}\left(s_H\right)-\Pi_t^{c,k}\left(s_L\right)=0$ has two solutions in ϕ_t^k. Our analysis is restricted to the domain $\phi_t^k \geq \phi^{\min} = b\left(s_H+s_L\right)+a\Delta$, where higher consumer preferences for quality lead to larger consumer surplus differences between consuming high and low quality.

difference in consumer preferences can lead to important differences in technology regulation.

A larger marginal ‘cost of quality’, represented by parameter b, results in a larger critical preference value of the government $\phi_1^{g,k}$, i.e. $\frac{\partial \phi_1^{g,k}}{\partial b} > 0$, and thus in a larger range of consumer preferences ϕ_1^k for which the cheap technology is allowed. This is intuitive: for larger b the additional ‘cost of quality’ of producing with the expensive technology is larger, so consumers pay relatively more for the high quality product. Thus consumer preferences need to be larger to support the prohibition of the cheap technology, which is reflected in a larger $\phi_1^{g,k}$.

A higher ‘investment cost’ of switching between regulations, represented by a larger value for a, reduces the government’s critical preference value $\phi_1^{g,k}$ $\left(\frac{\partial \phi_1^{g,k}}{\partial a} < 0 \right)$. With higher adjustment costs, consumers pay relatively more for the low quality product and are thus less in favor of allowing the cheap technology. This is represented by a lower critical preference value $\phi_1^{g,k}$ and thus a smaller range of ϕ_1^k for which $s_1^k = s_L$.

Period 2

The analysis of the political equilibrium in period 2 depends on the outcome in period 1, i.e. whether $s_1^k = s_H$ or $s_1^k = s_L$. Suppose first that $\phi_1^k \geq \phi_1^{g,k}$ such that $s_1^k = s_H$, i.e. the cheap technology is prohibited in period 1 (see Result 1). The political equilibrium is then the same as in the previous period, since in both periods $s_{t-1}^k = s_H$ and consumer preferences are constant. The government’s critical preference value in period 2 is the same as in period 1, $\phi_2^{g,k} = \phi_1^{g,k}$, and since $\phi_2^k = \phi_1^k$ it follows that $\phi_2^k \geq \phi_2^{g,k}$. Hence, if the political equilibrium is to prohibit the cheap technology in the first period and consumer preferences are constant, the ban on the cheap technology remains in the second period, i.e. $s_2^k = s_H$.

Second, suppose that $\phi_1^k < \phi_1^{g,k}$ such that $s_1^k = s_L$ and producers invest in the cheap technology in period 1. For the same reasons as in the previous period, producers are indifferent to the level of the standard. Because production costs and prices are different from period 1, the consumers' critical preference value – and also the government's critical preference value since producers are indifferent – changes with respect to period 1. Production under the cheap technology is less costly in period 2 as there is no longer a cost of switching $\left(c_2^k\left(s_L\right) = b\left(s_L\right)^2 < c_1^k\left(s_L\right)\right)$. Oppositely, production with the expensive technology is more costly because investment is necessary $\left(c_2^k\left(s_H\right) = b\left(s_H\right)^2 + a\Delta^2 > c_1^k\left(s_H\right)\right)$. The government's critical preference value in period 2 is then

$$\phi_2^{g,k} = \phi_2^{c,k} = \frac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right) + a\frac{\Delta^2}{\sqrt{s_H}}\right]. \qquad (12)$$

Comparing Equations (11) and (12) shows that $\phi_2^{g,k} > \phi_1^{g,k}$, and given constant consumer preferences, we find that $\phi_2^k < \phi_2^{g,k}$. Hence, if the cheap technology is allowed in the first period and consumer preferences are constant, the political equilibrium is to continue allowing the cheap technology in the second period, i.e. $s_2^k = s_L$.

Result 2: *With* $bs_L > a\Delta$, $\phi_t^A = \phi_t^B$ *and* $\phi_1^k = \phi_2^k$ *for* $t = 1,2$ *and* $k = A, B$ *:*

- $\forall \phi_t^k \in \left[\phi^{\min}, \phi_1^{g,k}\right[: s_t^k = s_L$ *;*
- $\forall \phi_t^k \in \left[\phi_1^{g,k}, \infty\right[: s_t^k = s_H$ *;*

with $\phi_1^{g,k} = \frac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right) - a\frac{\Delta^2}{\sqrt{s_L}}\right]$*;* $\phi^{\min} = b\left(s_H + s_L\right) + a\Delta$.

As summarized in Result 2, our dynamic political economy model shows that, if consumer preferences are identical between countries and constant over time, governments impose the same regulation in each period. Moreover, Result 2 shows that once a government has imposed a certain regulation while both technologies are available, it endorses the status quo. Result 2 also implies that minor differences in consumer preferences can lead to different technology regulations which persist over time.

4 Case (ii): Constant and Different Consumer Preferences between Countries

Without loss of generality, we assume that country A's consumers have higher preferences for quality than country B's consumers. Preferences remain constant over time: $\phi_1^A = \phi_2^A > \phi_1^B = \phi_2^B$.

Period 1

The analysis of the political equilibrium in period 1 is similar to that of case (i). The cheap technology becomes available in both countries. Prohibiting that technology results in a marginal cost of $c_1^k\left(s_H\right) = b\left(s_H\right)^2$, while approving it requires investment and the marginal cost is $c_1^k\left(s_L\right) = b\left(s_L\right)^2 + a\Delta^2$. Under the assumption of Bertrand competition with at least two producers in each country, the market price equals the marginal cost of the domestic producers, $p_1^k = c_1^k$, and $\Pi_1^{p,k}(s_H) = \Pi_1^{p,k}(s_L) = L$ if producers only supply their own domestic market.

The above outcome is always the case in period 1. Producers only supply their own market when standards are the same (see case (i)), but also when standards are different between both countries. Consider for example the situation where $s_1^A = s_H$ and $s_1^B = s_L$ such that $c_1^A(s_H) = b(s_H)^2$ and $c_1^B(s_L) = b(s_L)^2 + a\Delta^2$. First, it is prohibited for country B's producers to export to country A because they produce under a lower standard than what is required in country A $(s_1^B < s_1^A)$. Second, country A's producers are allowed to export to country B as they produce under a sufficiently stringent standard $(s_1^A > s_1^B)$. However, the inability of country A's producers to market their products as 'high quality' on country B's market prevents them from exporting since they incur a higher marginal cost $(c_1^A > c_1^B)$. In summary, producers do not export even with different standards because country A's producers cannot compete on country B's market based on marginal costs, while country B's producers cannot compete on country A's market based on technology standards. Therefore, producers only supply their domestic markets. This implies that $\Pi_1^{p,k}(s_H) = \Pi_1^{p,k}(s_L) = L$, and hence that producers are indifferent to the level of the standard in period 1.

Since the default situation is the same as in case (i) for both countries, the consumers' critical preference value $\phi_1^{c,k}$ is given by Equation (10) for $k = A, B$. From our assumption that $\phi_t^A > \phi_t^B$ follow three potential orderings of consumer preferences. First, if $\phi_1^B < \phi_1^A < \phi_1^{c,k}$, the analysis is the same as in case (i) and $s_t^k = s_L \ \forall t, k$. Likewise, if $\phi_1^{c,k} < \phi_1^B < \phi_1^A$, $s_t^k = s_H \ \forall t, k$. The third ordering, $\phi_1^B < \phi_1^{c,k} < \phi_1^A$, is the most interesting one and will be analyzed here.

It follows that country A's consumers prefer banning the cheap technology $\left(\phi_1^A > \phi_1^{c,A}\right)$ while country B's consumers are in favor of allowing it $\left(\phi_1^B < \phi_1^{c,B}\right)$. As producers are indifferent between the two technologies, the government's critical preference value is $\phi_1^{g,k} = \phi_1^{c,k}$ for $k = A, B$. Hence, country A's government bans the cheap technology $\left(s_1^A = s_H\right)$, while country B's government allows it $\left(s_1^B = s_L\right)$. This difference in regulation is due to different consumer preferences, and the differences in consumer preferences need not be large to result in different regulations. This is summarized in Result 3.

Result 3: *With* $bs_L > a\Delta$ *and* $\phi^{\min} < \phi_1^B < \phi_1^{c,k} < \phi_1^A$ *for* $k = A, B$*:*

- $s_1^A = s_H$ *and* $s_1^B = s_L$*;*

with $\phi_1^{c,k} = \dfrac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right) - a\dfrac{\Delta^2}{\sqrt{s_L}}\right]$*;* $\phi^{\min} = b\left(s_H + s_L\right) + a\Delta$.

Period 2

Given the outcome in period 1, the countries begin period 2 with different regulations, i.e. $s_1^A = s_H$ and $s_1^B = s_L$. This implies that in period 2 the marginal costs under selected standards are different between the countries. We first analyze country B's political equilibrium for each regulation selected by country A.

Suppose first that country A switches between regulations such that $s_2^A = s_L$ and $c_2^A\left(s_L\right) = b\left(s_L\right)^2 + a\Delta^2$. Country B's producers are then indifferent regarding the standard. Under $s_2^B = s_H$, country B's domestic market is protected from imports by a more stringent standard $\left(s_2^B > s_2^A\right)$ and country B's market price is $p_2^B = c_2^B\left(s_H\right) = b\left(s_H\right)^2 + a\Delta^2$. Under $s_2^B = s_L$, country B's producers competitively dominate country A's producers on prices since $c_2^B\left(s_L\right) = b\left(s_L\right)^2 < c_2^A\left(s_L\right)$, but these additional exports do not result in positive profits for country B's producers since they compete on prices. The market price in both countries is then $p_2^k = c_2^B\left(s_L\right)$. Hence, given $s_2^A = s_L$, $\Pi_2^{p,B}\left(s_H\right) = \Pi_2^{p,B}\left(s_L\right) = L$. Country B's consumers are however not indifferent, since the quality levels and corresponding market prices are different for $s_2^B = s_L$ and $s_2^B = s_H$. If the cheap technology is allowed, consumers benefit from lower prices than in period 1 as the investment cost has already been incurred by country B's producers, whereas if the expensive technology is imposed, investment is needed to switch. The consumers' critical preference value, $\phi_2^{c,B}$, is then given by Equation (12) which is higher than in period 1 (Equation (10)), $\phi_2^{c,B} > \phi_1^{c,B}$. In combination with constant consumer preferences and $\phi_1^B < \phi_1^{c,B}$, it follows that $\phi_2^B < \phi_2^{c,B}$. Country B's consumers thus prefer allowing the cheap technology. Since country B's producers are indifferent, the government of country B follows consumers' preferences and the political-economic optimum, given that $s_2^A = s_L$, is $s_2^B = s_L$.

Second, suppose that country A maintains its regulation such that $s_2^A = s_H$ and $c_2^A\left(s_H\right) = b\left(s_H\right)^2$. Country B's producers are then in favor of maintaining the status quo, i.e. $s_2^B = s_L$. Under $s_2^B = s_L$, country B's producers competitively dominate country A's producers on prices since $c_2^B\left(s_L\right) < c_2^A\left(s_H\right)$ and country A's product cannot be sold on the market of B as a high quality good. In contrast, with $s_2^B = s_H$, exports from A to B are allowed $\left(s_2^A = s_2^B\right)$ and cheaper $\left(c_2^A\left(s_H\right) < c_2^B\left(s_H\right)\right)$,[14] since country B's producers need to invest in switching technologies while country A's producers do not. Hence country B's producers are driven out of their own market with $s_2^B = s_H$, and therefore favor $s_2^B = s_L$. Country B's consumers are indifferent neither. With $s_2^B = s_L$, country B's domestic market price is $p_2^B = c_2^B\left(s_L\right)$, while for $s_2^B = s_H$, the domestic market price is $p_2^B = c_2^A\left(s_H\right)$ since imports from A are allowed and cheaper. With these prices, the consumers' critical preference value for country B in period 2, $\phi_2^{c,B}$, is

$$\phi_2^{c,B} = \frac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right)\right]. \tag{13}$$

Comparing Equations (13) and (10), one observes that $\phi_2^{c,B} > \phi_1^{c,B}$ and hence $\phi_2^B < \phi_2^{c,B}$ so that country B's consumers prefer to allow the cheap technology. As a result, since both country B's producers and consumers favor allowing the cheap technology, it is in the interest of country B's government to endorse this status quo, i.e. $s_2^B = s_L$, given that $s_2^A = s_H$.

To summarize, the political-economic optimum for country B's government is to continue its policy of allowing the cheap technology, i.e. $s_2^B = s_L$, irrespective of country A's regulation in period 2. Hence, once country B's government has chosen to allow the cheap technology, it will endorse the status quo in future periods and support the cheap technology, irrespective of the behavior of the other country's government. This policy persistence is summarized in the following result:

---

[14] This requires that transportation costs are smaller than the difference between $c_2^A\left(s_H\right)$ and $c_2^B\left(s_H\right)$. We assume that transportation costs are sufficiently small, such that we do not need to introduce them algebraically.

Result 4: *With* $bs_L > a\Delta$, $\phi_1^k = \phi_2^k$ *and* $\phi^{\min} < \phi_1^B < \phi_1^{c,k} < \phi_1^A$ *for* $k = A, B$*:*

- $s_2^B = s_L$, *independent of* s_2^A*;*

with $\phi_1^{c,k} = \dfrac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right) - a\dfrac{\Delta^2}{\sqrt{s_L}}\right]$; $\phi^{\min} = b\left(s_H + s_L\right) + a\Delta$.

Given this result, we only need to consider $s_2^B = s_L$ when evaluating country A's strategic response. If $s_2^A = s_L$, the marginal cost of country A's producers is $c_2^A\left(s_L\right) = b\left(s_L\right)^2 + a\Delta^2$ since they need to invest in switching. In contrast, country B's producers already made this investment and produce at $c_2^B\left(s_L\right) = b\left(s_L\right)^2$. In that case, profits of country A's producers are $\Pi_2^{p,A}\left(s_L\right) = L - aN\Delta^2\left[\phi_2^A - bs_L\right]$ if they wish to remain active in their own market since $p_2^A = c_2^B < c_2^A$ due to cheaper imports from country B. If $s_2^A = s_H$, country A's producers are protected from imports by a more stringent standard since $s_2^A > s_2^B$, such that under price competition $p_2^A = c_2^A\left(s_H\right) = b\left(s_H\right)^2$ and $\Pi_2^{p,A}\left(s_H\right) = L$. Accordingly, country A's producers always endorse the status quo in period 2, since

$$\Pi_2^{p,A}\left(s_H\right) - \Pi_2^{p,A}\left(s_L\right) = aN\Delta^2\left[\phi_2^A - bs_L\right] > 0. \qquad (14)$$

Country A's consumers may or may not favor the status quo in period 2. If $s_2^A = s_L$, consumers buy cheap but low quality imports and consumer surplus equals $\Pi_2^{c,A}\left(s_L\right) = \dfrac{Ns_L}{2}\left(\phi_2^A - bs_L\right)^2$. If $s_2^A = s_H$, consumers buy high quality at a high price, and $\Pi_2^{c,A}\left(s_H\right) = \dfrac{Ns_H}{2}\left(\phi_2^A - bs_H\right)^2$. Hence:

$$\Pi_2^{c,A}\left(s_H\right)-\Pi_2^{c,A}\left(s_L\right)=\frac{Ns_H}{2}\left(\phi_2^A-bs_H\right)^2-\frac{Ns_L}{2}\left(\phi_2^A-bs_L\right)^2, \tag{15}$$

which may be positive or negative and equals zero at the consumers' critical preference value, $\phi_2^{c,A}$, i.e.

$$\phi_2^{c,A}=\frac{1}{\left(\sqrt{s_H}-\sqrt{s_L}\right)}\left[b\left(s_H^{3/2}-s_L^{3/2}\right)\right]. \tag{16}$$

Comparing values (16) and (10) reveals that $\phi_2^{c,A}>\phi_1^{c,A}$. There are two situations according to the level of country A's consumer preferences, ϕ_2^A. First, if $\phi_1^{c,A}<\phi_2^{c,A}<\phi_2^A$, country A's consumers favor the status quo in period 2, i.e. $s_2^A=s_H$. As a result, it is optimal for country A's government to set $s_2^A=s_H$ since country A's producers also endorse the status quo.

In the second situation, $\phi_1^{c,A}<\phi_2^A<\phi_2^{c,A}$, country A's consumers are in favor of allowing the cheap technology in period 2 in contrast to the first period. The reason for this change in consumers' interests is that in period 2 the low quality good can be imported from country B at a lower price than in period 1 when it was still more expensive due to the investment cost. In this situation, a coalition switch takes place between period 1 and 2, since both producer interests (from being indifferent to favoring s_H) and consumer interests (from favoring s_H to favoring s_L) change.

Which regulation is then optimal for country A's government depends on the relative differences in producer profits and consumer surpluses between the two regulatory options, and the relative weight of producers' contributions in the government's objective function (α). Inserting Equations (14) and (15) into Equations (6) and (7) gives

$$\Psi=\left(1+\alpha\right)aN\Delta^2\left[\phi_2^A-bs_L\right]+\frac{Ns_H}{2}\left(\phi_2^A-bs_H\right)^2-\frac{Ns_L}{2}\left(\phi_2^A-bs_L\right)^2, \tag{17}$$

with $\Psi = \Pi_2^{g,A}(s_H) - \Pi_2^{g,A}(s_L)$. By definition of $\phi_2^{g,A}$, $\Psi = 0$ at $\phi_2^A = \phi_2^{g,A}$. Observe that the second and third term of Equation (17) together are identical to Equation (15) which equals zero at $\phi_2^{c,A}$. From Equation (14) it follows that $\Psi > 0$ at $\phi_2^A = \phi_2^{c,A}$. The derivative of Equation (17) with respect to ϕ_2^A is positive for $\phi_2^A > \phi^{\min}$:

$$\frac{\partial \Psi}{\partial \phi_2^A} > 0. \tag{18}$$

Combining these three findings, it follows that

$$\phi_2^{g,A} < \phi_2^{c,A}. \tag{19}$$

This inequality implies that for a certain range of consumer preferences, $\phi_2^A \in \left[\phi_2^{g,A}, \phi_2^{c,A}\right[$, lobbying by the producers' interest group is sufficiently powerful to induce country A's government to uphold the status quo even though consumers prefer to allow the cheap technology. For $\phi_2^A \in \left[\phi_1^{c,A}, \phi_2^{g,A}\right[$, the producers' interest group fails in pushing its agenda and the optimal decision for country A's government is to allow the cheap technology.

The value of $\phi_2^{g,A}$ depends on the political power of the producers' interest group, α. From Equation (17) follows that

$$\frac{\partial \Psi}{\partial \alpha} > 0. \tag{20}$$

We find by the implicit function theorem and using Equations (18) and (20) that

$$\frac{d\phi_2^{g,A}}{d\alpha} = -\frac{\partial \Psi / \partial \alpha}{\partial \Psi / \partial \phi_2^A} < 0. \tag{21}$$

Equation (21) implies that the government's critical preference value, $\phi_2^{g,A}$, decreases if the political power of the producers' interest group, α, increases. Intuitively, if the producers' interest group has more influence on the government, the range $\left[\phi_2^{g,A}, \phi_2^{c,A}\right[$

for which the government chooses to endorse the status quo expands. In the special case where α is sufficiently high such that $\phi_2^{g,A} \le \phi_1^{c,A}$, country A's government always prohibits the cheap technology since $\phi_1^{c,A} < \phi_1^A = \phi_2^A$. We summarize the results for the optimal behavior of country A's government in Result 5.

Result 5: *With* $bs_L > a\Delta$, $\phi_1^k = \phi_2^k$ *and* $\phi^{\min} < \phi_1^B < \phi_1^{c,k} < \phi_1^A$ *for* $k = A, B$, *and* $\Psi = 0$ *at* $\phi_2^A = \phi_2^{g,A}$, *then:*

- $s_1^A = s_H$; $s_1^B = s_2^B = s_L$;
- $\phi_1^{c,A} < \phi_2^{c,A}$; $\phi_2^{g,A} < \phi_2^{c,A}$;
- *for* $\phi_2^A \ge \phi_2^{g,A}$: $s_2^A = s_H$;
- *for* $\phi_2^A < \phi_2^{g,A}$: $s_2^A = s_L$;
- $\dfrac{d\phi_2^{g,A}}{d\alpha} < 0$;

with $\phi_1^{c,k} = \dfrac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right) - a\dfrac{\Delta^2}{\sqrt{s_L}}\right]$, $\phi_2^{c,k} = \dfrac{1}{\left(\sqrt{s_H} - \sqrt{s_L}\right)}\left[b\left(s_H^{3/2} - s_L^{3/2}\right)\right]$;

$\phi^{\min} = b\left(s_H + s_L\right) + a\Delta$.

Our dynamic political economy model shows that differences in consumer preferences between countries may lead to differences in technology regulation. These differences may persist over time, however not because of the differences in consumer preferences but for reasons of producer protectionism. This is driven by the investment cost that induces producers in both countries to switch from being indifferent in the first period to supporting the status quo in the second period. If a government chooses to allow the cheap technology, it prefers a regulatory status quo no matter what the other government decides. If a government chooses to ban the cheap technology, it will prefer the regulatory status quo depending on the relative impacts on consumers and producers of both regulatory options, and the political power of the producers' interest group. A larger political power of the producers' interest group leads to a larger range of circumstances where the status quo is maintained, even though consumers oppose it. Different technology regulations are initiated by differences in consumer preferences, but persistence in these regulatory differences is motivated by producers' interests.

5 Case (iii): A Temporary Difference in Consumer Preferences

In this section, we show that even if the difference in consumer preferences is only temporary and potentially small (a 'butterfly'), hysteresis in technology regulation and long-lasting regulatory differences may emerge between countries. To this end, we assume that consumer preferences are different between countries in period 1 but identical in period 2. There are two potential scenarios. In the first scenario, country A's consumer preferences are higher in period 1, $\phi_1^A > \phi_1^B$, but in period 2 they fall to the level of those in country B, $\phi_2^A = \phi_2^B$, which have remained constant $\left(\phi_1^B = \phi_2^B\right)$. In the second scenario, country A's consumer preferences are also higher in period 1, $\phi_1^A > \phi_1^B$, but in period 2 country B's consumer preferences rise to the level of those in country A, $\phi_2^A = \phi_2^B$, which have remained constant $\left(\phi_1^A = \phi_2^A\right)$.

Scenario 1: $\phi_1^A > \phi_1^B = \phi_2^B = \phi_2^A$

Assume, consistent with $\phi_1^A > \phi_1^B$, that $\phi_1^A \underset{\rightarrow}{\geq} \phi_1^{c,k}$ and $\phi_1^B \underset{\rightarrow}{\leq} \phi_1^{c,k}$, with $\phi_1^{c,k}$ as in Equation (10). The difference between ϕ_1^A and ϕ_1^B is only minor since both approach $\phi_1^{c,k}$

respectively from above and below.[15] In line with Result 3, the governments' optimal choices in period 1 are respectively $s_1^A = s_H$ and $s_1^B = s_L$. Country A's government prohibits the cheap technology, while country B's government allows it.

In period 2, country A's consumer preferences fall to the level of country B $\left(\phi_2^A = \phi_2^B = \phi_1^B \le \phi_1^{c,k}\right)$. Following Result 4, the political-economic equilibrium in country B is to unconditionally uphold the status quo whereas according to Result 5, country A's political-economic equilibrium depends on the political power of the producers' interest group. If α is sufficiently high such that $\phi_2^{g,A} \le \phi_2^A$, the producers' interest group lobbies successfully to endorse the status quo although consumers prefer to allow the cheap technology $\left(\phi_2^A \le \phi_1^{c,k} < \phi_2^{c,k}\right)$. If however the producers' interest group is politically weak (α low) such that $\phi_2^A < \phi_2^{g,A}$, the government allows the cheap technology. Table 1 summarizes the first scenario.

This scenario shows that if the producers' interest group in country A has sufficient political power, both countries remain having different technology regulations, even though consumer preferences are identical. The 'butterfly', the temporary difference in consumer preferences, triggers different initial regulatory choices and investment which lead to a coalition switch in country A as consumer and producer interests change. Country A's producers lobby successfully to uphold the status quo in period 2 which protects them from cheaper imports, while consumers prefer the cheap technology. Hence the temporary difference in consumer preferences leads to initial differences in regulation, but it are the producer protectionist motives that

[15] In terms of chaos theory, the situation in period 1 is a *hypersensitive* one (Smith 1991), meaning that other states arbitrarily close to the hypersensitive one could eventually lead to highly divergent dynamical behavior.

cause hysteresis and long-lasting differences in technology regulation.[16]

In Figure 1 we illustrate the interests of country A's producers in upholding the status quo where for simplicity world demand is assumed constant and equal to 1. The default situation is that initially only the expensive technology is available, i.e. $s_0^k = s_H$, $p_0^A = p_0^B = bs_H^2$, and the equilibrium is at E_0. In period 1, because of the temporary difference in consumer preferences, country B allows the cheap technology while country A prohibits it ($s_1^B = s_L$ and $s_1^A = s_H$). The marginal cost and price are lower in country B, although country B's producers incur an investment cost $\left(p_1^B = bs_L^2 + a\Delta^2 < bs_H^2 = p_1^A\right)$. Due to the different regulations and marginal costs, the markets are separated and the equilibrium is different for each country (E_1^A and E_1^B). In period 2, country B sticks unconditionally to the status quo such that its marginal cost and price decrease further $\left(p_2^B = bs_L^2 < p_1^B\right)$, and its equilibrium is at E_2^B. If country A would also allow the cheap technology, country A's producers would produce at marginal cost $bs_L^2 + a\Delta^2$. These are higher than in country B because they do not need to switch and have gained a first-mover advantage in the cheap technology. In that case, country A's equilibrium would be at $\tilde{E}_2^A$ and country A's producers would suffer a decrease in profits equal to $a\Delta^2/2$ in the figure. If however country A upholds its status quo, country A's equilibrium is at E_2^A, the markets remain separated, and country A's producers do not suffer a decrease in profits. Hence successful lobbying by country A's producers leads to hysteresis in technology regulation and long-lasting regulatory differences.

[16] In the classification of Göcke (2002), this hysteresis effect is a form of 'non-ideal relay hysteresis', which is part of the group 'microeconomic hysteresis'. This group shares the common feature that a certain critical value must be passed to induce persistent hysteresis effects.

Scenario 2: $\phi_1^B < \phi_1^A = \phi_2^A = \phi_2^B$

Define government B's critical preference value as $\phi_2^{g,B}$ which has two important properties:[17] $\phi_2^{g,B} > \phi_2^{c,k}$ and $d\phi_2^{g,B} / d\alpha > 0$. These properties imply that if the producers' political power is sufficiently strong in country B, the status quo in technology regulation is maintained $\left(s_2^B = s_L\right)$ for an additional range of consumer preferences $\phi_2^B \in \left[\phi_2^{c,k}, \phi_2^{g,B}\right[$.[18]

Table 2 summarizes the second scenario. Assume that in period 1, $\phi_1^A > \phi_2^{c,k}$ and $\phi_1^B < \phi_1^{c,k}$, which is consistent with $\phi_1^A > \phi_1^B$ since $\phi_1^{c,k} < \phi_2^{c,k}$ (defined by respectively Equations (10) and (16)). According to Result 3, $s_1^A = s_H$ and $s_1^B = s_L$. In period 2 consumer preferences increase in country B so that $\phi_2^B = \phi_2^A = \phi_1^A$. Since $\phi_2^A > \phi_2^{c,k}$, country A's government continues banning the cheap technology, $s_1^A = s_H$ (see Result 5). Whether country B's government chooses the status quo or not depends on the political power of the producers' interest group in country B. If the producers' interest group has sufficient political power (α high) such that $\phi_2^{g,B} > \phi_2^B$, the status quo will be endorsed although consumers prefer the expensive technology $\left(\phi_2^B > \phi_2^{c,k}\right)$. If α is low such that $\phi_2^{g,B} \le \phi_2^B$, the producers' interest group in country B is unsuccessful at pushing for the status quo, and the cheap technology is prohibited.

This scenario demonstrates that if the producers' interest group has sufficient political power in country B, its government continues allowing the cheap technology although consumers want to ban it, and the regulatory difference between the countries

[17] The derivations of these properties are similar to those of $\phi_2^{g,A}$ (Equations (18) to (21)).

[18] Since we assumed in the previous cases that $\phi_k^B < \phi_1^{c,k}$ and found that $\phi_1^{c,k} < \phi_2^{c,k}$, the range $\phi_2^B \in \left[\phi_2^{c,k}, \phi_2^{g,B}\right[$ was never relevant which explains why we did not introduce $\phi_2^{g,B}$ before.

persists although consumer preferences are identical. The temporary difference in consumer preferences triggers different regulatory choices and investment in period 1. Because country A's producers gain a first-mover advantage by not switching technologies in the first period, they produce in period 2 at a lower marginal cost with the expensive technology. By lobbying to uphold the status quo in technology regulation, country B's producers protect themselves from this competitive disadvantage. Hence also in the second scenario, the temporary difference in consumer preferences leads to different initial regulations, but it is again a producer protectionist motive that causes hysteresis in technology regulation and long-lasting differences in regulation between countries.

In conclusion, our dynamic political economy model shows that in the second period producers in both countries favor technology regulation that excludes foreign imports, due to technology-specific investments (or the absence of these investments) that were triggered by a temporary difference in consumer preferences in the first period. The model shows that policy persistence in (differences in) technology regulation may occur because governments cater domestic producers' interests, creating hysteresis in technology regulation.

6 Discussion and Implications

Our model indicates that both consumer preferences and protectionist motives play an important role in (differences in) technology regulation. We now apply the insights from our model to explain the difference in biotechnology regulation between the US and EU.

The food scares that plagued Europe in the second half of the 1990s, such as the *bovine spongiform encephalopathy* (BSE, commonly known as the 'mad cow' disease), the food and mouth disease (FMD) and dioxin crises triggered (temporarily) higher consumer preferences for quality and safety in Europe (Bernauer 2003; Vogel 2003; Graff and Zilberman 2007; Scholderer 2005). In line with case (ii) for permanently higher European consumer preferences, or with the first scenario of case (iii) for temporarily higher European consumer preferences, these differences induced different initial GM regulations and investments in the US and Europe. The US allowed GM technology (country B) and the EU de facto prohibited it (country A). Because of these different initial regulations producers' interests changed: US producers became supporters of GM technology, while European producers became opponents. By lobbying the government to protect their home markets, producers obtained the status quo and created hysteresis in biotechnology regulation. Hence the producers' interests are the reason that the differences in GM regulation persist, if the difference in preferences is permanent (case (ii)) or temporary (scenario 1 of case (iii)). This argument is supported by Graff and Zilberman (2004) who argue that GM regulation in name of consumer interests may equally support agrochemical companies and farmers by protecting against the comparative disadvantage from either investing or not investing in GM technology. It are thus differences in consumer preferences that created initial differences in GM regulation, but producer interests that lead to hysteresis in GM regulation. This is also consistent with the fact that, before the food safety crises, European producers were less opposed to GM technology (Bernauer 2003) and that initially EU and US GM regulations were on the same track (Vogel 2001).

The main cause of this regulatory hysteresis is that producers incur a cost of switching between different technologies. This is in line with Coate and Morris (1999) who argue that "*It is clear that the phenomena of [policy] persistence is driven by the existence of switching costs which drive a wedge between the firm's willingness to pay* *for the policy […]*.". The important implication is that to change biotechnology regulation in Europe, one needs to ensure that European producers have the possibility to adjust their production technology without losing profits to foreign imports. This fits well some of the recent German regulations on biotechnology. Germany allows cultivation of the 'Amflora' potato, a GM crop developed by the German chemicals group BASF while at the same time Germany bans cultivation and sale of GM maize (MON 810) produced by the US company Monsanto, despite the fact that both crops have been approved for cultivation at EU level. This suggests that Germany is providing time for its producers to switch between conventional and GM technology without loosing market share to foreign imports.

If it are instead the US consumer preferences that are temporarily lower, the second scenario of case (iii) explains the different GM regulation in the US and EU. In this view, temporarily lower US consumer preferences triggered differences in initial GM regulation. However US producers' interests are then the reason that differences in biotechnology regulation persist even if there is no longer a difference in consumer preferences. If the US producers' interest group has sufficient political power, they succeed in obtaining the regulatory status quo, which allows using GM technology. For example, Charles (2001) provides a fascinating account of the views and strategies of influential persons within Monsanto and other biotechnology-related companies and how their views changed the companies lobbying activities during certain periods. Charles (2001) also argues that the Reagan administration was very much opposed to additional regulations, and according to Stewart et al. (2002) the Bush administration explicitly decided to push for GM technology. These factors put higher political weight on producers' interests in the US which, according to our model, leads to a continuation of the approval of GM technology in the US, even if US consumers would oppose it, and causes regulatory hysteresis.

7 Extensions of the Model

It is possible to extend our model in several directions – we merely indicate some of them, where possible in application to GM technology. First, we have assumed that consumer preferences in the second period are independent from regulation in the first period, i.e. that $\phi_2^k = \phi_1^k + f\left(s_1^k\right)$ with $f\left(s_1^k\right) = 0$. However, it is not unlikely that consumer preferences are affected by previous regulation, for example because the experience of (not) consuming GM products alters consumer preferences. In countries where GM products are available consumer preferences may shift in favor of this technology, while inversely consumers may distrust GM technology more in countries where GM products have been banned.[19] Extending the model by assuming that $f\left(s_H\right) > 0$ and $f\left(s_L\right) < 0$ would reinforce our results. Consider case (ii) where consumer preferences are in period 1 higher in country A, and where consequently the cheap technology is banned in country A but not in country B $\left(s_1^A = s_H;\ s_1^B = s_L\right)$. The assumption that $\phi_2^k = \phi_1^k + f\left(s_1^k\right)$ with $f\left(s_H\right) > 0$ and $f\left(s_L\right) < 0$ implies that in period 2 consumer preferences in country A increase, whereas in country B consumer preferences decrease. It is straightforward from the previous analysis that Result 4 would not alter. Moreover, since then $\phi_2^A > \phi_1^A$, the range of situations where $\phi_2^A > \phi_2^{g,A}$ and $s_2^A = s_H$ would increase, thus extending the range where policy persistence in country A's technology ban occurs (see Result 5).

Another extension relates to the source of country differences. Hysteresis in

[19] Media could play an important role in this – see e.g. McCluskey and Swinnen (2004); Kuzyk et al. (2005).

differences in technology regulation may be caused by other factors than temporary differences in consumer preferences. For example, producers located in an environment favorable to technological innovation may have an advantage over other producers in investing in a new technology. A temporary investment advantage can be modeled by assuming that country B's producers incur a lower investment cost than country A's producers in period 1 $\left(a_1^B < a_1^A\right)$. This temporarily lower investment cost may also lead to (persistence in) different technology regulations. Assume that consumer preferences for quality ϕ_t^k are constant and identical between countries. The lower value of a_1^B leads to a higher value of $\phi_1^{c,k}$ in both countries (see Equation (10)) since also country A's consumers could benefit from the lower investment cost by importing the low quality good. With $\phi_t^k < \phi_1^{c,k}$, country B's government would allow the cheap technology since country B's producers are indifferent. Country A's producers however oppose the cheap technology since they would be competitively dominated if the cheap technology were allowed, as $a_1^A > a_1^B$. Therefore country A's producers lobby in favor of prohibiting the cheap technology, and $\phi_1^{g,A} < \phi_1^{c,k}$. If the political power of country A's producers is sufficiently high such that $\phi_1^{g,A} < \phi_1^k$, country A's government prohibits the cheap technology in the first period. The analysis of period 2, when $a_2^A = a_2^B$, is then similar to case (ii). Hence a temporary difference in investment costs may also lead to an initial difference in technology regulation which results in hysteresis in (differences in) technology regulation due to producer lobbying. According to Charles (2001), this was an important driver at Calgene, a biotechnology company located in Silicon Valley, US, that has been acquired by Monsanto in the meantime.

Another extension would be to specify the different subgroups that are aggregated in the group of 'producers'. In reality there exists considerable heterogeneity, both horizontally and vertically. For example, horizontally, there are different types of 'producers' who vary in productivity and ability to apply different technologies. Vertically, the supply chain consists of different agents such as for example in the case of GM technology, farmers, seed companies, biotechnology companies, and producers of other inputs such as agro-chemical companies. These agents may have conflicting interests with respect to GM regulation (Fulton and Giannakas 2004). For example, biotechnology companies oppose GM technology regulation to fully exploit their innovations. In contrast, agro-chemical companies who produce traditional crop-protection products that are incompatible with or substitutes of GM technology favor biotechnology regulation in order to protect their market share in the crop protection market. On the other hand, if such an agro-chemical company sells chemicals that are complementary to biotechnology, they also oppose GM technology restrictions (Just and Hueth 1993). Seed companies may prefer to restrict GM technology or not, depending on how much market power the biotechnology firms have and how much the seed companies' margins are squeezed by the biotechnology companies. Additionally, GM regulation may entail further costs on seed companies such as segregation costs (Kalaitzandonakes et al. 2007). Similarly, farmers may oppose or favor GM regulation, depending on the impact on input and output prices and whether they incur extra costs (Veyssiere and Giannakas 2006). Depending on how these different agents in the supply chain interact, the distribution of market power in the supply chain, and the political power of the different agents, different outcomes may result. Separating out these different interest groups substantially complicates the analysis and is left for future research.

Finally, we have assumed that technology regulation is a one-dimensional and dichotomous standard, while in reality governments have a broad range of policy instruments at their disposal. For example, we have not allowed for labeling policies that would give consumers the opportunity to choose (see e.g. Golan et al. 2001; Fulton and Giannakas 2004; Moschini 2008). In the case of GM technology, governments may also impose maximum contamination levels. Biotechnology regulation may also distinguish between GM technology that is used for animal feed, or food for human consumption. Of course, all these different regulations may have different effects on different actors in the market, and interest groups who oppose GM regulation may still prefer one type of regulation over another.

8 Conclusions

Our paper advances a dynamic political-economic model of regulation, in which two countries' governments need to decide which of two technologies to allow in each of two periods. One technology allows to produce at lower marginal cost, but consumers have some (heterogeneous) aversion to it. Switching between technologies involves a one-time marginal cost increase. First we have shown the existence of a critical (consumer) preference value above which the cheap technology is prohibited. A small variation in consumer preferences may thus determine whether a country bans a technology or not.

Second, the dynamic model showed that if consumer preferences are constant and identical between countries, countries adopt the same technology regulation and stick to the status quo independent of the initial technology regulation.

Third, constant but different consumer preferences between countries may lead to different technology regulations in the first period, depending on how the countries' consumer preferences are positioned with respect to the critical value. If different technologies are adopted in the first period, the government that initally allows the cheap technology always endorses the status quo in the long run, independent of the other country's regulation. The government that initially prohibits the cheap technology may also support the status quo because producers' interests switch around, even though consumers may wish to change. Producers are initially indifferent but because of the switching cost they suffer a competitive disadvantage in applying the cheap technology. Therefore they lobby to maintain the ban on the cheap technology to protect themselves from cheaper imports from the country that adopts the cheap technology, and succeed if their political power is sufficiently strong. Hence producer lobbying, not consumer preferences, leads to policy persistence and long-run differences in technology regulation.

Fourth, the previous results may also hold when the difference in consumer preferences is only temporary. A temporary difference in consumer preferences may trigger different initial regulations, and thus different investments. In the next period, producers in both countries favor technology regulation that excludes foreign imports, due to technology-specific investments (or the absence of these). Hence, despite identical consumer preferences in the long run, regulatory differences may be long-lasting because governments respond to pressures of domestic producers, creating hysteresis in technology regulation. We have demonstrated that similar results may be obtained from temporary differences in company strategies that result in different investment costs.

This model illustrates that both consumer preferences and protectionist motives play an important role in explaining the differences in GM technology regulation between the EU and US. Higher consumer preferences for regulation in Europe due to food safety crises triggered differences in initial GM regulation. However the domestic producer interests, in Europe and the US, are the reason that differences in biotechnology regulation persist even if there is no longer a difference in consumer preferences. By contributing to the government to protect their home markets, European as well as US producers create hysteresis in biotechnology regulation and long-lasting regulatory differences.

The main cause of this regulatory persistence is the cost of switching between different technologies. In order to induce a change in technology regulation one needs to ensure that producers can adjust their production technology without losing profits to foreign imports. This reduces producers' incentives to lobby in favor of a status quo in technology regulation, and would remove differences in regulation between countries, all else equal.

References

Alston, J.M., Norton, G.W., and Pardey, P.G., 1995. *Science under scarcity: Principles and practice of agricultural research evaluation and priority setting*. Ithaca, NY: Cornell University Press.

Amacher, G.S., Koskela, E., and Ollikainen, M., 2004. Environmental quality competition and eco-labeling. *Journal of Environmental Economics and Management* 47, 284-306.

Anderson, K., Damania, R., and Jackson, L.A., 2004. Trade, standards, and the political economy of genetically modified food. *CEPR Discussion Papers* 4526, C.E.P.R. Discussion Papers.

Anderson, K., and Jackson, L.A., 2006. Transgenic crops, EU precaution, and developing countries. *International Journal of Technology and Globalisation* 2, 65-80.

Arthur, W.B., 1989. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal* 99, 116-31.

Baldwin, R.E., and Krugman, P., 1989. Persistent trade effects of large exchange rate shocks. *Quarterly Journal of Economics* 104, 635-54.

Baltzer, K., 2006. The effects of food product standards in international trade. Paper prepared for the IATRC annual meeting, Florida, U.S., December 3-5, 2006.

Belke, A., and Göcke, M., 1999. A simple model of hysteresis in employment under exchange rate uncertainty. *Scottish Journal of Political Economy* 46(3), 260-86.

Bernauer, T., 2003. *Genes, Trade, and Regulation*. Princeton University Press, Princeton, New Jersey.

Bernheim, B.D., and Whinston, M.D., 1986. Menu auctions, resource allocation, and economic influence. *Quarterly Journal of Economics* 101(1), 1-31.

Charles, D., 2001. *Lords of the Harvest: Biotech, Big Money, and the Future of Food*. Cambridge, MA: Perseus Publishing.

Cowan, R., 1990. Nuclear power reactors: a study in technological lock-in. *Journal of Economic History* 50, 541-67.

Cross, R., and Allan, A., 1988. On the history of hysteresis. In Cross, R., ed., *Unemployment, Hysteresis and the Natural Rate Hypothesis*. Oxford: Basil Blackwell.

Curtis, K.R., McCluskey, J.J., and Wahl, T.I., 2004. Consumer acceptance of genetically modified food products in the developing world. *AgBioForum* 7(1& 2), 69-74.

David, P.A., 1985. Clio and the economics of QWERTY. *American Economic Review* 75, 332-7.

Dixit, A., 1980. The role of investment in entry deterrence. *The Economic Journal* 90, 95-101.

Dixit, A., 1989a. Entry and exit decisions under uncertainty. *Journal of Political Economy* 97(3), 620-38.

Dixit, A., 1989b. Hysteresis, import penetration, and exchange rate pass-through. *Quarterly Journal of Economics* 104(2), 205-28.

Dong, D., and Saha, A., 1998. He came, he saw, (and) he waited: an empirical analysis of inertia in technology adoption. *Applied Economics* 30, 893-905.

Falck-Zepeda, J.B., Traxler, G., and Nelson, R.G., 2000. Surplus distribution from the introduction of a biotechnology innovation. *American Journal of Agricultural Economics* 82, 360-69.

Farrell, J., and Saloner, G. 1985. Standardization, compatibility, and innovation. *RAND Journal of Economics* 16, 70-83.

Fulton, M., and Giannakas, K., 2004. Inserting GM products into the food chain: The market and welfare effects of different labeling and regulatory regimes. *American Journal of Agricultural Economics* 86(1), 42-60.

Gaskell, G., Bauer, M.W., Durant, J., and Allum, N.C., 1999. Worlds apart: The reception of genetically modified foods in Europe and the US. *Science* 285, 384-387.

Göcke, M., 2002. Various concepts of hysteresis applied in economics. *Journal of Economic Surveys* 16(2), 167-88.

Golan, E., Kuchler, F., and Mitchell, L., 2001. Economics of food labeling. *Journal of Consumer Policy* 24, 117-184.

Graff, G.D., and Zilberman, D., 2004. Explaining Europe's resistance to agricultural biotechnology. *Agricultural and Resource Economics Update* 7, 1-5.

Graff, G.D., and Zilberman, D., 2007. The political economy of intellectual property: Reexamining European policy on plant biotechnology. In Kesan, J.P., ed., *Agricultural Biotechnology and Intellectual Property: Seeds of Change*. Cambridge, MA: CAB International.

Grossman, G.M., Helpman, E., 1994. Protection for sale. *American Economic Review* 84(4), 833-850.

Grossman, G.M., Helpman, E., 1995. The politics of free-trade agreements. *American Economic Review* 85(4), 667-690.

Gulati, S., Roy, D., 2007. How standards drive taxes: The political economy of tailpipe pollution. *The B.E. Journal of Economic Analysis & Policy* 7(1).

Jeanneret, M., Verdier, T., 1996. Standardization and protection in a vertical differentiation model. *European Journal of Political Economy* 12, 253-271.

Josling, T., Roberts, D., and Orden, D., 2003. *Food regulation and trade. Toward a safe and open global system.* Institute for International Economics.

Just, R.E. and Hueth, D.L., 1993. Multimarket exploitation: The case of biotechnology and chemicals. *American Journal of Agricultural Economics* 75, 936-945.

Kalaitzandonakes, N., Alston, J.M., and Bradford, K.J., 2007. Compliance costs for regulatory approval of new biotech crops. *Nature Biotechnology* 25, 509-511.

Kuzyk, P., McCluskey, J.J., and Ross, S.D., 2005. Testing a political economic theory of the media: How were steel tariffs covered? *Social Science Quarterly* 86(4), 812-825.

Lapan, H.E., and Moschini, G., 2004. Innovation and trade with endogenous market failure: The case of genetically modified products. *American Journal of Agricultural Economics* 86, 634-648.

Lapan, H.E., and Moschini, G., 2007. Grading, minimum quality standards, and the labeling of genetically modified products. *American Journal of Agricultural Economics* 89, 769-783.

Lence, S., and Hayes, D., 2005. Genetically modified crops: Their market and welfare impacts. *American Journal of Agricultural Economics* 87, 931-950.

Lewis, P., 1992. Mutant foods create risks we can't yet guess. *The New York Times* June 16.

Lindbeck, A., and Snower, D.J., 1986. Wage setting, unemployment and insider-outsider relations. *American Economic Review* 73, 235-39.

Lopez, R.A., and Matschke, X., 2006. Food protection for sale. *Review of International Economics* 14(3), 380-391.

McCluskey, J.J., and Swinnen, J.F.M., 2004. Political economy of the media and consumer perceptions of biotechnology. *American Journal of Agricultural Economics* 86, 1230-1237.

Moschini, G., 2008. Biotechnology and the development of food markets: Retrospect and prospects. *European Review of Agricultural Economics* 35(3), 331-356.

Moschini, G., and Lapan, H., 1997. Intellectual property rights and the welfare effects of agricultural R&D. *American Journal of Agricultural Economics* 79, 1229-1242.

Moschini, G., Lapan, H., and Sobolevsky, A., 2000. Roundup ready soybeans and welfare effects in the soybean complex. *Agribusiness* 16, 33-55.

Moschini, G., Menapace, L., and Pick, D. 2008. Geographical indications and the competitive provision of quality in agricultural markets. *American Journal of Agricultural Economics* 90(3), 794-812.

Mussa, M., and Rosen, S., 1978. Monopoly and product quality. *Journal of Economic Theory* 18, 301-317.

Nelson, C.H., 2001. Risk perception, behavior, and consumer response to genetically modified organisms. *American Behavioral Scientist* 44, 1371-1388.

Paarlberg, R., 2008. *Starved for science. How biotechnology is being kept out of Africa.* Cambridge, MA: Harvard University Press.

Puffert, D., 2002. Path dependence in spatial networks: the standardization of the railway track gauge. *Journal of Economic History* 39, 282-314.

Ronnen, U., 1991. Minimum quality standards, fixed costs, and competition. *RAND Journal of Economics* 22(4), 490-504.

Scholderer, J., 2005. The GM foods debate in Europe: History, regulatory solutions, and consumer response research. *Journal of Public Affairs* 5, 263-274.

Secretariat of the Convention on Biological Diversity, 2000. Cartagena Protocol on Biosafety to the Convention on Biological Diversity: Text and annexes. Montreal: Secretariat of the Convention on Biological Diversity.

Sheldon, I., 2002. Regulation of biotechnology: Will we ever 'freely' trade GMOs?

European Review of Agricultural Economics 29, 155-176.

Smith, P., 1991. The butterfly effect. *Proceedings of the Aristotelian Society* 91, 247-267.

Sobolevsky, A., Moschini, G., and Lapan, H., 2005. Genetically modified crops and product differentiation: Trade and welfare effects in the soybean complex. *American Journal of Agricultural Economics* 87, 621-644.

Spence, M., 1976. Product differentiation and welfare. *American Economic Review* 66, 407-414.

Spence, M., 1977. Entry, capacity, investment and oligopolistic pricing. *Bell Journal of Economics* 10, 1-19.

Stewart, P.A., Harding, D., and Day, E., 2002. Regulating the new agricultural biotechnology by managing innovation diffusion. *The American Review of Public Administration* 32(1): 78-99.

Swinnen, J.F.M., and Vandemoortele, T., 2008. The political economy of nutrition and health standards in food markets. *Review of Agricultural Economics* 30(3), 460-468.

Swinnen, J.F.M., and Vandemoortele, T., 2009a. Are food safety standards different from other food standards? A political economy perspective. *European Review of Agricultural Economics* 36(4), 507-523.

Swinnen, J.F.M., and Vandemoortele, T., 2009b. Trade, development, and the political economy of public standards. *LICOS Discussion Paper* 236/2009.

Tirole, J., 1988. The theory of industrial organization. Cambridge, MA: MIT Press.

Valletti, T.M., 2000. Minimum quality standards under Cournot competition. *Journal of Regulatory Economics* 18(3), 235-245.

Veyssiere, L., and Giannakas, K., 2006. Strategic labeling and trade of GMOs. *Journal of Agricultural and Food Industrial Organization* 24, 1-38.

Vogel, D., 2001. Ships passing in the night: The changing politics of risk regulation in Europe and the United States. *EUI Working Papers* RSC No. 2001/16. Dan Domenico, Italy: European University Institute.

Vogel, D., 2003. The hare and the tortoise revisited: The new politics of consumer and environmental regulation in Europe. *British Journal of Political Science* 33, 557-580.

Tables

Table 1: A Temporary Difference in Consumer Preferences: Scenario 1 with $\phi_1^A > \phi_1^B = \phi_2^B = \phi_2^A$

t	A	B	s_t^k
1	$\phi_1^A \geq \phi_1^{c,k}$	$\phi_1^B \leq \phi_1^{c,k}$	$s_1^A = s_H$ $s_1^B = s_L$
2	$\phi_2^A < \phi_2^{c,k}$	$\phi_2^B < \phi_2^{c,k}$	$s_2^A = \begin{cases} s_H & \text{if } \phi_2^{g,A} \leq \phi_2^A \; (\alpha \text{ high}) \\ s_L & \text{if } \phi_2^{g,A} > \phi_2^A \; (\alpha \text{ low}) \end{cases}$ $s_2^B = s_L$

Table 2: A Temporary Difference in Consumer Preferences: Scenario 2 with $\phi_1^B < \phi_1^A = \phi_2^A = \phi_2^B$

t	A	B	s_t^k
1	$\phi_1^A > \left(\phi_2^{c,k} >\right) \phi_1^{c,k}$	$\phi_1^B < \phi_1^{c,k}$	$s_1^A = s_H$ $s_1^B = s_L$
2	$\phi_2^A > \phi_2^{c,k}$	$\phi_2^B > \phi_2^{c,k}$	$s_2^A = s_H$ $s_2^B = \begin{cases} s_L & \text{if } \phi_2^{g,B} > \phi_2^B \; (\alpha \text{ high}) \\ s_H & \text{if } \phi_2^{g,B} \leq \phi_2^B \; (\alpha \text{ low}) \end{cases}$

Figures

Figure 1: Interests at Stake of Country A's Producers to Maintain the Status Quo in Technology Regulation