An Economic Theory of Green Consumer Culture and Sustainable Technological Change*

Emeline Bezin†

March 9, 2017

Abstract

A model shows how systematic interactions between ethical consumer culture and sustainable technologies can give rise to aggregate increasing returns in sustainable innovation processes. Ethical preferences are formed through cultural transmission which involves rational socialization actions as pioneered by Bisin and Verdier (2001). Transmission is influenced by the technology. Moreover, innovation is endogenously directed to sustainable or unsustainable sectors depending on culture through market size effects. The dynamics generally exhibits complementarities resulting in multiple equilibria. The theory accounts for a number of stylized facts including the cross-country correlation between ethical consumption attitudes and the development of sustainable production methods.

Keywords: Ethical consumption; Cultural transmission; Directed technological change
JEL Codes: Z13, D11, 033, H41

*I am grateful to Thomas Baudin, Matthias Doepke, David de la Croix, Fabien Moizeau, Franois Salanié and Katheline Schubert for very helpful comments. I also thank participants to Overlapping Generations Days 2013, the 20th Annual Conference of the European Assocation of Envionmental and Resource Economists (Toulouse), Overlapping Generations Days 2014, the 8th Louvain Symposium in Economic Dynamics Sustainability, Institutions and Development, the 64th annual meeting of the French Economic Association (Rennes).

†Paris School of Economics, 48 Boulevard Jourdan, 75014 Paris, France. Corresponding author: +33 (0)1 43 13 63 80. E-mail:emeline.bezin@gmail.com

1 Introduction

"*Every buyer determines in some degree the direction of industry. The market is a democracy where every penny gives the right to vote.*" (Franck A. Fetter, 1907, p394).

Recent empirical studies have provided suggestive evidence for path dependency in the direction of sustainable innovation processes (Popp, 2002, Aghion *et al.*, 2016). For example, Aghion *et al.* (2016) build on firm-level panel data on auto industry innovation to show that countries and firms that have experienced cleaner innovation are more likely to innovate in clean technologies in the future. A formal argument has been developed in Acemoglu *et al.* (2012) where path dependency arises due to the existence of increasing returns to past research and a high substitutability between clean and dirty goods[1]. This paper proposes a different and complementary explanation based on the interdependence between the "ethical consumer culture" and innovation in "sustainable technologies"[2].

Empirical evidence indicates that attitudes toward ethical consumption have been decisive in the development of sustainable production methods. Popp *et al.* (2006) use patents data to examine the determinants of the dramatic rise in chlorine free paper technologies during the 1990s. Their study indicates that innovation was due to changes in consumers concern over chlorine in paper. This empirical finding is strengthened by cross-country analysis of the relationship between attitudes toward ethical consumption, on the one hand, and sustainable technologies, on the other hand. For instance, Figure 1 displays the scatterplot between the (log-) share of people who embed an environmental dimension in their consumption decisions and the (log-) development of organic farming across countries. A positive relationship exists between the share of environmentally friendly consumers and the prevalence of organic production methods[3].

From a policy perspective, it matters to account for existing interactions between consumer culture and sustainable innovation. Otherwise current decisions should have unexpected long run consequences on production technologies. In this paper, I build a theoretical framework which interacts the formation of ethical consumer preferences and the direction of technological change in

[1]Both assumptions have been extensively discussed due to contradicting evidence (see Popp, 2002, Hassler *et al.*, 2012, Pottier *et al.*, 2014)

[2]The expression ethical consumer culture has come to describe consumption practices which integrate a concern for collective or social issues, be it environmental protection, animal welfare or human rights. Here, sustainable technologies include a large set of production techniques which directly or indirectly reduces harmful impact on the aforementioned collective issues.

[3]This relationship is robust to controlling for several variables. Further empirical evidence is presented in Section 2.

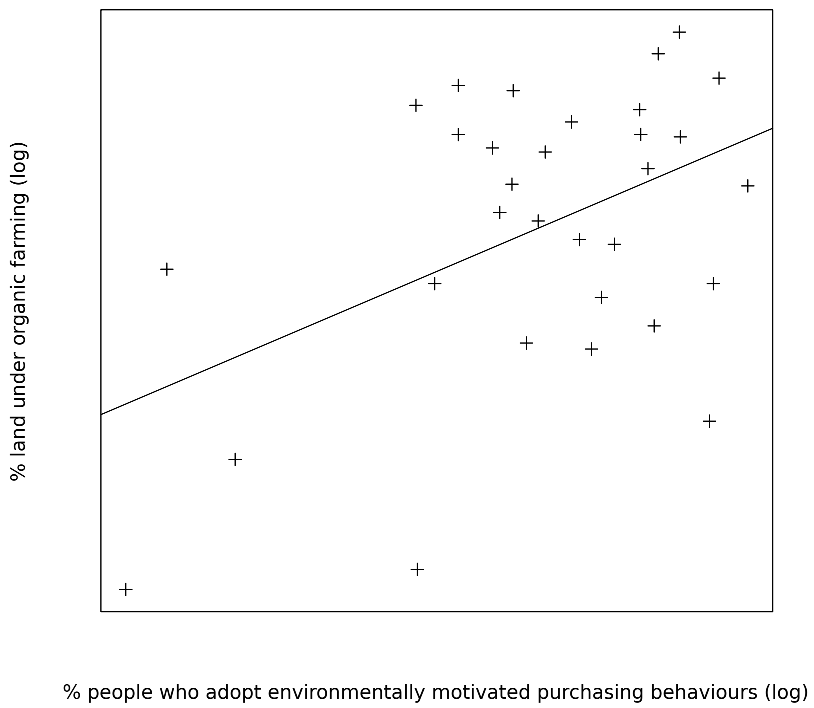


Figure 1: Cross-country correlation between the percentage of land under organic farming and the fraction of respondents to the ISSP survey who make consumption choices for environmental reasons (R-squared=0,19). Source: FIBL (2015) and ISSP (2012).

sustainable technologies. This model provides a rational for the cross-country correlation between environmentally friendly attitudes and the development of sustainable production methods. The framework embeds the following key features: (i) some agents value ethical consumption, i.e., the purchase of certain goods whose production or consumption reduces harmful impacts (possibly increases positive ones) on some public good (e.g., environmental quality, natural resources, animal welfare, human rights); (ii) these preferences are formed through a cultural transmission mechanism which involves a rational choice by parents and interactions within the society at a whole; (iii) technology is endogenous: profit-motivated agents direct innovation toward two different sectors: the "unsustainable sector" (e.g., polluting industries, intensive farming) and the "sustainable sector" (e.g, organic farming, renewable energy, sectors with high labour standards).

I consider overlapping generations of individuals who live for two periods: as a child and as an adult. Adults have heterogeneous preferences over consumption, some of them attaching higher value to sustainable products[4]. I consider two types of agents: the "ethical consumers" and the "conventional consumers" where the former have higher preferences for sustainable goods. In addition,

[4]Section 2 provides empirical support for this assumption.

ethical consumers attach higher value to the level of public good[5]. These preferences are adopted during childhood through social interactions taking place inside the family and within the society. I follow Bisin and Verdier (2001) by considering parents who exert a costly effort so as to transmit their own preferences. Incentives to do so come from a form of altruism whereby parents are able to correctly assess the optimal choices of their child but through the filter of their own preferences. In this general equilibrium framework, the parents' gain to have a child with the same preferences, referred to as "cultural intolerance", depends on relative prices and so on productivity in each sector.

The supply side of the economy is captured by a two-sectors model with directed technological change based on Acemoglu *et al.* (2012). Both sectors, sustainable and unsustainable, produce a final good by using labour and a continuum of sector-specific machines supplied by firms in monopolistic competition. The productivity of these machines is endogenous. In particular, scientists motivated by profit opportunities decide to direct their research toward the unsustainable or sustainable sector. This decision critically depends on the market size for final goods and, consequently, on the relative importance of preferences for ethical consumption within the population.

I study the joint dynamics of the technology and ethical consumer culture. The dynamics of ethical consumer culture is ruled out by two opposite effects. First, a high fraction of ethical consumers has a negative effect on the future fraction of these agents. This is due to a "group free-riding effect" lying on the existence of cultural substitutability: when the culture of ethical consumption prevails (resp. is low), transmission of the ethical (resp. conventional) trait by the society is efficient so that ethical (resp. conventional) parents have an incentive to reduce their own socialization effort. Second there is a positive effect of sustainable technological change on the future share of ethical consumers, referred to as the "technological effect on socialization". When the relative productivity in the sustainable sector increases, at equilibrium, the relative price of the sustainable good decreases which positively affects the welfare of a child with the ethical trait and then the socialization effort of ethical parents. As well, the dynamics of relative productivity is shaped by two opposite forces. Consider the sustainable technology. In this framework, there is a negative effect from past sustainable innovation. This is because I purposefully assume (i) decreasing returns to past research and (ii) a low elasticity of substitution between consumption goods. However, there is second positive effect coming from cultural change. When ethical consumer culture rises, the market size of the sustainable

[5]Empirical evidence suggests a strong correlation between attitudes toward sustainable products and concern for social or environmental issues (see Kalof *et al.*, 1999, Shaw and Newholm, 2002, Honkanen *et al.*, 2006, Dimantopoulos *et al.*, 2003). Nevertheless, I could have assumed that both types of agents value the public good. None of the results would be affected. Note that ethical consumption cannot be induced by preferences for the public good as, in such framework, the impact of one's individual consumption on public good provision vanishes to zero.

sector increases which positively affects incentives to innovate in this sector. This second effect, is called the "market size effect of culture".

I show that depending on the relative intensity of these four effects, the economy either converges to a unique stationary equilibrium or there exist multiple attracting steady states. The rational goes as follows. When the group free-riding effect on culture outweighs the technological effect on socialization, a rise in the fraction of ethical consumers negatively affects the future share of these agents. In addition, when the effect of past technology on innovation is high compared to the market size effect of culture, innovation in the sustainable sector negatively impacts future relative productivity in this sector. Due to global substitutability, the system converges to a unique stationary equilibrium. However, when the market size effect of culture and the technological effect on socialization grows large, a rise in past variables (i.e., the fraction of ethical consumers and relative productivity in the sustainable sector) has a positive effect on future ones: there exist global complementarities. In this case we observe aggregate increasing returns to innovation as suggested by empirical evidence. Moreover, two distinct equilibrium outcomes emerge: an equilibrium with few ethical consumers and where the unsustainable technology of production prevails, an equilibrium where preferences for ethical consumption are widespread and production methods are biased toward the sustainable technology. This result provides a rational for the cross-country correlation between attitudes to ethical consumption and the development of sustainable technologies.

The model has far-reaching policy implications. When complementarities exist, any policy shock that affects culture has long lasting consequences for production technologies. In particular, I analyse the impact of an integration shock (assuming that complementarities hold). This is interesting in such context because the civil society has expressed strong concern about the consequences of globalization on national culture. The problem has been mostly ignored by economists as it deals with non purely economic phenomena[6]. In this framework, the impact of economic integration on culture cannot be disregarded as it matters for long run economic outcomes. I extend the model to allow for international trade in goods (both final and intermediate, i.e., machines). After integration, the technology used by final producers is the same in each countries. This technological change implies cultural convergence in attitudes toward ethical consumption, which result is supported by the data. Moreover, I show that the integrated economy converges to the state of the economy which owns the most efficient technology. The intuition unfolds as follows. The country with the most efficient technology experiences a lower technological shock which turns into a lower cultural shock. Suppose that

[6]Recent exceptions include Olivier *et al.*, 2008, Maystre *et al.*, 2014.

this country is the one which was initially at the equilibrium with few ethical consumers and where the unsustainable technology prevails, let say the "conventional equilibrium". Since technological and cultural shocks are lower in this country, at the world level, the technological and cultural change are respectively biased to the unsustainable technology and conventional consumer culture. When global complementarities hold, the initial reduction in the productivity of the sustainable sector and the world fraction of ethical consumers, implies further decrease in both variables. Therefore, the world economy (and thus both countries) converges to the conventional equilibrium. This extension contributes to the "fair trade" debate which embeds a strong concern for trade integration when there is some inconsistency between foreign production methods and domestic norms and values (see Howse and Trebilcock, 1996).

From a theoretical point of view, this work relates to economic models of cultural transmission pioneered by Bisin and Verdier (2001). Several papers base on this framework to study interactions between the evolution of some cultural traits and changes in the structure of production (see François and Zabojnik, 2005, Olivier *et al.*, 2008, Hiller, 2011, Klasing, 2014, Maystre *et al.*, 2014). The model developed in Maystre *et al.* (2014) is relatively close as it includes (i) cultural traits determining different types of consumption, (ii) market size effects due to monopoly powers. However, the fundamental interaction between cultural types and the production side comes from a different channel. In their paper, changes of the structure of production correspond to an increase in varieties of a given type of cultural good. This affects culture through a love-for-variety feature embodied in preferences. Here, technological change lowers the production cost of a particular type of good which impacts culture by the natural channel of relative prices. My approach allows to characterize the steady state relationship between culture and the technology which accounts for the cross-country correlation between attitudes toward ethical consumption and sustainable production methods.

This paper is also inspired from models of directed technological change first formalized in Acemoglu (2002). I draw upon Acemoglu *et al.* (2012) by considering innovation in two different sectors with a distinct impact on the level of public good. However, I introduce endogenous changes in consumers preferences which impact market sizes and the direction of technological change. In this framework, path dependency in the direction of innovation does not anymore require increasing returns to past research nor a high substitutability between dirty and clean goods.

More generally, this work contributes to a flourishing literature which has focused on interactions between culture and technologies of production to explain persistence in economic outcomes. This body of research entails a number of empirical studies (Alesina *et al.*, 2013, Talhelm *et al.*, 2014, Bénabou *et al.*, 2015a,b). For example, Bénabou *et al.* (2015a) find a significant, cross-country as well as US cross-state, negative relationship between religiosity and innovation. Bénabou *et al.* (2015b) confirm this result at the individual level. Theoretical works which are not based on Bisin and Verdier's framework include Doepke and Zilibotti (2008), Doepke and Zilibotti (2014), Bénabou *et al.* (2015a).

The rest of this paper is organized as follows. Section 2 exposes some motivating evidence for the main assumptions. Section 3 presents a simple model which is solved in section 4 for equilibrium variables and the resulting dynamics of ethical consumption and the sustainable technology. Section 5 highlights some welfare implications. Section 6 considers an extension to international trade. The last section concludes.

2 Interactions between ethical consumer culture and sustainable technologies: some evidence

I model interactions between ethical consumption and sustainable technologies by assuming that (i) some agents attach higher value to the consumption of sustainable products, (ii) changes in preferences for ethical consumption affect innovation through market size effects, (iii) such preferences are transmitted internationally through social interactions with active parents and role models. In this section I provide supportive empirical evidence for this theory. Figure 2 sheds light on the existence of a positive correlation between the share of people who embed an environmental dimension in their consumption decisions and the development of organic farming across countries. As Table 1 shows the correlation is significant and robust to controlling for GDP per capita and a measure of support for environmental policies. Such a result indicates that the relationship between the two variables does not arise through a "technological effect" as described in Grossman and Krueger (1991) nor through the political economy channel[7].

The cross-country relationship between attitudes toward ethical consumption and technology is not limited to one example. Figure 3 displays the scatterplot between the fraction of people who agree with the idea of buying goods for environmental reasons and the share of EU firms who had introduced one eco-innovative product or service during the last two years. There also exists a positive correlation, which, as Table 2 shows is significant and robust to controlling for GDP per

[7]According to the technological effect, higher income nations, who can afford greater spending on R&D, are better able to develop cleaner technologies. A priory, one could also think that ethical attitudes increase with income so that we observe a correlation between the two variables.

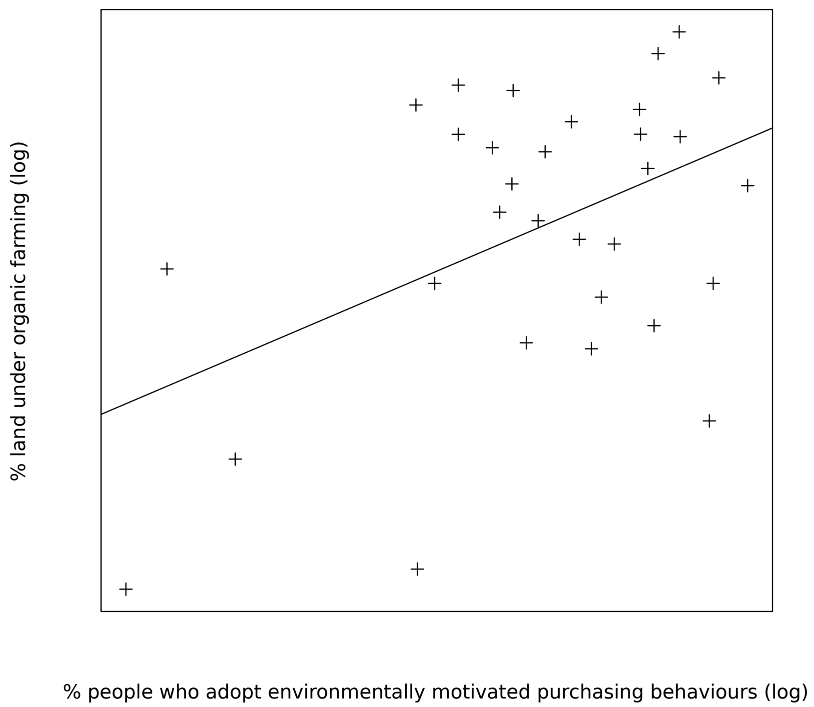


Figure 2: Cross-country correlation between the percentage of land under organic farming and the fraction of respondents to the ISSP survey who at least sometimes make consumption choices for environmental reasons. Source: FIBL (2015) and ISSP (2012).

Table 1: Percentage land under organic farming and share of the population who adopt environmentally motivated purchasing behaviours: cross-country estimates.

Dependant variable: *% land under organic farming*	1	2	3
% who adopt environmentally motivated purchasing behaviours	3,99*** (1,42)	3,22** (1,53)	3,42** (1,43)
GDP per capita		0,47 (0,34)	0,66** (0,33)
% willing to pay much higher taxes for the environment			-1,5** (0,66)
R-squared	0,19	0.23	0.40

Source: GDP per capita from World Development Indicators and percentage of individuals who are willing to pay much higher taxes to protect the environment from ISSP (2012).
*OLS Estimates. Standard errors in parentheses. *Significant at 10%, **Significant at 5%, ***Significant at 1%.*

capita and a measure of environmental policies, i.e., green taxes as a percentage of GDP[8,9].

The model builds on the idea that some consumers value sustainable products, i.e., products

[8]Green taxes include energy taxes, transport taxes, pollution taxes and resource taxes.

[9]As another evidence for the relevance of ethical consumption for the development of ethically friendly production processes, Flash Eurobarometer 315 (2011) reveals that 88% of European firms surveyed mention increasing market demand for green products as an important driver of innovation, with 36% declaring it as a very important driver.

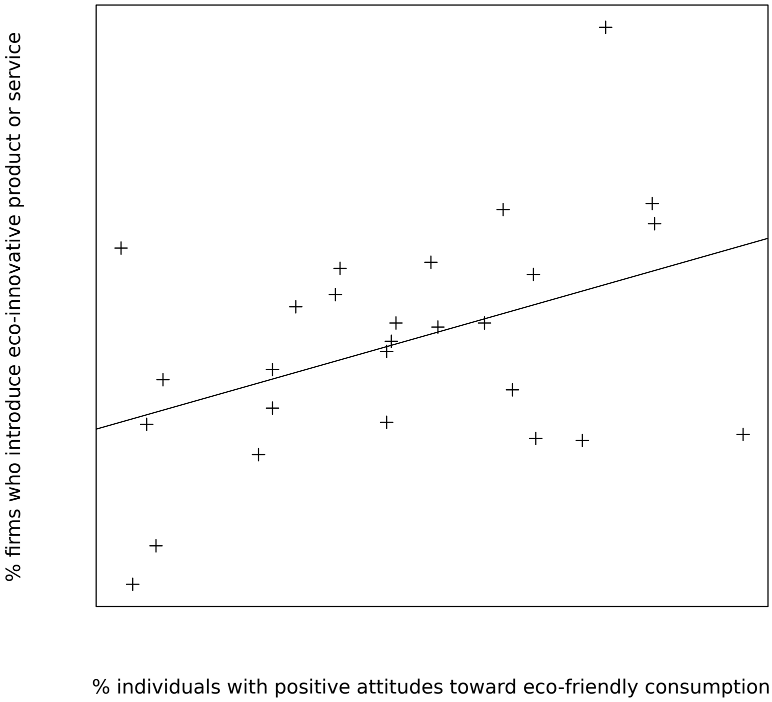


Figure 3: Cross-country correlation between the share of firms who introduced an eco-innovative product or service during the last two years and the fraction of respondents to the Eurobarometer who agree with the statement “You are ready to buy environmentally friendly products even if they cost a little bit more.”. Source: Flash Eurobarometer 315 (2011) and European Commission (2011).

Table 2: Percentage firms who introduced an eco-innovative product or service and the fraction of the population with positive attitudes toward eco-friendly consumption: cross-country estimates.

Dependant variable: *% firms who introduced an eco-innovative product or service*	1	2	3
% with positive attitudes toward eco-friendly consumption	0,33**	0,44**	0,56***
	(0,14)	(0,18)	(0,19)
GDP per capita		$-6{\cdot}10^{-5}$	-3,2*
		$(6{\cdot}10^{-5})$	(0,18)
Green taxes			-810^{-5}
			$(6{\cdot}10^{-5})$
R-squared	0,19	0.22	0.31

*Source: GDP per capita from World Development Indicators and Green taxes from EUROSTAT. OLS Estimates. Standard errors in parentheses. *Significant at 10%, **Significant at 5%, ***Significant at 1%.*

with a more favourable impact on some social or environmental issue (e.g., preservation of natural resources, climate change, animal welfare, human rights). This assumption has broad empirical support. For instance, a European survey reveals that more than 8 over 10 EU citizens felt that a product’s impact on the environment is a critical element when deciding which product to buy (Flash Eurobarometer 256, 2009). Another poll highlights that 62 % of European citizens would be prepared to change shopping habits in order to buy animal-friendly products (Special Eurobarometer 270, 2006). More generally, according to a European survey, nearly half European citizens would be willing to pay more for products or services from companies that respect ethical considerations (Flash Eurobarometer 256, 2009). Another poll in the US reveals that (i) 68 % of the population would pay significantly more for a twenty-dollar sweater made under good working conditions, (ii) 75 % of coffee buyers would be willing to pay at least 50 cents more per pound for fair-trade coffee (Hertel *et al.*, 2009). This figure is strengthened by a field experiment carried out in a shop of South Michigan where individuals had to choose between two alternative products among which one was labelled with good working conditions. The authors found that when the price for the labelled products was raised by 5%, 10%, 20%, 30% and 40% respectively, between 25% and 30% of the customers chose the labelled variant (Hiscox *et al.*, 2006). Also, in Sweden, Schollenberg (2012) uses a revealed preferences approach on weekly scanner sales panel data and finds a significant price premium (38%) for fare trade labelled coffee. There also exist studies on actual behaviours regarding environmentally friendly products. For instance, Teisl *et al.* (2002) use aggregate time series to study the impact of the dolphin-safe label on consumption of canned Tuna in the United States. They find that the label had a significant (positive) effect on consumer's behaviours. In the same vein, Bjørner *et al.* (2004) investigate the effect of the Swan label on Danish consumers choice. Using a panel data set, they provide evidence for a significant effect of the label on consumers' choice. Estimates of the marginal willingness to pay for the Swan-labelled paper ranges between 13% and 18% of the price. Researches on vegetarianism provide another empirical support. In particular, sociological studies indicate that people who adopt a vegetarian diet are mainly motivated by ethical reasons, i.e., environmental protection and animal welfare (Beardsworth and Keil, 1992, Kalof *et al.* 1999).

The last main assumption is that consumers' ethical attitudes are transmitted internationally as a result of social interactions which involve purposeful socialization actions. There exists a large literature on the determinants of ethical purchasing behaviours where it has proven difficult to find significant effects of socio-demographic characteristics (Diamantopoulos, 2003, Special Eurobarometer 270, 2006)[10]. Rather various works suggest that norms and social interactions are major determinants of ethical consumption (see Shaw and Clark, 1999, Thøgersen, 1999, Starr, 2009, for ethical consumption choices in general, Wilhite *et al.*, 1996, for energy use behaviour, Ek and Söderholm,

[10] Rob Harrison, a Director at Ethical Consumer Research Association, declared "The annual Ethical Consumer Markets Reports have shown significant growth each year since the onset of the recession. This clearly demonstrates that the trend towards ethical buying is not a luxury which consumers choose to drop when the going gets tough, but an important long-term change in the way people are making buying.", quoted in the Ethical Market Report 2013

2008 for purchases of green electricity). In particular, the study by Shaw and Clark reveals that family and friends play an important role in influencing ethical consumers.

Works on environmentally friendly attitudes suggest more precisely that (i) these attitudes are acquired during childhood (see Inglehart 1995, 2000), (ii) parents and peers are involved in children's socialization to environmental preferences (see Chawla, 1998, Villacorta *et al.*, 2003). Sociologists have more precisely interested in socialization to organic food consumption practices. One qualitative study on 53 women in Canada indicates that parents wanted their child to be socialize into their ethical purchasing behaviours (Cairns *et al.*, 2013). For example, one respondent to the survey declared:

"I want my daughter to learn where things come from... I think it's the education, like setting examples for your kids". Parents also reported to consciously bring children to farmers markets so that they could develop a sense of connection to their food source. For instance, one parent said

"it is just about teaching my kids what are ethical choices. It matters where we buy things from, it matters how much we consume.".

Sociological studies on vegetarianism have also documented the existence of a socialization process which involves parents' and peers' socialization actions (Maurer, 2010, Boyle, 2011). One survey on a group of vegetarian reveals that 63% of them say to have become vegetarian after meeting another vegetarian while 40% of the same respondants claim to have influenced the decision of becoming vegetarian of at least one people (Maurer, 2010). Boyle writes that "major agents of socialization in the process of affiliating to vegetarianism are other individuals (which includes family, peers, and educators)". In a survey on 45 vegetarians, he found that 34 claimed they became vegetarians because of being in contact with some other vegetarians: either family members or role models. One respondent declared:

"I have pretty much grown up with it [vegetarianism]. My grandmother is a vegetarian. My mom passed away when I was young, but she was a vegetarian. [...]. That had some influence." (p.98). Another reported that:

"it was an environmentally focused English class [...] We had this book that was a compilation of a bunch of different environmental essays. One of the one's she made us read was called "Beyond Beef" by Jeremy Rifkin [...] basically deals with the environmental effects of cattle ranching. [...] The environment and food consumption was never really brought to my attention. I never really did any research on my own, but I immediately stopped eating beef at the time." (p 100).

The importance of social interactions in the transmission of the vegetarian lifestyle has also been highlighted by leaders of the movement as Keith Akers, who stressed that "even if it were possible for vegetarians to live a life apart from non-vegetarians, it would not be desirable; the spread of vegetarian ideas is greatly facilitated by a social mixing of vegetarians in the larger non-vegetarian population." (Maurer, 2010, P.91).

3 The model

3.1 Ethical and conventional consumers

3.1.1 The demand for sustainable versus unsustainable products

I consider an economy with an overlapping generations structure. Each cohort is a continuum of agents with measure normalized to one. Individuals live for two periods. During the first period, which is childhood, all members are identical and are subject to socialization. Once adult, agents differ according to their preferences which are defined over an unsustainable good, a sustainable good and some public good[11]. Ethical consumers, associated with the superscript E, have higher preferences for the sustainable good and also enjoy the level of public good G[12]. Conventional agents, associated with the superscript C, only derive utility from consumption of private goods and have higher preferences for the unsustainable good. At time t, utilities of agents E and C are respectively given by

$$U^E(x_{st}, x_{ut}, G_t) = {x_{st}}^{\theta} \cdot {x_{ut}}^{1-\theta} + v(G_t), \tag{1}$$

$$U^C(x_{st}, x_{ut}) = {x_{st}}^{1-\theta} \cdot {x_{ut}}^{\theta}, \tag{2}$$

with $v^{'} > 0$, $v^{''} \leq 0$ and where x_{jt} is consumption of good $j \in \{s, u\}$ at time t and $\theta \in]\frac{1}{2}, 1]$ captures preferences for the sustainable, s, (resp. unsustainable, u) good of ethical (resp. conventional) agents[13,14].

[11] I shall make clearer the precise effect of these two types of goods on the production of public good later on.

[12] As highlighted in footnote 5, the last assumption has empirical foundation. However I could have assumed that both types of agents identically value the public good. Note that due to a continuum of agents, preferences for ethical consumption cannot be induced by preferences for the public good (as agents do not internalize the effect of their own consumption on the public good).

[13] I choose simple forms for utility functions because I want this model to be as transparent as possible. I could consider non-symmetric preferences. Assuming that conventional agents have higher preferences for the unsustainable is not necessary. One merely requires that ethical agents value more the sustainable good. Also, I could choose a CES utility function. I purposefully consider a low substitutability to show that my results do not rely on a high substitutability assumption.

[14] I assume that the level of public good and the amount of ethical consumption enter separately in the utility function. This assumption allows me to keep analytical tractability. Note that for sufficiently simple forms for G_t,

Agent maximise their utility subject to the budget constraint

$$I_t = p_{st}x_{st} + p_{ut}x_{ut}, \tag{3}$$

where I_t is the individual income and p_{st} (resp. p_{ut}) the price of the sustainable (resp. deteriorating) good[15]. It leads to the following individual demand functions for agents E and C respectively,

$$x^E_{s\,t} = \tfrac{I_t}{p_{st}}\theta, \qquad x^E_{u\,t} = \tfrac{I_t}{p_{ut}}(1-\theta),$$

$$x^C_{s\,t} = \tfrac{I_t}{p_{st}}(1-\theta), \qquad x^C_{u\,t} = \tfrac{I_t}{p_{ut}}\theta.$$

Let denote by q_t the fraction of agents of type E at time t. The aggregate demand for sustainable and unsustainable goods are respectively given by

$$X_{st} = \tfrac{I_t}{p_{st}}\left(q_t\theta + (1-q_t)(1-\theta)\right),$$

$$X_{ut} = \tfrac{I_t}{p_{ut}}\left(q_t(1-\theta) + (1-q_t)\theta\right).$$

3.1.2 Dynamics of Preferences

I follow the model proposed in Bisin and Verdier (2001) by assuming that preferences are transmitted intergenerationally through social interactions taking place within the family and the society. Each parent has one child who is born without defined preferences. The child, who is first exposed to socialization by family, adopts its parent's preferences with some probability p^i, $i \in \{E, C\}$. If socialization by the family, (referred to as "direct transmission") fails, the child picks up the trait of a model chosen randomly within the society (called "oblique transmission"). Hence, the probability to choose a model of type E (resp. C) is the fraction of agents E (resp. C) in the population, namely q_t (resp. $1-q_t$). Let me denote by $P^{ii'}_t$ the probability for a parent of type i to have a child of type

e.g., $G_t = \frac{Y_{st}}{Y_{ut}}$, one could still solve the model analytically. This would produce an additional effect of technological change on ethical consumer culture through a change in the amount of public good. This new force works in the same direction that the one I already emphasize in the model so that results would be preserved.

[15]Income consists in labour income plus a share of firms' profit.

i', one has

$$P_t^{EE} = p_t^E + (1 - p_t^E)q_t, \qquad P_t^{EC} = (1 - p_t^E)(1 - q_t),$$
$$P_t^{CC} = p_t^C + (1 - p_t^C)(1 - q_t), \quad \text{and} \quad P_t^{CE} = (1 - p_t^C)q_t,$$

which leads the dynamics of q_t to be given by

$$q_{t+1} = q_t + q_t(1 - q_t)(p^E - p^C). \tag{4}$$

Socialization choices of parents

Motivated by evidence exposed in Section 2, I assume that parents may exert a socialization effort τ in order to increase the probability to transmit their preferences[16]. This effort generates a utility cost $c(\tau)$. In what follows, I assume $p^i = \epsilon \ln(\tau^i)$ and $c(\tau^i) = C\tau^i$[17]. The incentive to transmit one's own preferences comes from imperfect altruism, i.e., parents are able to correctly assess the optimal choices of their child but only through the filter of their own preferences. Also, I suppose that parents are myopic: they assess the future welfare of their child with current economic variables rather than future ones[18]. At time t, the parent of type i chooses τ^i to maximise,

$$P_t^{ii} V_t^{ii} + P_t^{ii'} V_t^{ii'} - c(\tau^i).$$

Given the expressions for P^{ii}, $P^{ii'}$, this leads to

$$\tau_t^E = \frac{\epsilon}{C}(1 - q_t)\Delta V^E,$$
$$\tau_t^C = \frac{\epsilon}{C} q_t \Delta V^C,$$

[16]Both ethical and conventional parents are assumed to exert a socialization effort. This assumption may be rationalized on an empirical basis. One reason is that consumption of unsustainable goods has been associated with social status (e.g., eating meet, buying car), which preferences are arguably transmitted in such a way (see Janoski and Wilson, 1995, for empirical evidence, Bisin and Verdier, 1998 for a theoretical framework). However, I could derive these results from a model where only ethical agents actively socialize their child. This would require some refinements of the transmission process, for instance (i) the conventional trait is adopted by default and (ii) transmission by role model is biased (see Bezin, 2015).

[17]This particular functional forms simplify the study of the transitory dynamics since they allow to have a two- rather than a three-dimensional system. Clearly, they do not affect results on steady states.

[18]This assumption allows to avoid multiple equilibria generating by self-fulfilling expectations. For the purpose of this paper, this would not generate further interesting results while considerably complicating the analysis.

where

$$\Delta V^E = \frac{I_t}{p_{st}} \frac{p_{st}}{p_{ut}}^{(1-\theta)} \Theta,$$
$$\Delta V^C = \frac{I_t}{p_{ut}} \frac{p_{st}}{p_{ut}}^{-(1-\theta)} \Theta,$$

and $\Theta = \theta^\theta (1-\theta)^{(1-\theta)} - \theta^{(1-\theta)}(1-\theta)^\theta$. Socialization efforts depend on two forces. First, there is a (negative) "group free-riding effect" due to cultural substitutability: as the fraction of agents with similar preferences increases, oblique transmission within the society is more effective which reduces the incentive to actively transmit one's own preferences. Second there is a (positive) price effect: when the relative price of the sustainable (resp. deteriorating) good is lower, the gain for type E (resp. type C) parents to transmit their own preferences increases. The price effect rises the incentive to actively transmit the ethical (resp. conventional) trait.

At equilibrium, the dynamics of the share of type-E agents is given by[19]

$$q_{t+1} = q_t + q_t(1-q_t)\epsilon \left(\ln(\frac{\epsilon}{C}(1-q_t)\frac{I_t}{p_{st}} \frac{p_{st}}{p_{ut}}^{(1-\theta)} \Theta) - \ln(\frac{\epsilon}{C} q_t \frac{I_t}{p_{ut}} \frac{p_{st}}{p_{ut}}^{-(1-\theta)} \Theta) \right). \tag{5}$$

3.2 The technology

3.2.1 The supply of sustainable versus unsustainable products

The production structure is in line with Acemoglu *et al.* (2012). Two sectors in perfect competition produce either a sustainable good or an unsustainable good using labour and a continuum of sector-specific machines. In the sustainable and unsustainable sector respectively the production functions are given by

$$Y_{st} = L_{st}^{1-\alpha} \int_0^1 A_{skt}^{1-\alpha} z_{skt}^\alpha dk, \qquad Y_{ut} = L_{ut}^{1-\alpha} \int_0^1 A_{ukt}^{1-\alpha} z_{ukt}^\alpha dk, \tag{6}$$

with $\alpha \in [0,1]$, L_{jt} is the quantity of labour used in sector $j \in \{s,u\}$ at time t, z_{jkt} is the quantity of machine k used in sector j at time t and A_{jkt} the productivity of this machine.

The machines are supplied by firms in monopolistic competition. These firms use labour to produce machines: producing one unit of machine requires Ψ units of labour.

[19]Note that parameters C and ϵ can always be chosen such that $p^i \in [0,1]$ $\forall i \in \{E, C\}$.

The supply of labour is inelastic. Labour market clearing requires

$$L_{st} + L_{ut} + \Psi \int_0^1 z_{skt} dk + \Psi \int_0^1 z_{ukt} dk \leq 1. \tag{7}$$

3.2.2 The innovation possibility frontier

I consider a continuum of scientists with mass normalize to 1, who have to decide whether to direct their research toward the sustainable or the unsustainable sector. At the beginning of period t, a scientist decides to undertake research in sector j. He is then randomly allocated to one machine, indexed by k, and is successful in innovation with some probability $\eta \frac{{A_{jt-1}}^{\lambda} A_{j't-1}^{1-\lambda}}{A_{jkt-1}}$, $\lambda \in [0,1]$. In such a case, he increases the productivity of machine k by a factor γ and becomes the monopolist producer of this machine. The probability of success captures two important features. First, there exist positive aggregate knowledge spillovers (including cross-sector spillovers), i.e., productivity in both sectors has a positive impact on future productivity of the firm. Second, I assume decreasing returns to innovation, i.e., a negative effect of a firm's own past research on the return to future innovation[20]. If the scientist is not successful, monopoly rights are randomly allocated to entrepreneurs drawn from the pool of all potential entrepreneurs who then use the old technology.

Let assume that there is symmetry, i.e., $A_{jk} = A_{jk'}$ $\forall j$, and denote by r_t, the share of scientists who work in sector s at time t, the dynamics of relative productivity is given by

$$\frac{A_{st+1}}{A_{ut+1}} = \frac{1 + \gamma\eta r_{t+1} {\frac{A_{st}}{A_{ut}}}^{\lambda-1}}{1 + \gamma\eta(1 - r_{t+1}) {\frac{A_{st}}{A_{ut}}}^{1-\lambda}} \frac{A_{st}}{A_{ut}} \tag{8}$$

3.3 The public good

For the production of public good, I suppose the following general formulation,

$$G_t = G(G_{t-1}, Y_{st}, Y_{ut}), \tag{9}$$

with $\frac{\partial G}{\partial G_{t-1}} \geq 0$, $\frac{\partial G}{\partial Y_{st}} > \frac{\partial G}{\partial Y_{ut}}$. This production function captures the simple idea that certain technologies are more harmful to given public goods than others. For a fixed level of production, the level of public good G_t is enhanced whenever the share of sustainable good in total production is higher[21].

[20]This assumption is purposefully introduced so as to show that, in the present framework, increasing returns are not necessary anymore.

[21]There exist many possible functional forms for the public good production function. More refinements on this function will be done when needed later on.

4 Equilibrium Dynamics

Definition 1 (Temporary Equilibrium) *For $j \in \{s,u\}$, $i \in \{E,C\}$, an equilibrium consists in prices for final goods (p_{jt}), individual demands for final goods (x^i_{jt}), socialization choices (τ^i_t), prices for machines (p_{jkt}), demands for machines (z_{jkt}), labour demands (L_{jt}), research allocation $\{r_t\}$, distribution of preferences for ethical consumption $\{q_t\}$ and level of public good, G_t, such that at each t, (i) (x^i_{st}, x^i_{ut}, τ^i_t) maximizes utility of individuals of type i, (ii) (p_{jkt}, z_{jkt}) maximizes the profit for the producer of machine k in sector j, (iii) L_{jt} maximises the profit of the producer of the final good j, (iv) (p_{jt}, w_t) respectively clears the market for final good j and the labour market, (v) r_t maximises the expected profit of scientists.*

Let the wage be the numeraire. Profit maximisation by producer in final sector j delivers

$$1 = (1-\alpha)\, p_{jt} L_{jt}^{-\alpha} \int_0^1 A_{jkt}^{1-\alpha} z_{jkt}^{\alpha} dk, \qquad j \in \{s,u\}\,, \tag{10}$$

$$z_{jkt} = \left(\frac{\alpha p_{jt}}{p_{jkt}}\right)^{\frac{1}{1-\alpha}} A_{jkt} L_{jt}, \qquad j \in \{s,u\}\,. \tag{11}$$

Equalizing equation (10) for all $j \in \{s,u\}$, one deduces

$$\frac{p_{st}}{p_{ut}} = \frac{A_{st}}{A_{ut}}^{-(1-\alpha)}. \tag{12}$$

The producer of machine k in sector j maximises its profit given by $\pi_{jkt} = (p_{jkt} - \Psi) z_{jkt}$. Given the iso-elastic demand curve for machines, the price of machine k in sector j is set to $p_{jkt} = \frac{\alpha}{\Psi}$. Let assume $\Psi = \alpha^2$, the equilibrium demand for machine k in sector j is given by

$$z_{jkt} = p_{jt}^{\frac{1}{(1-\alpha)}} A_{jt} L_{jt}.$$

I deduce the equilibrium profit of the producer of machine k in sector j

$$\pi_{jkt} = \alpha(1-\alpha) p_{jt}^{\frac{1}{(1-\alpha)}} A_{jt} L_{jt},$$

The expected profit of a scientist who engages in sector j at time t is given by

$$\Pi_{jt} = \eta \frac{A_{jt-1}}{A_{j't-1}}^{\lambda-1} \alpha(1-\alpha)(1+\gamma) p_{jt}^{\frac{1}{1-\alpha}} L_{jt} A_{jt-1}.$$

At equilibrium, the ratio of expected profits for scientists then writes as

$$\frac{\Pi_{st}}{\Pi_{ut}} = f(q_t)\left(\frac{A_{st-1}}{A_{ut-1}}\right)^{2(\lambda-1)} \frac{1+\gamma\eta(1-r_t)(\frac{A_{st-1}}{A_{ut-1}})^{(1-\lambda)}}{1+\gamma\eta r_t(\frac{A_{st-1}}{A_{ut-1}})^{(\lambda-1)}}, \tag{13}$$

where

$$\begin{aligned} f(q_t) &= \frac{q_t\theta + (1-q_t)(1-\theta)}{(1-q_t)\theta + q_t(1-\theta)} \\ &= \frac{q_t(2\theta-1)+(1-\theta)}{\theta - q_t(2\theta-1)}. \end{aligned}$$

The higher this ratio, the more profitable it is to undertake research in the sustainable sector. At equilibrium, incentives to conduct R&D in the sustainable sector are shaped by two opposite forces, (i) a positive "market size effect of culture": the more prevalent is ethical consumer culture as given by q_t, the higher the market size for sustainable goods and the higher the incentive for scientists to undertake research in the sustainable sector, (ii) a negative impact of decreasing returns in past research, i.e., the more intensive the past research in the sustainable sector (the higher the ratio $\frac{A_{st-1}}{A_{ut-1}}$), the lower additional profits in the sustainable sector and the lower the incentive to direct research to this sector.

Lemma 1 *Suppose that $\epsilon < \frac{(1-\lambda)(1-\alpha)(2\theta-1)^2}{4\theta(1-\theta)}$, there exists an increasing map X going from $[0,1]$ into $\mathbb{R}^+$, implicitely given by $f\left(Q(q,X(q))\right)\cdot X(q)^{2(\lambda-1)} = 1$, and such that*

$$\begin{aligned} &\frac{A_{st+1}}{A_{ut+1}} \geq \frac{A_{st}}{A_{ut}}, \\ \Leftrightarrow &\frac{A_{st}}{A_{ut}} \leq X(q_t). \end{aligned}$$

Proof. See Appendix 8.1. ■

The two forces that shape relative profits determine the dynamics of relative productivities given in Lemma 1. On the one hand, due to decreasing returns in past research, the higher the ratio of past productivities $\frac{A_{st}}{A_{ut}}$, the lower the incentive to make research in the sustainable sector which negatively affects the future relative productivity in this sector. On the other hand, due to the market size effect of culture, the more prevalent is ethical consumer culture, the higher profits in the sustainable sector and so is the incentive to undertake research in this sector. This positively affects future productivity of machines in the sustainable sector[22].

Lemma 2 (Equilibrium Dynamics of Preferences) *There exists a function Y mapping $[0,1]$ into $\mathbb{R}^+$ given by $Y(q_t) = {\frac{q_t}{1-q_t}}^{\frac{1}{(1-\alpha)(2\theta-1)}}$, such that*

$$q_{t+1} - q_t \geq 0 \Leftrightarrow \frac{A_{st}}{A_{ut}} \geq Y(q_t). \tag{14}$$

Proof. Using equations (5) and (12), the proof is straightforward. ■

According to Lemma 2, the fraction of ethical consumers increases when (i) the past fraction of ethical consumers is low, (ii) productivity in the sustainable sector is high. Due to the group fee riding effect, the higher the fraction of ethical (resp. conventional) agents, the lower the incentive to actively transmit the ethical (resp. conventional) cultural trait. This negatively affects the dynamics of preferences for ethical (resp. conventional) consumption. The second effect is the technological effect on socialization. When relative productivity in the sustainable (resp. deteriorating) sector increases, the relative price of the sustainable (resp. deteriorating) good reduces. This change positively (resp. negatively) affects the gain for ethical parents to transmit preferences for ethical consumption which increases the incentive to socialize children to the ethical trait.

From both previous Lemma, we deduce the dynamics of the economy which is summed up in the following Proposition.

Proposition 1 *Suppose that $\lambda > \frac{1}{2}$,*

(i) If $(1-\alpha)(2\theta-1)^2 < 2(1-\lambda)$, the system admits one attracting fixed point $(q, \frac{A_s}{A_u}) = (\frac{1}{2}, 1)$. For all $\frac{A_{s0}}{A_{u0}} \in \mathbb{R}^+$, and all $q_0 \in [0,1]$, $(q_t, \frac{A_{st}}{A_{ut}})$ converges to $(\frac{1}{2}, 1)$.

(ii) If $(1-\alpha)(2\theta-1)^2 > 2(1-\lambda)$, the system admits two attracting fixed points $(\bar{q}_1, \frac{\bar{A}_{s1}}{\bar{A}_{u1}}$, $(\bar{q}_2, \frac{\bar{A}_{s2}}{\bar{A}_{u2}})$ with $\bar{q}_1 < \frac{1}{2} < \bar{q}_2$ and $\frac{\bar{A}_{s1}}{\bar{A}_{u1}} < \frac{1}{2} < \frac{\bar{A}_{s2}}{\bar{A}_{u2}}$. For all $\frac{A_{s0}}{A_{u0}} < 1$, $q_0 < \frac{1}{2}$, $(q_t, \frac{A_{st}}{A_{ut}})$ converges to $(\bar{q}_1, \frac{\bar{A}_{s1}}{\bar{A}_{u1}})$. For all $\frac{A_{s0}}{A_{u0}} > 1$, $q_0 > \frac{1}{2}$, $(q_t, \frac{A_{st}}{A_{ut}})$ converges to $(\bar{q}_2, \frac{\bar{A}_{s2}}{\bar{A}_{u2}})$.

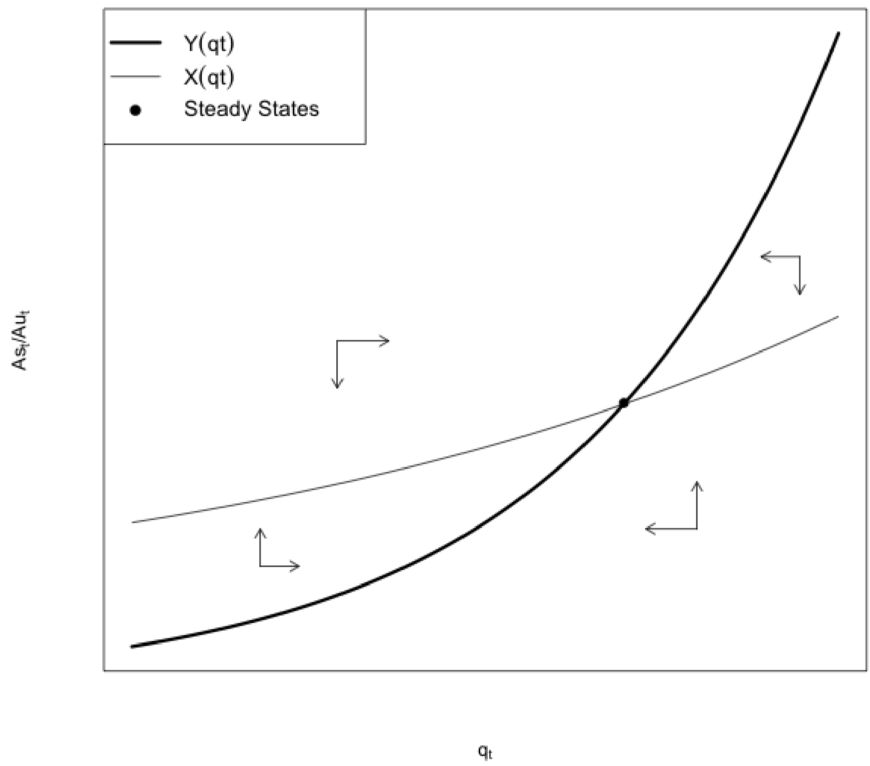
[22] Actually, there is an additional effect from past productivity through its effect on socialization effort and then on ethical consumer culture at time t. With $\epsilon < \frac{(1-\lambda)(1-\alpha)(2\theta-1)^2}{4\theta(1-\theta)}$, I assume that this effect is small enough compared to decreasing returns. Had this effect been high, an additional force toward aggregate increasing returns would have arisen.

Proof. See Appendix 8.2. ■

The rational for Proposition 1 goes as follows. Four forces shape the global dynamics of the economy. These forces can be divided into two groups: forces to substitutability and forces to complementarities. The first set includes the group free-riding effect and the impact of decreasing returns to innovation. Due to the group free-riding effect, a rise in the share of ethical consumers, q_t, negatively affects the future share of these consumers. At point $(\frac{1}{2}, 1)$, the strength of the group-free riding effect is equal to one. Moreover, given decreasing returns in past research, an increase in the relative productivity in the sustainable sector, $\frac{A_{st}}{A_{ut}}$, has a negative impact on future relative productivity in this sector, which impact is measured by the term $2(1-\lambda)$. The second set of forces captures the novelty of this model, i.e., interactions between ethical consumer culture and the technology. The first new force is the market size effect of culture as measured by $(2\theta-1)$: the higher θ, which captures relative preferences for clean goods, the higher the impact of a cultural change on relative profits. The second force is the technological effect on socialization given by $(2\theta-1)(1-\alpha)$: (i) the lower α, the higher the share of labour in final goods production, the stronger the impact of technological change on relative prices, (ii) the higher θ, the greater the impact of a price change on the welfare of ethical child and so on socialization effort of ethical parents.

If $(1-\alpha)(2\theta-1)^2 < 2(1-\lambda)$, the forces to global substitutability outweigh the forces to complementarities. At point $(q, \frac{A_s}{A_u}) = (\frac{1}{2}, 1)$, any rise in $(q_t, \frac{A_{st}}{A_{ut}})$ induces a decrease in the future level of both variables so that the fixed point $(\frac{1}{2}, 1)$ is attracting. If, however, $(1-\alpha)(2\theta-1)^2 > 2(1-\lambda)$, then global complementarities prevail which means that at point $(\frac{1}{2}, 1)$ a rise in $(q_t, \frac{A_{st}}{A_{ut}})$ results in further growth of both variables and the point $(\frac{1}{2}, 1)$ is repelling.

The result of Proposition 1 is illustrated in Figure 4 which depicts the phase diagram of the dynamical system for two different combinations of the parameters: (i) at the top, θ is low with respect to α and λ, (ii) at the bottom, θ is high with respect to α and λ. We see that when θ grows large, there exists path dependency in the direction of innovation: economies which begin with a low productivity in the sustainable sector will innovate less in that sector in the future and will be locked into unsustainable technology-intensive production system.



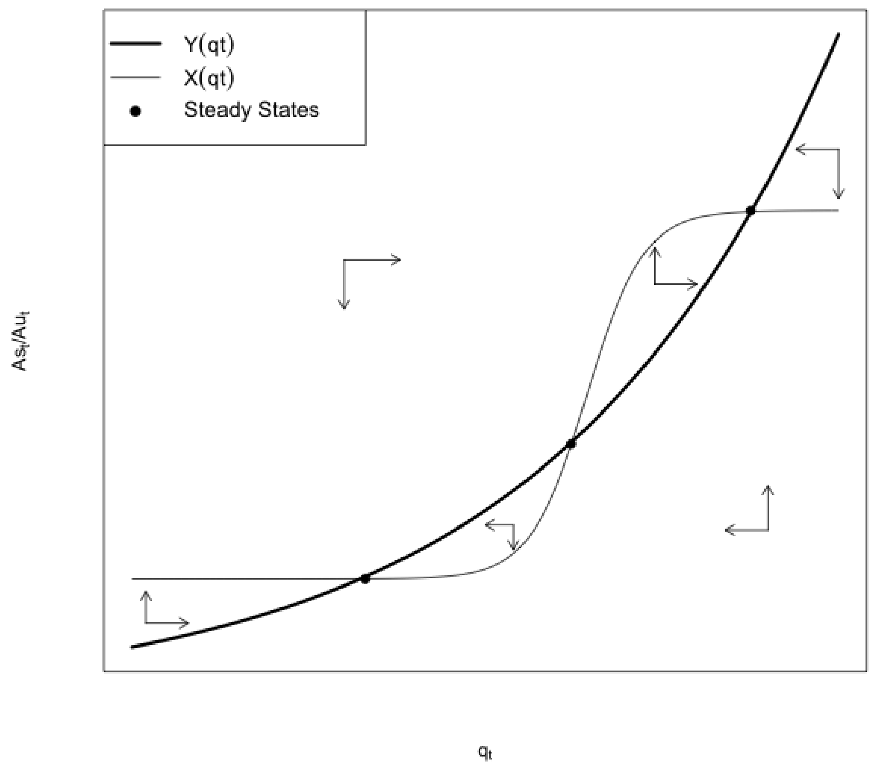


Figure 4: Phase diagram in the $(q_t, \frac{A_{st}}{A_{ut}})$ space when $(1-\alpha)(2\theta-1)^2 < 2(1-\lambda)$ (top) and when $(1-\alpha)(2\theta-1)^2 > 2(1-\lambda)$ (bottom).

This result complements the model proposed in Acemoglu *et al.* (2012). In their paper, path dependency in the direction of innovation relies on strong conditions on the elasticity of substitution between sustainable and unsustainable goods and on the returns on past research. One possible reason is that their framework captures only the technological side of the story. Once we account for interactions between ethical consumer culture and sustainable technological change, conditions on the elasticity of substitution and the returns on past research become much more plausible[23].

Interestingly, when there exists global complementarities, the model predicts that a temporary shock on culture will have long lasting consequences on sustainable technologies. This phenomenon is illustrated in Figure 5 where I draw the evolution of the ratio of productivity $\frac{A_{st}}{A_{ut}}$ beginning at $\frac{A_{s0}}{A_{u0}} = 0.5$ and at two different values of q_0, i.e., $q_0 = 0.4$ (left-hand side) and $q_0 = 0.7$ (right-hand side). A cultural shock has dramatic consequences for long run production methods. One can see that, for the chosen parameters, when $q_0 = 0.4$ the ratio of productivity converges to 0.1 while for $q_0 = 0.7$, this ratio converges to 10.

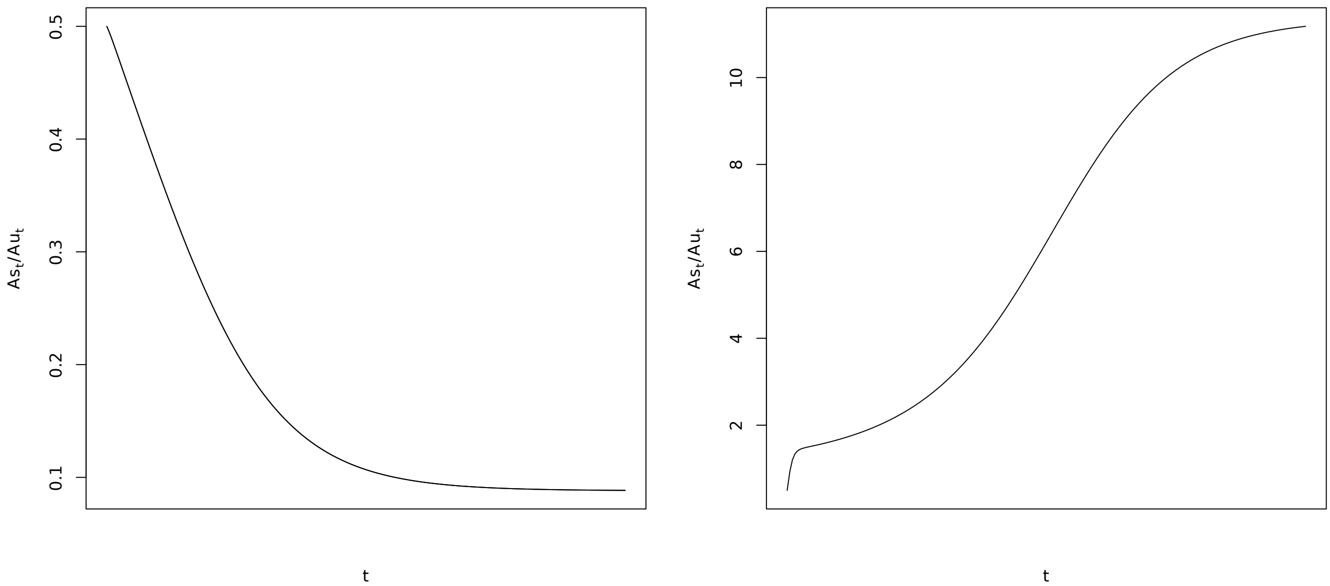


Figure 5: Evolution of the relative productivity in the sustainable sector for $\frac{A_{s0}}{A_{u0}} = 0.5$, $q_0 = 0.4$ (left-hand side) and $q_0 = 0.7$ (right-hand side) with parameters such that $\alpha = 0.1$, $\theta = 0.85$, $\lambda = 0.8$, $\epsilon = 0.3$, $\gamma = 0.9$.

An example of such phenomenon is provided by the impact of the Bovine spongiform encephalopathy (BSE) crisis on organic sector. It is well documented that the crisis had a significant impact on

[23]Remind that, here, the elasticity of substitution is equal to one and there exist decreasing returns on past research.

consumers of organic products (see Corsi and Novelli, 2011, for the impact on willingness to pay for organic beef, Beardsworth and Bryman, 2004, for the effect on the rise of vegetarians in the UK). Long lasting effects of the food crisis may well explain why empirical studies find that current policies have extremely limited effects on the development of organic sector (Padel *et al.*, 1999, Nicholas *et al.*, 2006, European Commission, 2010). In particular, Nicholas *et al.* (2006) find that several years later, the BSE crisis rather than organic farming support policies explains organic farming uptake rates.

In the subsequent part of this paper, I assume $(1-\alpha)(2\theta-1)^2 > 2(1-\lambda)$. Also, in order to be able to solve the model analytically, I set $v(G_t) = G_t^{\mu}$, $\mu \in [0,1]$ and,

$$G_t = \max\{(1+b)G_{t-1} - Y_{ut}, 0\}$$

where b captures a natural regeneration rate. This functional form, which was also adopted in Acemoglu *et al.* (2012) corresponds to the case of a non exhaustible natural resource (e.g., biodiversity, atmosphere).

5 Welfare and public policies

Due to endogenous preferences, this framework is not suitable for standard welfare analysis. In order to gain insights on welfare implications of the previous results, I introduce a partial ordering reflecting Pareto considerations. Since steady state utilities are not constant due to the growth of productivity in each sector, the criteria does not rely on the level of welfare at steady state but rather on its long run growth rate.

Definition 2 (Long run growth rate) *Situation A is a welfare improvement over Situation B if and only if the long run growth rate of utility for each type of agent is at least as great in situation B and, moreover, the long run growth rate of utility for at least one of the agent types is strictly higher in A than in B*[24].

The question I ask here is as follows: which long run equilibrium between the one in which

[24]Note that the criteria could not be growth of GDP. Actually, GDP does not grow here since a scarce factor, i.e., labour, is used for the production of machines. Alternatively, I could have assumed that a mix of the two final goods is used for the production of machines. In such a case, I should have make additional assumptions about this particular production function. Both the impact of GDP growth and of the impact of the characteristics of this production function on equilibrium are beyond the scope of this paper.

$(q, \frac{A_s}{A_u}) = (\bar{q_1}, \frac{\bar{A}_{s1}}{\bar{A}_{u1}})$, i.e., the equilibrium where the unsustainable technology prevails, let say the "conventional equilibrium" and the one in which $(q, \frac{A_s}{A_u}) = (\bar{q_2}, \frac{\bar{A}_{s2}}{\bar{A}_{u2}})$, i.e., the equilibrium where the sustainable technology prevails, referred to as the "ethical equilibrium", is more desirable from the point of view of the criteria introduced in definition 2?

To be able to compare welfare in distinct long run equilibria, I introduce the following parameter which stands for total productivity differences between two economies at distinct steady states.

Lemma 3 *Let $\beta \in \mathbb{R}^+$ such that $\bar{A_{u1}} = \beta \bar{A_{s2}}$, one has $\bar{A_{s1}} = \beta \bar{A_{u2}}$. Whenever $\beta > 1$ (resp. $\beta < 1$) total productivity is higher in the conventional (resp. social) equilibrium.*

Proof. See Appendix 9.1. ■

Assumption 1 *Suppose that*

$$(i) \quad (1+b) > (1+\gamma\eta)^{1-\alpha},$$

$$(ii) \quad \min\{G_0/Z_1, G_0/Z_2\} > 1/\left(1 - \frac{(1+\gamma(\frac{\bar{A}_{s2}}{\bar{A}_{u2}}))}{1+b}\right),$$

where $\gamma(\frac{A_s}{A_u}) = \gamma\eta/\left(\frac{A_s}{A_u}^{1-\lambda} + \frac{A_s}{A_u}^{\lambda-1}\right)$ *and* $Z_i = \frac{I(1-\alpha)^{(1-\alpha)}(\bar{q}_i(1-\theta)+(1-\bar{q}_i)\theta)}{(1+b)} \bar{A_{di}}^{(1-\alpha)}$ *with* $i \in \{1, 2\}$.

I assume that the natural resource grows at a positive rate. This requires that the natural regeneration rate of the resource be higher than the growth rate of consumption[25].

Proposition 2 *Suppose that $\mu \geq (1+\alpha)$, there exists a unique $\beta^* \in]\bar{\beta}, 1[$, with $\bar{\beta} = 1/\left(f(\bar{q_1})\frac{\bar{A}_{s1}}{\bar{A}_{u1}}^{1-\alpha}\right)^{\frac{1}{1-\alpha}}$ such that, if $\beta > \beta^*$, the ethical equilibrium is welfare improvement over the conventional equilibrium.*

Proof. See Appendix 9.2. ■

The ethical equilibrium ensures a higher growth of welfare for a large set of β, the total productivity gap (i.e., for $\beta > \beta^*$). For conventional agents, the growth rate of welfare remains unchanged since productivity in each sector grows at the same rate whatever the long run equilibrium. However, for a large set of β, the ethical equilibrium generates higher growth of the natural resource which turns into higher growth rate of welfare for type E-agents (provided that preferences for the natural

[25] If this condition does not hold, then the stock of natural resource reaches zero in a finite time. Hence, from some date t, the growth rate of the natural resource is zero in each steady state and one trivially shows that the long run growth rate of welfare is the same whatever the long run equilibrium.

resource are high enough i.e., $\mu \geq (1+\alpha)$). Suppose that $\beta = 1$ meaning that total production is the same in each equilibrium. Then, production of unsustainable goods is necessarily lower in the ethical equilibrium. This is because, in that equilibrium, (i) there exists a cultural bias toward ethical consumer, (ii) technology is bias toward the sustainable technology making unsustainable goods more expensive. A lower production of unsustainable goods in the ethical equilibrium implies a higher growth of the natural resource which turns into higher growth of welfare for ethical consumers.

A comment on this result is worthwhile. Under Assumption 1, I consider a case where the natural resource is growing, the alternative situation being trivial with the chosen functional form. Interestingly, one could consider a functional form with multiplicative, rather than linear, negative effects of the unsustainable sector (e.g., $G_{t+1} = \frac{(1+b)G_t}{Y_{ut}}$). Then one could consider cases where the natural resource is decreasing over time. The result would be even stronger. When the natural resource is low, preferences are extremely sensitive to a reduction in the stock of natural resource due to concavity of the utility function. On the contrary, when consumption is high, growth in consumption generates low growth in utility. As a result, in the long run, further decrease in the natural resource induces higher lost of welfare than further increase in consumption.

Which policy can be implemented to reach the Pareto superior equilibrium? In this framework a temporary intervention is sufficient. Let me enlighten this result by considering a subsidy to research in the sustainable sector. Suppose that the government implements a subsidy S (financed through lump-sum tax on consumers' income) such that

$$(1+S)f\left(Q(q_{t-1}, \frac{A_{st-1}}{A_{ut-1}})\right) \cdot \left(\frac{A_{st-1}}{A_{ut-1}}\right)^{2(\lambda-1)} \cdot \frac{1+\gamma\eta(1-r_t)(\frac{A_{st-1}}{A_{ut-1}})^{(1-\lambda)}}{1+\gamma\eta r_t(\frac{A_{st-1}}{A_{ut-1}})^{(\lambda-1)}} > 1.$$

As long as the policy is implemented $\frac{A_{st+1}}{A_{ut+1}} > \frac{A_{st}}{A_{ut}}$ so that there exists $\tilde{t}$ such that $\frac{A_{s\tilde{t}}}{A_{u\tilde{t}}} > 1$. Then, there are two cases.

(i) $\frac{A_{st}}{A_{ut}} < Y(q_t)$, which implies $Y(q_t) > 1 \Leftrightarrow q_t > \frac{1}{2}$. If the government set $S = 0$, given Proposition 1, the system converges to $(\bar{q}_2, \frac{\bar{A}_{s2}}{A_{u2}})$.

(ii) $\frac{A_{st}}{A_{ut}} > Y(q_t)$ which implies $q_{t+1} > q_t$. Either there exists $\tilde{t}$ such that $q_{\tilde{t}} > \frac{1}{2}$. Then the government can set $S = 0$ and given Proposition 1, the system converges to $(\bar{q}_2, \frac{\bar{A}_{s2}}{A_{u2}})$; or there exists $\tilde{t}$ such that $\frac{A_{st}}{A_{ut}} < Y(q_{\tilde{t}})$ and we are in case (i) so that the system converges to $(\bar{q}_2, \frac{\bar{A}_{s2}}{A_{u2}})$ with $S = 0$.

Hence, the subsidy can be implemented for a finite number of periods. This result echoes the conclusions of Acemoglu *et al.* (2012)[26]. In the present framework, however, the policy result relies on the interdependency between consumer culture and technological change.

As highlighted in section 4, not only technology-oriented policies but also government's actions that affect culture (e.g., communication campaign) are relevant instrument to induce long run Pareto-improvements. The next section is dedicated to illustrate the effect of a particular shock on culture, namely an integration shock.

6 International trade

6.1 Theory

In this section, I extend the previous framework to allow for international trade in goods. I am interested in the impact of openness to trade on long run equilibria and implications for welfare.

Let open trade in goods both final and intermediate between two economies which have converged to different steady states but are identical otherwise. Let label these economies the domestic and the foreign economy, the latter being denoted by an asterisk. I assume $(q_0^*, \frac{A_{s0}}{A_{u0}}^*) = (\bar{q}_1, \frac{\bar{A_{s1}}}{\bar{A_{u1}}})$, $(q_0, \frac{A_{s0}}{A_{u0}}) = (\bar{q}_2, \frac{\bar{A_{s2}}}{\bar{A_{u2}}})$ and $A_{s0} > A_{s0}^*$ so that the domestic (resp. foreign) economy has an advantage in producing sustainable (resp. deteriorating) goods, i.e., it produces sustainable (resp. deteriorating) goods at a lower cost[27].

Following openness to trade, within each intermediate sector the world market can be monopolized by the producer with the lowest cost (the range of machines being the same in both countries). In each country, final producers can take advantage of greater productive efficiency: in domestic and foreign country respectively, the production of final good j is then given by

$$Y_{jt} = L_{jt}^{1-\alpha} \int_0^1 \hat{A_{jkt}}^{1-\alpha} z_{jkt}^{\alpha} dk, \qquad Y_{jt}^* = L_{jt}^{*1-\alpha} \int_0^1 \hat{A_{jkt}}^{1-\alpha} z_{djt}^{*\alpha} dk,$$

where $\hat{A_{jkt}} = \max\{A_{jkt}, A_{jkt}^*\}$. In each country, final producer of good j maximises its profit leading

[26] This framework is not suitable for an analysis of optimal policies (see Acemoglu *et al.*, 2012, for a discussion on the optimal use of carbon taxes and subsidies to research in clean sectors).

[27] I skip cases where one country is more efficient in producing each type of good since, then, conclusions are trivial. The less efficient economy converges to the state of the more efficient one.

to the global demand for machines k in sector j,

$$Z_{jkt} = \left(\frac{\alpha \hat{p_{jt}}}{p_{jkt}}\right)^{\frac{1}{1-\alpha}} \hat{A_{jkt}}(L_{jt} + L_{jt}^*), \qquad j \in \{s, u\},$$

where $\hat{p_{jt}}$ is the world price. Also, in each country, final producers equalize marginal productivity of labour to one[28]. One easily deduces that $L_{jt} = L_{jt}^*$ and that the monopolist producer still chooses $p_{jkt} = \alpha$. Replacing $p_{jkt} = \alpha$ in each country's demand for machines and then in the final production function one obtains,

$$Y_{jt} = \hat{p_{jt}}^{\frac{\alpha}{1-\alpha}} \hat{A}_{jt} L_{jt}, \qquad Y_{jt}^* = \hat{p_{jt}}^{\frac{\alpha}{1-\alpha}} \hat{A}_{jt} L_{jt}^*.$$

The world supply then equals $\hat{Y}_j = Y_{jt} + Y_{jt}^*$. Moreover, world demands for final good s and u are respectively given by

$$X_{st} = \tfrac{\hat{I}_t}{\hat{p_{st}}} \left((q_t + q_t^*)\theta + (2 - q_t - q_t^*)(1-\theta)\right),$$

$$X_{ut} = \tfrac{\hat{I}_t}{\hat{p_{ut}}} \left((q_t + q_t^*)(1-\theta) + (2 - q_t - q_t^*)\theta\right).$$

Due to symmetry within producers of machines, it is easy to show that income is the same in both countries after trade integration. One deduces the new ratio of profits at equilibrium as

$$\frac{\Pi_{st}}{\Pi_{ut}} = f(\hat{q}_t) \left(\frac{\hat{A_{st-1}}}{A_{ut-1}}\right)^{2(\lambda-1)} \frac{1 + \gamma\eta(1 - r_t)(\frac{\hat{A_{st-1}}}{A_{ut-1}})^{(1-\lambda)}}{1 + \gamma\eta r_t (\frac{\hat{A_{st-1}}}{A_{ut-1}})^{(\lambda-1)}}, \tag{15}$$

where $\hat{q}_t = \frac{1}{2}q_t + \frac{1}{2}q_t^*$. The dynamics of the economy is described by a system with three state variables $(\frac{\hat{A_{st}}}{A_{ut}}, q_t, q_t^*)$ which, given Lemmas 1 and 2 can be summed up by the following Lemma.

Lemma 4 (Dynamics with international trade)

$$\frac{\hat{A_{st+1}}}{A_{ut+1}} \geq \frac{\hat{A_{st}}}{A_{ut}}, \Leftrightarrow \frac{\hat{A_{st}}}{A_{ut}} \leq X(\hat{q}_t).$$

$$q_{t+1} - q_t \geq 0 \Leftrightarrow \frac{\hat{A_{st}}}{A_{ut}} \geq Y(q_t).$$

$$q_{t+1}^* - q_t^* \geq 0 \Leftrightarrow \frac{\hat{A_{st}}}{A_{ut}} \geq Y(q_t^*).$$

[28] The wage is the same in both countries since marginal productivity of labour naturally equalizes across countries.

Steady states $(\frac{\hat{A_s}}{A_u}, q, q^*)$ are such that

$$\begin{cases} \frac{A_{st+1}\hat{}}{A_{ut+1}} = \frac{\hat{A_{st}}}{A_{ut}} \\ q_{t+1} = q_t \\ q^*_{t+1} = q^*_t \end{cases}$$
$$\Leftrightarrow \begin{cases} \frac{\hat{A_s}}{A_u} = X(\hat{q}) \\ \frac{\hat{A_s}}{A_u} = Y(q) \\ \frac{\hat{A_s}}{A_u} = Y(q^*) \end{cases}$$

This implies $Y(q) = Y(q^*)$ that is $q = q^*$ (since Y is a continuous and monotonous function). I deduce Proposition 3 below.

Proposition 3 *In the long run, trade integration implies convergence of attitudes to ethical consumption across countries.*

Hence, trade integration has critical consequences for ethical consumer culture. This cultural convergence property has been highlighted in Maystre *et al.* (2014) in the context of cultural goods. In the present framework, trade not only has consequences for culture but also for the technology. This is discussed in Proposition 4 below. Note that in this international framework, $\beta > 1$ means that the unsustainable technology is more efficient worldwide than the sustainable technology.

Proposition 4 *After trade integration,*
(i) if the unsustainable technology is more efficient than the sustainable technology, i.e., $\beta > 1$*, the dynamic system described by* $(q_t, q_t^*, \frac{A_{st}}{A_{ut}})$ *converges to* $(\bar{q}_1, \bar{q}_1, \frac{\bar{A_{s1}}}{A_{u1}})$*,*
(ii) if the sustainable technology is more efficient than the unsustainable technology, i.e., $\beta < 1$*, the dynamic system described by* $(q_t, q_t^*, \frac{A_{st}}{A_{ut}})$ *converges to* $(\bar{q}_2, \bar{q}_2, \frac{\bar{A_{s2}}}{A_{u2}})$*.*

Proof. See Appendix 9.3. ■

Trade integration has both short run and long run effects on the technology. In the short run, there is a classical competitiveness effect on the technology, i.e., openness to trade forces the less efficient firms out the market. In this framework, it implies that each country specializes in the production of one type of good. The new ratio of productivities is given by $\frac{\bar{A_{s2}}}{A_{u1}}$. Due to path dependency, the initial technological shock has long lasting effects on the technology. Consider the case $\beta > 1$ which means that the unsustainable technology is the most efficient worldwide, i.e., $\bar{A_{u1}} > \bar{A_{s2}}$. Then, the short run shock is biased toward the unsustainable technology. This implies that the intensity of the initial technological shock is higher in the domestic economy and so is the cultural shock. More precisely, the decrease in the fraction of ethical consumer which takes place in the domestic economy (due to a decrease in $\frac{A_s}{A_u}$) is higher than the rise in the fraction of these agents in the foreign economy (which is due to an increase in $\frac{A_s}{A_u}$). The world fraction of ethical consumer thus reduces. Due to complementarities the decrease in both variables, the ratio of productivities and the fraction of ethical consumer, translates into further decreases and the economy converges to the conventional equilibrium[29].

Corollary 1 *Welfare in the autarkic and integrated equilibrium.*
(i) If the long run productivity gap between the two economies is such that $\beta \in]\beta^*, 1[$, the integrated world equilibrium is welfare improvement over the autarkic equilibrium,
(ii) If the long run productivity gap between the two economies is such that $\beta > 1$, the integrated world equilibrium is welfare deterioration over the autarkic equilibrium.

Proof. Proof is deduced from Proposition 2 and 4. ■

When the productivity gap at steady state is not too low, i.e., $\beta > \beta^*$, the ethical equilibrium is welfare improvement over the conventional equilibrium. Furthermore, when this productivity gap is not too high, i.e., $\beta < 1$, the integrated economy converges to the ethical equilibrium. One can deduce that trade integration leads to welfare improvement. However, when the productivity gap is high i.e., $\beta > 1$, the integrated economy converges to the conventional equilibrium so that trade integration results in welfare deterioration[30].

This model makes a contribution to the "fair trade" debate which has brought heated controversy within the economic field and beyond (see for instance Bhagwati, 1993, 2014, Brittan, 1995, Howse and Trebilcock, 1996). Much of the discussion is about "procedural fairness", that is the consistency between foreign production methods and domestic norms and values. According to Dany Rodick "people attach values to processes as well as outcomes. This is reflected in the norms that shape and constrain the domestic environment in which goods and services are produced." (Rodick, 1997,

[29] The reverse reasoning is true for item (ii) of Proposition 4. Since $\beta < 1$, the integrated economy converges to the ethical equilibrium.

[30] Note that I can only compare steady state situations since (i) absolute productivities in each sector matter for welfare, (ii) this productivities are growing at a non constant rate along the transition path. That is why this Proposition requires a statement about the long run productivity differential.

P.5). In this debate, those who have advocated against trade integration have generally argued that trade has detrimental effects on nationally more sustainable production methods and/or on domestic preferences for this technologies.

Several international disputes illustrate how some countries have intended to impose trade restrictions in order to protect domestic sustainable production methods (e.g., US versus Mexico in the "tuna-dolphin" case, the "US-shrimp" case, the "US-Gasoline" case). For instance, the "US-shrimp" dispute concerned the manner in which fishermen harvested shrimp. In the US, where citizens had been strongly concerned with the preservation of marine biodiversity, new fishing methods were developed to avoid incidental killing of endangered sea turtles. In many trade partner countries, though, fishing methods resulted in a high rate of incidental killing of sea turtles. In order to protect, their own fishing methods, the US imposed an import ban on exporters from other countries: to avoid the ban, exporters were required to demonstrate the use of equipments limiting the incidental catch of endangered sea turtles. The embargo was justified by invoking GATT Article XX of General Exceptions which allows trade restrictions when they aim to protect human and animal life or to conserve natural resources[31,32].

Furthermore, some scholars have argued that countries should be able to refuse trade when it is likely to erode domestic norms and values (see Lamy 2004, Rodick, 1997, Jackson, 1997). Pascal Lamy, a former European Commissioner, claimed that international trade is a threat to nationally chosen collective preferences since "traded goods and services are both an embodiment of and vehicle for the collective preferences of the countries producing them" (Lamy, 2004, p.3). Dany Rodick stressed that "free trade among countries with very different domestic practices requires either a willing to countenance the erosion of domestic structures or the acceptance of a certain degree of harmonization (convergence)" (Rodick, 1997, P.37). An essential argument developed by these scholars for preserving domestic norms is that these norms contribute to the sustainability of their society. According to Dany Rodick, international economic integration may lead to "domestic social disintegration" (p.2).

The present model provides theoretical foundations for the arguments developed by free trade opponents. In particular, if the domestic technology is less efficient than the foreign one, the domestic

[31] Article XX allows measures which are "necessary to protect human, animal or plant life or health; relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption.". Note that in some cases, e.g., the "tuna-dolphin" case, trade restrictions are rejected in spite of Article XX because of inconsistency with other articles. The difficulty with such cases is to disentangle real consumers' concern from protectionism purposes.

[32] See United States - Import Prohibition of Certain Shrimp and Shrimp Products - WTO Doc. WT/DS58/AB/R. World Trade Organization, Appelate Body, Octobre 12, 1998.

economy converges both from a cultural and technical point of view to the foreign economy.

6.2 Empirical evidence: convergence in ethical attitudes

According to Proposition 3, one should find a higher cross-country cultural proximity for attitudes toward goods which are subject to more intense international exchanges. In this section I conduct a small empirical analysis in order to gain insights on the validity of this theoretical prediction.

I consider attitudes toward three different goods, i.e., organic products, cars and an electricity source, i.e., nuclear energy. These examples are relevant for my purpose because these goods are not equally traded across countries. The two first types of good play a major role in international trade while the last one is subject to very few international exchanges. According to the World Trade Organisation, in 2013 agricultural products represented a share of 9.5% in trade of total merchandises and a 30% of total traded primary goods (WTO, 2014). Moreover, in spite of various standards and country-specific regulations which naturally act as trade barriers, around 15% of the USD 14-17 billion organic market are traded (Jones, 2003). Major actors, i.e., United States and European Union import respectively 47 and 42 % of their own consumption.

The car industry also plays a major role in international trade. Automotive products represent 7.4 % of total traded merchandises and 11.4 % of traded manufactured good worldwide (WTO, 2014)[33]. In European Union, which produces a quarter of all motor vehicles, trade in new and used motor cars accounts for 6 % of the total value of all extra-EU exports in 2011 (Eurostat, 2012).

The figure is really different for electricity. Global exports of electricity are currently around 3 percent of total production. In comparison, 64 percent of all oil produced is traded (IEA, 2010). In 2011, exports of electricity amounted to only 0.225% of the value of worldwide trade. This pattern is due to important trade barriers resulting from physical constraints (problem of long distance power transmission) and also regulatory and administrative issues (i.e., country-specific rules and regulations).

Data on attitudes come from the International Social Survey Programme Environment III which covers 33 countries. In the survey, respondents were asked about their attitudes regarding different environmental issues. I consider answers to the three following questions

- "What do you think about pesticides and chemicals used in farming?",
- "What do you think about air pollution caused by cars?",

[33]According to WTO automotive products refer to motor cars and other motor vehicles principally designed for the transport of persons.

- “What do you think about nuclear power stations?”,

There were 5 possible answers: Extremely dangerous for the environment, Very dangerous, Somewhat dangerous, Not very dangerous, Not dangerous at all for the environment[34].

To measure cultural distance between two countries, I use an index of fractionalization proposed in Alesina *et al.* (2003). Denote by ρ_{ij} the fraction of individuals who answer response $i = 1, .., n$, in country j to the question, the fractionalization index $F_{jj'}$ associated to the country-pair (j, j') is given by

$$F_{jj'} = 1 - \sum_{i=1}^{n} \rho_{ij}\rho_{ij'},$$

where $F_{jj'}$ measures the probability that two individuals chosen randomly within each country did not give the same answer to the question about environmental attitudes.

Results are depicted in Figure 6 in which I draw the distribution of fractionalization indexes within the sample for each three kinds of attitudes. The probability distribution of indexes of fractionalization for attitudes to nuclear energy is clearly translated to the right compared to the probability distribution of attitudes to cars and pesticides in farming. Moreover, the mean index of fractionalization is significantly higher for attitudes to nuclear station: 0,74 against 0.70 for pesticides in farming with a t-test significant at more than 1 percent and 0,74 against 0.69 for attitudes to cars also significantly different at more than 1 percent.

I also consider data from Special Eurobarometer 217 (2004) on attitudes toward pesticides in farming and nuclear station. Distributions of fractionalization indexes are drawn in Figure 7. We observe the same pattern, i.e., a higher cross-country distance in attitudes related to goods which are not subject to international exchanges (the mean fractionalization indexes are given by 0.70 and 0.72 for attitudes toward pesticides in farming and attitudes toward nuclear station respectively with a t-test significant at more than 1 percent).

Note that it would be difficult to run a regression with indexes of fractionalization explained by the volume of trade between two countries for a given good. The first practical reason is that we lack data on the volume of trade for this type of goods. For instance, the Research Institute of Organic

[34] I consider attitudes toward the environmental issue rather than attitudes toward consumption of the good as I did not have such data for all the goods considered. This approach has empirical foundations. Evidence indicates that concern about environmental and social issues is an important predictor of attitudes regarding sustainable consumption (see Kalof *et al.*, 1999, for vegetarian diet, Shaw and Newholm, 2002, for ethical consumption, Honkanen *et al.*, 2006, for organic food purchases, Dimantopoulos *et al.*, 2003, for environmentally friendly consumption).

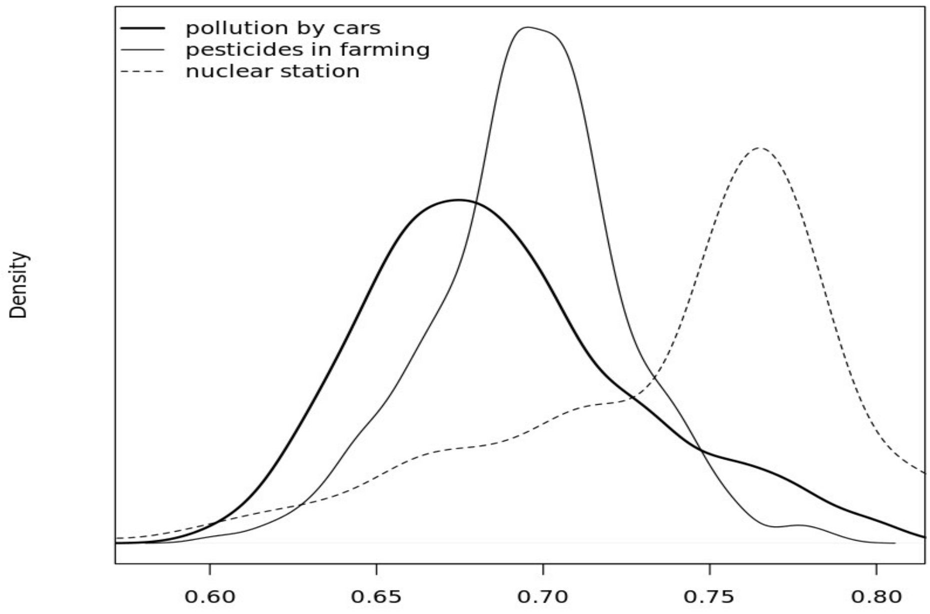


Figure 6: Distribution of fractionalization indexes for attitudes toward air pollution by cars, pesticides in farming and nuclear energy (ISSP, 2012), N=561. Student test for nuclear energy versus pesticides in farming: t = -16, p-value$< 2 \cdot 10^{-16}$; student test for nuclear energy versus cars: t = 17, p-value$< 2 \cdot 10^{-16}$.

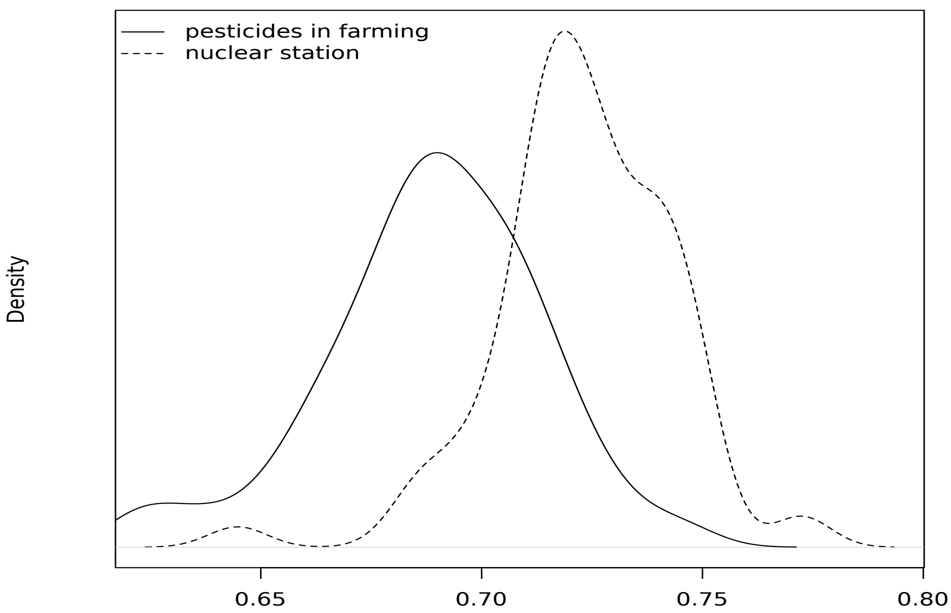


Figure 7: Distribution of fractionalization indexes for attitudes toward pesticides in farming and nuclear energy (Spetial Eurobarometer 217), N=129. Student test for nuclear energy versus pesticides in farming: t = 14, p-value$< 2 \cdot 10^{-16}$.

Agriculture (FIBL) provides data on total exports of organic products by countries. However (i) these data are not systematically comparable between countries due to various collection methods, (ii) data on the volume of trade by pair of countries are not available. Second, there will be an endogeneity issue as it could be the case that two countries exchange more environmentally friendly goods because of similar attitudes. For instance, similar attitudes toward pesticides in farming should imply similar regulation for organic production which should reduce non-tariff trade barriers. The small empirical exercise that is carried out here allows to get rid of this issue as I compare goods rather than the amount of trade across countries.

7 Concluding remarks

This paper has explored a new channel for path dependency in the direction of sustainable innovation. I develop an economic theory where technological lock-in arises from systematic interactions between ethical consumer culture and the technology. This idea has received attention beyond the economic field, where scholars have already argued that economies get stuck into unsustainable production-based systems through a process which involves the co-evolution between norms and technologies (see Unruh, 2000). To the best of my knowledge, no economic approach had been proposed so far. This is mainly because economists have been reluctant to include non market forces in their studies as models could lose any predictive power. To overcome this issue, I draw upon the approach pioneered by Bisin and Verdier (2001) to set up a model where the formation of ethical consumer culture is rooted in the rational choice paradigm. This modelling strategy enables to build a framework which allows to explicitly study the dynamic evolution of ethical consumption, which is affected by the rate of innovation, and the direction of technological change, which depends on the share of ethical consumers.

I show that under plausible conditions, interactions between ethical consumer culture and the technology give rise to aggregate increasing returns to innovation in sustainable sectors. This theory complements the model developed in Acemoglu *et al.* (2012) where path dependency arises but only under strong conditions on the elasticity of substitution between clean and dirty goods and on the returns on past research. One explanation which is explored in this paper is that they have focused only on the technological side of the story. Once we account for interactions with ethical consumer culture, those conditions are substantially relaxed.

The theory is consistent with a number of observations. I show that when conditions for path dependency hold, the joint dynamics of culture and technology implies two distinct long run outcomes: an equilibrium with weak ethical consumer culture and where unsustainable technologies of production prevail, an equilibrium where ethical consumption attitudes are widespread and production methods are biased to sustainable technologies. This result provides a rational for the cross-country correlation between ethical consumption attitudes and the development of sustainable production methods. The theory also predicts that a shock on consumer culture should have long lasting consequences on the technology. This result can contribute to explaining some empirical evidence, e.g., why the current development of organic farming methods is better explained by the BSE crisis than present-day agricultural policies. In addition, I extend the framework to allow for international trade. Here, I show that trade integration implies cross-countries convergence in attitudes toward ethical consumption which is confirmed by the data.

Other extensions could be envisioned. In the present framework, the impact of a public policy is rather trivial. One could have interesting results by endogenizing the policy through a voting mechanism on, for instance, a tax on unsustainable products. Interactions between ethical consumer culture and the technology would also go through the channel of the political economy[35]. Also, while I think of socialization has being realized by parents and role models, I could enrich this framework by introducing other socialization agents (e.g., mass media, NGO leaders). A particularly interesting avenue for further research is to investigate how a cultural leader motivated by some long run environmental objective, affect the dynamics of ethical consumer culture and sustainable technologies.

This research has offered a macroeconomic perspective on the culture of ethical consumption. Future works should explore the microeconomics of ethical choices intending to clarify the role of cultural factors (e.g, social norms, socialization, learning).

[35]There will be two opposite effects: since the tax increases the price of the conventional good, it would positively affect the transmission of ethical consumer culture. However, since a rise in the share of ethical consumer positively affects the level of the public good, the tax would be negatively affected by the prevalence of ethical consumers.

8 Appendix

8.1 Proof of Lemma 1

Decreasing returns to innovation.

Let me start by expressing the relative profit in sector e as a function of variables at time $t-1$ only.

First, using equations (5) and (12), at equilibirum,

$$q_{t+1} = q_t + q_t(1-q_t)\epsilon \ln\left(\frac{1-q_t}{q_t}\frac{A_{st}}{A_{ut}}^{(1-\alpha)(2\theta-1)}\right) \equiv Q(q_t, \frac{A_{st}}{A_{ut}}).$$

Hence, the ratio of profits at time t can be re-written as

$$\frac{\Pi_{st}}{\Pi_{ut}} = f\left(Q(q_{t-1}, \frac{A_{ct-1}}{A_{ut-1}})\right) \cdot \left(\frac{A_{ct-1}}{A_{ut-1}}\right)^{2(\lambda-1)} \cdot \frac{1+\gamma\eta(1-r_t)(\frac{A_{ct-1}}{A_{ut-1}})^{(1-\lambda)}}{1+\gamma\eta r_t(\frac{A_{ct-1}}{A_{ut-1}})^{(\lambda-1)}} \equiv F(r_t, q_{t-1}, \frac{A_{ct-1}}{A_{ut-1}}).$$

Let compute the derivative of the function F with respect to the variable $\frac{A_s}{A_u}$ (omitting time indexation)

$$\begin{aligned}\frac{\partial F}{\partial \frac{A_s}{A_u}} =& f'(Q(q, \frac{A_s}{A_u}))\frac{q(1-q)(1-\alpha)(2\theta-1)\epsilon}{\frac{A_s}{A_u}} \cdot \frac{\frac{A_s}{A_u}^{\lambda-1}+\gamma(1-r)}{\frac{A_s}{A_u}^{1-\lambda}+\gamma r} \\ &- \left[\frac{(1-\lambda)f(Q(q,\frac{A_s}{A_u}))}{\frac{A_s}{A_u}(\frac{A_s}{A_u}^{1-\lambda}+\gamma r)^2}\left((1+\gamma r\frac{A_s}{A_u}^{\lambda-1}) + (1+\gamma(1-r)\frac{A_s}{A_u}^{1-\lambda})\right)\right].\end{aligned}$$

After few manipulations, one finds

$$\begin{aligned}&\frac{\partial F}{\partial \frac{A_s}{A_u}} < 0, \\ \Leftrightarrow &\frac{f'(Q(q,\frac{A_s}{A_u}))}{f(Q(q,\frac{A_s}{A_u}))} q(1-q)(1-\alpha)(2\theta-1)\epsilon < (1-\lambda)\left(1+\frac{1+\gamma r\frac{A_s}{A_u}^{\lambda-1}}{1+\gamma(1-r)\frac{A_s}{A_u}^{1-\lambda}}\right).\end{aligned}$$

-The right-hand side is bounded below by $1-\lambda$.

-Since $\frac{f'(q)}{f(q)}$ is maximal at $q=1$ or 0 and $q(1-q)$ at $q=\frac{1}{2}$, it is easy to show that the left-hand side is bounded above by $\frac{(2\theta-1)^2}{4\theta(1-\theta)}(1-\alpha)\epsilon$.

A sufficient condition for $\frac{\partial F}{\partial \frac{A_s}{A_u}} < 0$ is therefore,

$$\frac{(2\theta-1)^2}{4\theta(1-\theta)}(1-\alpha)\epsilon < 1-\lambda,$$

which is assumed in Lemma 1.

Short run equilibrium for scientits.

From equation (8), one deduces

$$\begin{aligned} &\frac{A_{st+1}}{A_{ut+1}} \geq \frac{A_{st}}{A_{ut}} \\ \Leftrightarrow &\frac{1+\gamma\eta r_{t+1}\frac{A_{st}}{A_{ut}}^{\lambda-1}}{1+\gamma\eta(1-r_{t+1})\frac{A_{st}}{A_{ut}}^{1-\lambda}} \geq 1, \\ \Leftrightarrow &r_{t+1} \geq r(\frac{A_{st}}{A_{ut}}), \end{aligned}$$

where $r(\frac{A_{st}}{A_{ut}}) \in]0,1[$ is such that $\frac{1+\gamma\eta r(\frac{A_{st}}{A_{ut}})\frac{A_{st}}{A_{ut}}^{\lambda-1}}{1+\gamma\eta(1-r(\frac{A_{st}}{A_{ut}}))\frac{A_{st}}{A_{ut}}^{1-\lambda}} = 1$. One easily shows that the map F is decreasing in s. Hence, there exists one unique equilibrium given by

-$r_{t+1} = 1$, iif $F(1, q_t, \frac{A_{st}}{A_{ut}}) \geq 1$,

-$r_{t+1} = 0$, iif $F(0, q_t, \frac{A_{st}}{A_{ut}}) \leq 1$,

-$r_{t+1} \in]0,1[$, iif $F(r_{t+1}, q_t, \frac{A_{st}}{A_{ut}}) = 1$.

Hence,

$$\begin{aligned} &\frac{A_{st+1}}{A_{ut+1}} \geq \frac{A_{st}}{A_{ut}} \\ \Leftrightarrow &r_{t+1} \geq r(\frac{A_{st}}{A_{ut}}), \\ \Leftrightarrow &f\left(Q(q_t, \frac{A_{st}}{A_{ut}})\right) \cdot \left(\frac{A_{st}}{A_{ut}}\right)^{2(\lambda-1)} \geq 1, \\ \Leftrightarrow &\frac{A_{st}}{A_{ut}} \leq X(q_t), \quad \text{where } X(q) \text{ is implicitly given by } \; f\left(Q(q, X(q))\right) \cdot X(q)^{2(\lambda-1)} = 1. \end{aligned}$$

The implicit function theorem gives

$$\frac{dX}{dq} = -\frac{\frac{\partial F}{\partial \frac{A_s}{A_u}}}{\frac{\partial F}{\partial q}} > 0.$$

8.2 Proof of Proposition 1

Existence.

One defines $A(q_t, \frac{A_{st}}{A_{ut}}) \equiv \frac{1+\gamma\eta r_{t+1}\frac{A_{st}}{A_{ut}}^{\lambda-1}}{1+\gamma\eta(1-r_{t+1})\frac{A_{st}}{A_{ut}}^{1-\lambda}}\frac{A_{st}}{A_{ut}}$ since at equilibrium, r_{t+1} is equal to 0, 1 or to a function of variables q_t and $\frac{A_{st}}{A_{ut}}$ implicitly given by $F(r_{t+1}, q_t, \frac{A_{st}}{A_{ut}}) = 1$.

Let study the dynamical system given by

$$\begin{cases} q_{t+1} = Q(q_t, \frac{A_{st}}{A_{ut}}) \\ \frac{A_{st+1}}{A_{ut+1}} = A(q_t, \frac{A_{st}}{A_{ut}}). \end{cases}$$

Stationary equilibria are such that

$$\begin{cases} q_{t+1} = q_t \\ \frac{A_{st+1}}{A_{ut+1}} = \frac{A_{st}}{A_{ut}}. \end{cases}$$

$$\Leftrightarrow \begin{cases} q_{t+1} = q_t \\ \frac{A_{st}}{A_{ut}} = f(q_{t+1})^{\frac{1}{2(1-\lambda)}}, \end{cases}$$

$$\Leftrightarrow \begin{cases} q = 0, \text{ or } q = 1 \text{ or } \frac{A_{st}}{A_{ut}} = (\frac{q_t}{1-q_t})^{\frac{1}{(1-\alpha)(2\theta-1)}} \\ \frac{A_{st}}{A_{ut}} = f(q_t)^{\frac{1}{2(1-\lambda)}}. \end{cases}$$

Two obvious fixed points of the dynamical system are $(0, \frac{1-\theta}{\theta}^{\frac{1}{2(1-\lambda)}})$, and $(1, \frac{\theta}{1-\theta}^{\frac{1}{2(1-\lambda)}})$. Other stationary equilibria are such that ***ici

$$f(q)^{\frac{1}{2(1-\lambda)}} = (\frac{q}{1-q})^{\frac{1}{(1-\alpha)(\theta^G+\theta^B-1)}}, \quad \text{and} \quad \frac{A_c}{A_d} = f(q)^{\frac{1}{2(1-\lambda)}}$$
$$\Leftrightarrow G(q) = 1, \quad \text{where } G(q) \equiv (\frac{q}{1-q})^{\frac{2(1-\lambda)}{(1-\alpha)(2\theta-1)}} f(q)^{-1}, \quad \text{and} \quad \frac{A_s}{A_u} = f(q)^{\frac{1}{2(1-\lambda)}}.$$

Let examine existence of solutions for the equation $G(q) = 1$.

(i) First we have $G(0) = 0$, $G(1) = +\infty$ so that by continuity of the function G, I deduce that

$G(q) = 1$ admits at least one solution which is $q = \frac{1}{2}$.

(ii) Let perform

$$G^{'}(q) = G(q)\left(\frac{2(1-\lambda)}{(1-\alpha)(\theta^G + \theta^B - 1)}\frac{1}{q(1-q)} - \frac{f^{'}(q)}{f(q)}\right).$$

Hence,

$$G^{'}(q) = 0 \Leftrightarrow \begin{cases} G(q) = 0 \Leftrightarrow q = 0, \\ \text{or} \quad \frac{2(1-\lambda)}{(1-\alpha)(2\theta-1)}\frac{1}{q(1-q)} - \frac{f^{'}(q)}{f(q)} = 0 \quad \Leftrightarrow \quad H(q) = 0, \end{cases}$$

where $H(q)$ is a polynomial of order two defined by $H(q) \equiv 2(1-\lambda)\left(\theta - q(2\theta-1)\right)\left(1+\theta+q(2\theta-1)\right) - (1-\alpha)(2\theta-1)^2 q(1-q)$. On $]0,\infty[$, the equation $G^{'}(q) = 0$ admits at least two solutions which implies that on $]0,\infty[$ $G(q) = 1$ admits at most three solutions.

(iii) Then, one deduces that,

if $G^{'}(\frac{1}{2}) \geq 0$, then the equation $G(q) = 1$ admits one unique solution $q = \frac{1}{2}$,

if $G^{'}(\frac{1}{2}) < 0$, then the equation $G(q) = 1$ admits three solutions $\bar{q}_1$, $\frac{1}{2}$ and $\bar{q}_2$ with $\bar{q}_1 < \frac{1}{2} < \bar{q}_2$.

The dynamical system admits one interior fixed point $(q, \frac{A_s}{A_u}) = (\frac{1}{2}, 1)$ if and only if $G^{'}(\frac{1}{2}) \geq 0$ which is equivalent to $2(1-\lambda) > (1-\alpha)(2\theta-1)^2$. The system admits three interior fixed points $(\bar{q}_1, \frac{\bar{A}_{s1}}{A_{u1}})$, $(\frac{1}{2}, 1)$ and $(\bar{q}_2, \frac{\bar{A}_{s2}}{A_{u2}})$ with $\bar{q}_1 < \frac{1}{2} < \bar{q}_2$ and $\frac{\bar{A}_{s1}}{A_{u1}} = f(\bar{q}_1)^{\frac{1}{2(1-\lambda)}} < 1 < \frac{\bar{A}_{s2}}{A_{u2}} = f(\bar{q}_2)^{\frac{1}{2(1-\lambda)}}$ if and only if $G^{'}(\frac{1}{2}) < 0$ or equivalently $2(1-\lambda) < (1-\alpha)(2\theta-1)^2$.

Stability.

First, one shows that fixed points $(0, \frac{1-\theta}{\theta}^{\frac{1}{2(1-\lambda)}})$, and $(1, \frac{\theta}{1-\theta}^{\frac{1}{2(1-\lambda)}})$ are locally unstable. The Jacobian matrix associated to points $(0, \frac{1-\theta}{\theta}^{\frac{1}{2(1-\lambda)}})$ is given by

$$J = \begin{pmatrix} 2(\lambda-1) & \frac{\partial A}{\partial q} \\ 0 & 1 + d^E - d^C \end{pmatrix}$$

The characteristic polynomial associated to this matrix is $P(x) = (2(\lambda-1)-x)(1+d^E-d^C-x)$. Since at point 0, the term $d^E - d^C$ is positive one deduces than one eigenvalue is higher than one so that the point is repelling. For the fixed point $(1, \frac{\theta}{1-\theta}^{\frac{1}{2(1-\lambda)}})$, $P(x) = (2(\lambda-1)-x)(1+d^C-d^E-x)$, with $d^C - d^E > 0$ so that this point is repelling too.

At any interior steady state, the Jacobian matrix associated to the dynamical system is given by,

$$J = \begin{pmatrix} \frac{\partial A}{\partial \frac{A_s}{A_u}} & \frac{\partial A}{\partial q} \\ \frac{\partial Q}{\partial \frac{A_s}{A_u}} & \frac{\partial Q}{\partial q} \end{pmatrix}$$

with

$$\begin{aligned}
\frac{\partial A}{\partial \frac{A_s}{A_u}} &= f(q).\frac{A_s}{A_u}^{2(\lambda-1)}.2(\lambda-1) + \frac{A_s}{A_u}^{2(\lambda-1)} \frac{A_s}{A_u} f^{'}(q) \frac{\partial Q}{\partial \frac{A_s}{A_u}} > 0, \\
\frac{\partial A}{\partial q} &= \frac{A_s}{A_u}^{2(\lambda-1)} \frac{A_s}{A_u} f^{'}(q) \frac{\partial Q}{\partial q} > 0, \\
\frac{\partial Q}{\partial \frac{A_s}{A_u}} &= q(1-q)\epsilon(1-\alpha)(2\theta-1).\frac{A_s}{A_u}^{-1} > 0, \\
\frac{\partial Q}{\partial q} &= 1-\epsilon > 0.
\end{aligned}$$

The determinant of J, $\det(J)$, is then given by

$$\det(J) = f(q).\frac{A_s}{A_u}^{2(\lambda-1)}.2(\lambda-1)(1-\epsilon) > 0.$$

Let study $P(x)$, the characteristic polynomial of J. Since $\det(J) > 0$, $P(0) > 0$. Furthermore, $P^{'}(0) = -Tr(J) < 0$ and $Tr(J)^2 - 4\det(J) > 0$ so that the equation $P(x) = 0$ admits two positive solutions. Each eigenvalue of the matrix J is of magnitude lower than one if and only if the highest eigenvalue of J is of magnitude lower than one, i.e.,

$$\begin{aligned}
&\frac{1}{2}\left(Tr(J) + \sqrt{Tr(J)^2 - 4\det(J)}\right) < 1, \\
&\Leftrightarrow -Tr(J) + \det(J) + 1 > 0, \\
&\Leftrightarrow -[f(q).\frac{A_s}{A_u}^{2(\lambda-1)}.(2\lambda-1) + \frac{A_s}{A_u}^{2(\lambda-1)} \frac{A_s}{A_u} f^{'}(q) \frac{\partial Q}{\partial \frac{A_s}{A_u}} + (1-\epsilon)] + 1 + (2\lambda-1)(1-\epsilon) > 0, \\
&\Leftrightarrow -[f(q).\frac{A_s}{A_u}^{2(\lambda-1)}.(2\lambda-1) + \frac{A_s}{A_u}^{2(\lambda-1)} q(1-q)\epsilon(1-\alpha)(2\theta-1)f^{'}(q) + (1-\epsilon)] + 1 + (2\lambda-1)(1-\epsilon) > 0 \\
&\quad \Leftrightarrow 2(1-\lambda) > \frac{f^{'}(q)}{f(q)} q(1-q)(1-\alpha)(2\theta-1).
\end{aligned}$$

This condition is equivalent to

$$G'(q) > 0.$$

In part (1) on existence, one showed that if $G'(\frac{1}{2}) \geq 0$, then $(\frac{1}{2}, 1)$ is the unique interior steady state. Here, one deduces that when it is the unique interior steady state, then this fixed point is locally stable. Furthermore, one shows that if $G'(\frac{1}{2}) < 0$, then the dynamical system admits two additional steady states which, by continuity of G are such that $G'(\bar{q}_1) > 0$, $G'(\bar{q}_2) > 0$. Hence, if $G'(\frac{1}{2}) < 0$, $(\frac{1}{2}, 1)$ is a repelling fixed point while $(\bar{q}_1, \frac{\bar{A}_{s1}}{\bar{A}_{u1}})$ and $(\bar{q}_2, \frac{\bar{A}_{s2}}{\bar{A}_{u2}})$ are locally stable.

Basin of attraction

A. Consider the case $2(1-\lambda) > (1-\alpha)(2\theta-1)^2$. Let define the following sets (see Figure 8.2),

$S_1 = \{q_t < \frac{1}{2}, \frac{A_{st}}{A_{ut}} > 1\}$,

$S_2 = \{q_t < \frac{1}{2}, 1 > \frac{A_{st}}{A_{ut}} > X(q_t)\}$,

$S_3 = \{q_t < \frac{1}{2}, X(q_t) > \frac{A_{st}}{A_{ut}} > Y(q_t)\}$,

$S_4 = \{q_t < \frac{1}{2}, \frac{A_{st}}{A_{ut}} < Y(q_t)\}$,

$S_5 = \{q_t > \frac{1}{2}, \frac{A_{st}}{A_{ut}} < 1\}$,

$S_6 = \{q_t > \frac{1}{2}, 1 < \frac{A_{st}}{A_{ut}} < X(q_t)\}$,

$S_7 = \{q_t > \frac{1}{2}, X(q_t) < \frac{A_{st}}{A_{ut}} < Y(q_t)\}$,

$S_8 = \{q_t > \frac{1}{2}, \frac{A_{st}}{A_{ut}} > Y(q_t)\}$.

1. Suppose that $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_2 \cup S_3 \cup S_4$ which is equivalent to $q_0 < \frac{1}{2}$, $\frac{A_{s0}}{A_{u0}} < 1$. First, one shows that $(q_t, \frac{A_{st}}{A_{ut}}) \in S_2 \cup S_3 \cup S_4$ for all $t \in \mathbb{N}$.

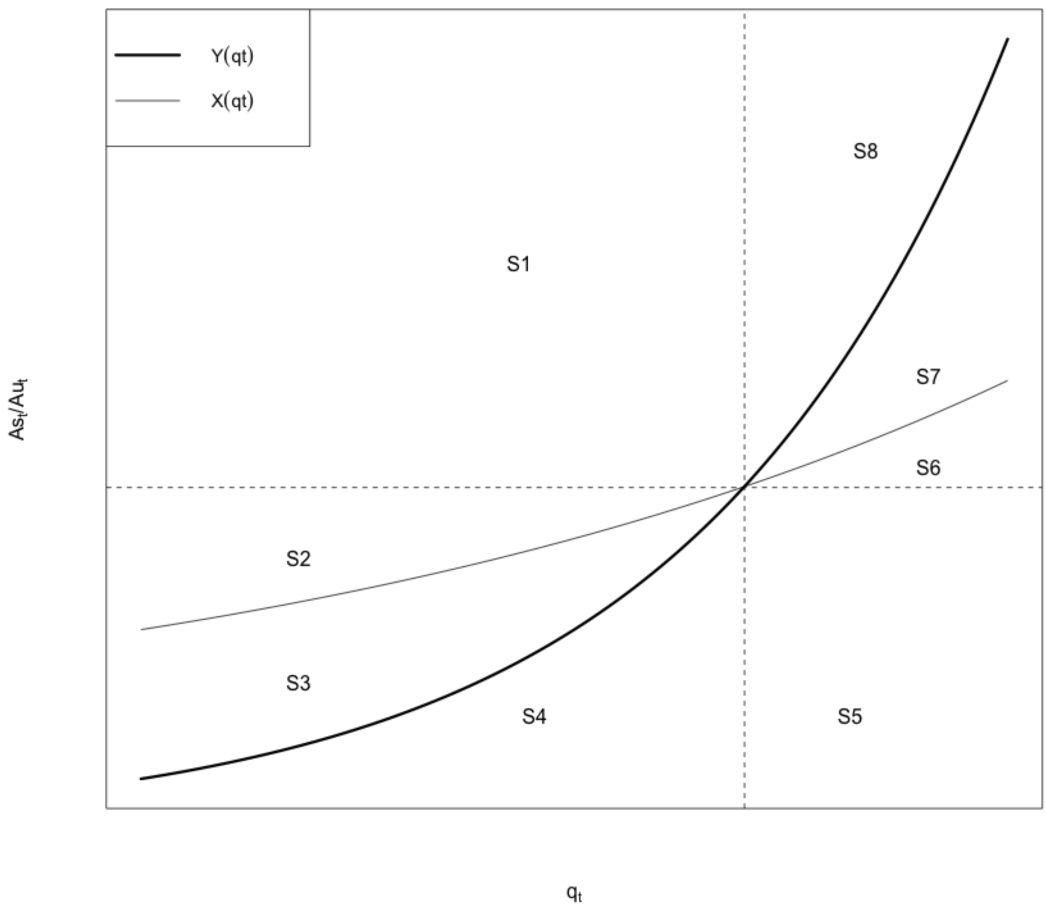
One has

-$q_1 = Q(q_0, \frac{A_{s0}}{A_{u0}}) < Q(q_0, 1) < Q(\frac{1}{2}, 1) = \frac{1}{2}$.

-$\frac{A_{s1}}{A_{u1}} = A(q_0, \frac{A_{s0}}{A_{u0}}) < A(q_0, 1) < A(\frac{1}{2}, 1) = 1$.

Hence $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_2 \cup S_3 \cup S_4$ implies $(q_1, \frac{A_{s1}}{A_{u1}}) \in S_2 \cup S_3 \cup S_4$ and by recurrence $(q_t, \frac{A_{st}}{A_{ut}}) \in S_2 \cup S_3 \cup S_4$ for all $t \in \mathbb{N}$. One deduces that $\forall (q_0, \frac{A_{s0}}{A_{u0}}) \in S_2 \cup S_3 \cup S_4$, the sequences q_t and $\frac{A_{st}}{A_{ut}}$ are bounded above.

i. Suppose that $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_3$. For all t, one has $\frac{A_{st+1}}{A_{ut+1}} > \frac{A_{st}}{A_{ut}}$ and $q_{t+1} > q_t$. In S_3, both sequences q_t and $\frac{A_{st}}{A_{ut}}$ are increasing and bounded above (respectively by $\frac{1}{2}$ and 1) so that they converge. Due



to continuity of maps Q and A in their variables, both sequences converge to their fixed points, i.e., $(q_t\frac{A_{st}}{A_{ut}}) \rightarrow (\frac{1}{2}, 1)$.

ii. Suppose that $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_2 \cup S_4$ which is equivalent $q_0 < Y^{-1}(\frac{A_{s0}}{A_{u0}})$, $\frac{A_{s0}}{A_{u0}} < X(q_0)$ (where $Y^{-1} : \mathbb{R}^+ \rightarrow [0,1]$ is the inverse function of Y.).

-Either $(q_t\frac{A_{st}}{A_{ut}}) \rightarrow (\frac{1}{2}, 1)$.

-Or, it exists $\tilde{t}$ such that for all $t > \tilde{t}$, $(q_t, \frac{A_{st}}{A_{ut}}) \in S_3$. We are in case (1.i).

-Or points jump forever from to S_2 to S_4, i.e., $\forall (q_t, \frac{A_{st}}{A_{ut}}) \in S_2$ there exists $i > 0$ such that $(q_{t+i}, \frac{A_{st+i}}{A_{ut+i}}) \in S_4$ and $\forall (q_t, \frac{A_{st}}{A_{ut}}) \in S_2$ there exists $i^{'} > 0$ such that $(q_{t+i^{'}}, \frac{A_{st+i^{'}}}{A_{ut+i^{'}}}) \in S_2$.

Assuming that points jump forever from to S_2 to S_4, one shows that points enter a neighbourhood of the fixed point $(\frac{1}{2}, 1)$ so that the sequenced converge to the fixed point. The reasoning is as follows. Suppose that $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_4$ which is equivalent to $q_0 > Y^{-1}(\frac{A_{s0}}{A_{u0}})$ and $\frac{A_{s0}}{A_{u0}} < X(q_0)$[36]. Because maps

[36]The same reasoning applies if $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_2$. I skip this case to alleviate the proof.

Q and A are increasing in both variables q and $\frac{A_s}{A_u}$, one has

$$q_1 > Y^{-1}(\frac{A_{s0}}{A_{u0}}),$$
$$\frac{A_{s1}}{A_{u1}} < X(q_0).$$

For any $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_4$, $(q_1, \frac{A_{s1}}{A_{u1}})$ belongs to the rectangle whose area is given by $R_0 = [(Y^{-1}(\frac{A_{s0}}{A_{u0}}), \frac{A_{s0}}{A_{u0}}), (\frac{1}{2}, 1)]$.

Now suppose that $(q_1, \frac{A_{s1}}{A_{u1}}) \in S_2$[37]. It is equivalent to $q_1 < Y^{-1}(\frac{A_{s1}}{A_{u1}}) < Y^{-1}(X(q_0))$ and $\frac{A_{s1}}{A_{u1}} > X(q_1) > X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))$. Because maps Q and A are increasing, one deduces

$$q_2 < Y^{-1}(X(q_0)),$$
$$\frac{A_{s2}}{A_{u2}} > X(Y^{-1}(\frac{A_{s0}}{A_{u0}})).$$

Then, suppose that $(q_2, \frac{A_{s2}}{A_{u2}}) \in S_4$. It is equivalent to $q_2 > Y^{-1}(\frac{A_{s2}}{A_{u2}}) > Y^{-1}(X(Y^{-1}(\frac{A_{s0}}{A_{u0}})))$ and $\frac{A_{s2}}{A_{u2}} < X(q_2) < X(Y^{-1}(X(q_0)))$. Because maps Q and A are increasing, one has

$$q_3 > Y^{-1}(X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))),$$
$$\frac{A_{s3}}{A_{u3}} < X(Y^{-1}(X(q_0))).$$

Finally, suppose that $(q_3, \frac{A_{s3}}{A_{u3}}) \in S_2$. It is equivalent to $q_3 < Y^{-1}(\frac{A_{s3}}{A_{u3}}) < Y^{-1}(X(Y^{-1}(X(q_0))))$ and $\frac{A_{s3}}{A_{u3}} > X(q_3) > X(Y^{-1}(X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))))$.

Supposing that points jump from S_4 to S_2, I deduce that for any $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_4$,

-$(q_0, \frac{A_{s0}}{A_{u0}}) \in R_0$ with $R_0 = [(Y^{-1}(\frac{A_{s0}}{A_{u0}}), X_0), (\frac{1}{2}, 1)]$,

-$(q_1, \frac{A_{s1}}{A_{u1}}) \in R_1$ with $R_1 = [(Y^{-1}(\frac{A_{s0}}{A_{u0}}), X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))), (\frac{1}{2}, 1)]$,

-$(q_2, \frac{A_{s2}}{A_{u2}}) \in R_2$ with $R_2 = [Y^{-1}(X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))), X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))), (\frac{1}{2}, 1)]$.

-$(q_3, \frac{A_{s3}}{A_{u3}}) \in R_3$ with $R_3 = [Y^{-1}(X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))), X(Y^{-1}(X(Y^{-1}(\frac{A_{s0}}{A_{u0}})))), (\frac{1}{2}, 1)]$.

Let define $V(x) \equiv Y^{-1}(X(x))$, $x_0 \equiv Y^{-1}(\frac{A_{s0}}{A_{u0}})$, and denote by $V^t(x_0)$, the t-th iteration of x_0 by map

[37] For the sake of clarity, I assume that points directly jump from S_2 to S_4 but the proof easily extends to cases where points do not directly jump from one set to another.

V. By recurrence one deduces, for any $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_4$, $(q_t, \frac{A_{st}}{A_{ut}}) \in R_t$ with $R_t = [(V^{\frac{t}{2}}(x_0), X(V^{\frac{t}{2}-1}(x_0)), (\frac{1}{2}, 1)]$ when t is even and $R_t = [(V^{\frac{t}{2}-1}(x_0), X(V^{\frac{t-1}{2}}(x_0)), (\frac{1}{2}, 1)]$ when t is odd.

Now, I show that $\lim_{t\to\infty} V^{\frac{t}{2}}(x_0) - \frac{1}{2} = 0$ and $\lim_{t\to\infty} X(V^{\frac{t}{2}}(x_0)) - 1 = 0$, i.e., both the length and the height of R_t tend to zero when t goes to infinity implying that iterations of the dynamical system $(q_{t+1} = Q(q_t, \frac{A_{st}}{A_{ut}}), \frac{A_{st+1}}{A_{ut+1}} = A(q_t, \frac{A_{st}}{A_{ut}}))$, enter a neighbourhood of the fixed point[38].

(1) The sequence $x_{t+1} = V(x_t)$ is increasing for any $x_0 < \frac{1}{2}$. Indeed,

$$\begin{aligned}
&x_1 > x_0,\\
\Leftrightarrow &V(x_0) > x_0,\\
\Leftrightarrow &Y^{-1}(X(Y^{-1}(\frac{A_{s0}}{A_{u0}}))) > Y^{-1}(\frac{A_{s0}}{A_{u0}}),\\
\Leftrightarrow &X(Y^{-1}(\frac{A_{s0}}{A_{u0}})) > \frac{A_{s0}}{A_{u0}},\\
\Leftrightarrow &Y^{-1}(\frac{A_{s0}}{A_{u0}}) > X^{-1}(\frac{A_{s0}}{A_{u0}}),
\end{aligned}$$

which is true since for $q < \frac{1}{2}$, $\frac{A_{s0}}{A_{u0}} < 1$ (see the graph above).

(2) In addition, the sequence x_t is bounded above since for all $x_0 < \frac{1}{2}$

$$\begin{aligned}
&V(x_0) < V(\frac{1}{2}), \quad \text{since V is increasing in } x_t\\
\Leftrightarrow &x_1 < \frac{1}{2}, \quad \Rightarrow x_t < \frac{1}{2}, \forall t.
\end{aligned}$$

Since it is increasing (1) and bounded above (2) the sequence x_t converges to a limit L.

(3) Convergence to the fixed point $\frac{1}{2}$.
Since both functions X and Y^{-1} are continuous, the function V is continuous so that the limit L is the fixed point $\frac{1}{2}$. I conclude that $\lim_{t\to\infty} V^{\frac{t}{2}}(x_0) = \frac{1}{2}$ which implies $\lim_{t\to\infty} X(V^{\frac{t}{2}}(x_0)) = X(\frac{1}{2}) = 1$. Hence the length and height of R_t tend to 0 as t goes to infinity. For some t sufficiently large, iterations of the two-dimensional system enter a neighbourhood of $(\frac{1}{2}, 1)$ and thus converge to this point.

[38] The case when t is odd is similar.

2. When $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_6 \cup S_7 \cup S_8$, or $(q_0, \frac{A_{s0}}{A_{u0}}) \in S_1 \cup S_5$, a similar reasoning allows to show that $(q_t \frac{A_{st}}{A_{ut}}) \rightarrow (\frac{1}{2}, 1)$.

B. When $2(1-\lambda) < (1-\alpha)(2\theta-1)^2$. Similar arguments allow to show that

-for all $\frac{A_{s0}}{A_{u0}} < 1$, $q_0 < \frac{1}{2}$, $(q_t, \frac{A_{st}}{A_{ut}}) \rightarrow (\bar{q}_1, \bar{\frac{A_s}{A_u}}_1)$.

-for all $\frac{A_{s0}}{A_{u0}} > 1$, $q_0 > \frac{1}{2}$, $(q_t, \frac{A_{st}}{A_{ut}}) \rightarrow (\bar{q}_2, \bar{\frac{A_s}{A_u}}_2)$.

9 Online Appendix- For Online Publication

9.1 Proof of Lemma 3

Here, one shows that the two attracting steady states are such that $\bar{q}_1 = 1 - \bar{q}_2$ and $\frac{\bar{A}_{s1}}{A_{u1}} = 1/\frac{\bar{A}_{s2}}{A_{u2}}$.

Let consider $\delta \in \mathbb{R}^+$ which is such that $\frac{\bar{A}_{s1}}{A_{u1}} = \delta/\frac{\bar{A}_{s2}}{A_{u2}}$. Since $\frac{\bar{A}_{s1}}{A_{u1}} = \frac{\bar{q}_1}{1-\bar{q}_1}^{\frac{1}{(1-\alpha)(2\theta-1)}}$, $\frac{\bar{A}_{s2}}{A_{u2}} = \frac{\bar{q}_2}{1-\bar{q}_2}^{\frac{1}{(1-\alpha)(2\theta-1)}}$, one has

$$
\begin{aligned}
&\frac{\bar{q}_1}{1-\bar{q}_1}^{\frac{1}{(1-\alpha)(2\theta-1)}} = \delta/(\frac{\bar{q}_2}{1-\bar{q}_2}^{\frac{1}{(1-\alpha)(2\theta-1)}}),\\
\Leftrightarrow &\frac{\bar{q}_1}{1-\bar{q}_1} = \delta^{(1-\alpha)(2\theta-1)}/(\frac{\bar{q}_2}{1-\bar{q}_2}).
\end{aligned}
$$

Furthermore, $\frac{\bar{A}_{s1}}{A_{u1}} = f(\bar{q}_1)^{\frac{1}{2(1-\lambda)}}$, $\frac{\bar{A}_{s2}}{A_{u2}} = f(\bar{q}_2)^{\frac{1}{2(1-\lambda)}}$. Hence,

$$
\begin{aligned}
&f(\bar{q}_1)f(\bar{q}_2) = \delta^{2(1-\lambda)},\\
\Leftrightarrow &\frac{\bar{q}_2\theta + (1-\bar{q}_2)(1-\theta)}{\bar{q}_2(1-\theta) + (1-\bar{q}_2)\theta} \cdot \frac{\bar{q}_1\theta + (1-\bar{q}_1)(1-\theta)}{\bar{q}_1(1-\theta) + (1-\bar{q}_1)\theta} = \delta^{2(1-\lambda)},\\
\Leftrightarrow &\frac{\frac{\bar{q}_2}{(1-\bar{q}_2)}\theta + (1-\theta)}{\frac{\bar{q}_2}{(1-\bar{q}_2)}(1-\theta) + \theta} \cdot \frac{\frac{\bar{q}_1}{(1-\bar{q}_1)}\theta + (1-\theta)}{\frac{\bar{q}_1}{(1-\bar{q}_1)}(1-\theta) + \theta} = \delta^{2(1-\lambda)},.
\end{aligned}
$$

Let replace $\frac{\bar{q}_1}{(1-\bar{q}_1)}$ by $\delta^{(1-\alpha)(2\theta-1)} \cdot \frac{1-\bar{q}_2}{\bar{q}_2}$ so that it is equivalent to

$$
\begin{aligned}
&\frac{\frac{\bar{q}_2}{(1-\bar{q}_2)}\theta + (1-\theta)}{\frac{\bar{q}_2}{(1-\bar{q}_2)}(1-\theta) + \theta} \cdot \frac{\delta^{(1-\alpha)(2\theta-1)} \cdot \frac{1-\bar{q}_2}{\bar{q}_2}\theta + (1-\theta)}{\delta^{(1-\alpha)(2\theta-1)} \cdot \frac{1-\bar{q}_2}{\bar{q}_2}(1-\theta) + \theta} = \delta^{2(1-\lambda)},\\
\Leftrightarrow &\frac{\bar{q}_2\theta + (1-\bar{q}_2)(1-\theta)}{\bar{q}_2(1-\theta) + (1-\bar{q}_2)\theta} \cdot \frac{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)\theta + \bar{q}_2(1-\theta)}{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta) + \bar{q}_2\theta} = \delta^{2(1-\lambda)},\\
\Leftrightarrow &\frac{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)\theta + \bar{q}_2(1-\theta)}{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta) + \bar{q}_2\theta} = \delta^{2(1-\lambda)} \frac{\bar{q}_2(1-\theta) + (1-\bar{q}_2)\theta}{\bar{q}_2\theta + (1-\bar{q}_2)(1-\theta)},\\
\Leftrightarrow &\left(\frac{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)\theta + \bar{q}_2(1-\theta)}{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta) + \bar{q}_2\theta}\right)^{1/2(1-\lambda)} = \delta \cdot \frac{\bar{q}_2(1-\theta) + (1-\bar{q}_2)\theta}{\bar{q}_2\theta + (1-\bar{q}_2)(1-\theta)},
\end{aligned}
$$

The above equality holds in $\delta = 1$. The right-hand side stands for a line with a positive slope and equal to zero at $\delta = 0$. Let study the left hand side and define

$$
\frac{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)\theta + \bar{q}_2(1-\theta)}{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta) + \bar{q}_2\theta} = u(\delta).
$$

One has

$$u^{'}(\delta) = \frac{(1-\alpha)(2\theta-1)\delta^{(1-\alpha)(2\theta-1)-1}(1-\bar{q}_2)\bar{q}_2(2\theta-1)}{(\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta)+\bar{q}_2\theta)^2} > 0,$$

and

$$u^{''}(\delta) = \frac{(1-\alpha)(2\theta-1)\delta^{(1-\alpha)(2\theta-1)-2}(1-\bar{q}_2)\bar{q}_2(2\theta-1)}{(\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta)+\bar{q}_2\theta)^2}\left[(1-\alpha)(2\theta-1)-1\right.$$
$$\left.-2\cdot\frac{(1-\alpha)(2\theta-1)\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta)}{\delta^{(1-\alpha)(2\theta-1)}(1-\bar{q}_2)(1-\theta)+\bar{q}_2\theta}\right] < 0.$$

The derivative and second derivative of the expression at the left-hand side of the relevant equality are respectively given by

$$\frac{1}{2(1-\lambda)}u^{'}(\delta)\cdot u(\delta)^{\frac{1}{2(1-\lambda)}-1} > 0,$$
$$\frac{1}{2(1-\lambda)}u^{''}(\delta)\cdot u(\delta)^{\frac{1}{2(1-\lambda)}-1} + \frac{1}{2(1-\lambda)}\left(\frac{1}{2(1-\lambda)}-1\right)u^{'}(\delta)u^{'}(\delta)\cdot u(\delta)^{\frac{1}{2(1-\lambda)}-2} < 0, \quad \text{since} \quad \lambda > \frac{1}{2}.$$

One deduces that the left-hand side is an increasing and concave function of δ equal to $\frac{1-\theta}{\theta}$ at $\delta = 0$. Therefore, $\delta = 1$ is the unique point such that the equality holds. I conclude $\frac{\bar{A}_{s1}}{A_{u1}} = 1/\frac{\bar{A}_{s2}}{A_{u2}}$ which implies $\bar{q}_1 = 1-\bar{q}_2$. Hence, if $\bar{A}_{u1} = \beta\bar{A}_{s2}$, then $\bar{A}_{s1} = \beta\bar{A}_{u2}$.

9.2 Proof of Proposition 2

In this section, I first show that the growth of welfare of type C-agents is the same whatever the long run equilibrium. Then I compare, the growth of welfare of type E-agents in each equilibrium. In a first step, I show that the growth of welfare which is due to consumption growth is the same whatever the long run equilibrium. In a second step, assuming that the natural resource is growing, I show that the growth of the natural resource is higher in the ethical equilibrium whenever β is not too low. I finally prove that if preferences for the natural resource are high enough, the growth of the natural resource turns into higher growth of welfare whenever β is not too low (i.e., $\beta > \beta^*$, $\beta^* < 1$).

A. Growth rate of welfare for agents of type C at steady states.

$$\begin{aligned}\frac{U_{t+1}^C - U_t^C}{U_t^C} &= \frac{\frac{I(1-\theta)}{p_{st+1}}^{1-\theta}\frac{I\theta}{p_{dt+1}}^{\theta} - \frac{I(1-\theta)}{p_{st}}^{1-\theta}\frac{I\theta}{p_{ut}}^{\theta}}{\frac{I(1-\theta)}{p_{st}}^{1-\theta}\frac{I\theta}{p_{ut}}^{\theta}},\\ &= \frac{{A_{st+1}}^{(1-\theta)(1-\alpha)}{A_{ut+1}}^{\theta(1-\alpha)} - {A_{st}}^{(1-\theta)(1-\alpha)}{A_{ut}}^{\theta(1-\alpha)}}{{A_{st}}^{(1-\theta)(1-\alpha)}{A_{ut}}^{\theta(1-\alpha)}},\\ &= (1+\gamma(\frac{A_s}{A_u}))^{(1-\alpha)} - 1,\end{aligned}$$

where $\gamma(\frac{A_s}{A_u}) = \gamma\eta/\left(\frac{A_s}{A_u}^{1-\lambda} + \frac{A_s}{A_u}^{\lambda-1}\right)$. Note that, since $\frac{\bar{A_{s1}}}{\bar{A_{u1}}} = 1/\frac{\bar{A_{s2}}}{\bar{A_{u2}}}$, one has $\gamma(\frac{\bar{A_{s1}}}{\bar{A_{u1}}}) = \gamma(\frac{\bar{A_{s2}}}{\bar{A_{u2}}})$ so that the long run growth rate of welfare for agents of type C is the same whatever the long run equilibrium.

B. Growth rate of welfare for agents of type E at steady states.

$$\begin{aligned}\frac{U_{t+1}^E - U_t^E}{U_t^E} &= \frac{\frac{I\theta}{p_{st+1}}^{\theta}\frac{I(1-\theta)}{p_{dt+1}}^{1-\theta} - \frac{I\theta}{p_{st}}^{\theta}\frac{I(1-\theta)}{p_{ut}}^{1-\theta} + {G_{t+1}}^{\mu}}{\frac{I\theta}{p_{st}}^{\theta}\frac{I(1-\theta)}{p_{ut}}^{1-\theta} + {G_t}^{\mu}},\\ &= \frac{\mathcal{B}{A_{st+1}}^{\theta(1-\alpha)}{A_{ut+1}}^{(1-\theta)(1-\alpha)} - \mathcal{B}{A_{st}}^{\theta(1-\alpha)}{A_{ut}}^{(1-\theta)(1-\alpha)} + {G_{t+1}}^{\mu}}{\mathcal{B}{A_{st}}^{\theta(1-\alpha)}{A_{ut}}^{(1-\theta)(1-\alpha)} + {G_t}^{\mu}},\end{aligned}$$

with $\mathcal{B} = I\theta^{\theta}I(1-\theta)^{1-\theta}(1-\alpha)^{(1-\alpha)}$. Let compare the growth rate of U^E in the conventional equilibrium, given by $(\bar{q}_1\ \frac{\bar{A_{s1}}}{\bar{A_{u1}}})$ and the growth rate of U^E in the ethical equilibrium, given by $(\bar{q}_2\ \frac{\bar{A_{s2}}}{\bar{A_{u2}}})$.

(1) Growth of welfare due to consumption. In a first step, we interest in the growth rate of welfare due to growth of consumption. Using the same development than for the growth of welfare for type-C agents we deduce that the growth of welfare due to consumption for type-E agents is the same in the green and in the brown equilibrium.

Before computing the growth of welfare due to natural resource, it will be useful to compare the level of utility provided by consumption in each long run equilibrium. Let us define $W_t \equiv \mathcal{B}{A_{st}}^{\theta(1-\alpha)}{A_{ut}}^{(1-\theta)(1-\alpha)}$ and perform $\frac{W_t^1}{W_t^2}$, where W_t^1 stands for W_t in the dirty equilibrium, and W_t^2, W_t in the green equilibrium. For all $t \geq 0$,

$$\begin{aligned}W_t^1/W_t^2 =& \mathcal{B}(1+\gamma(\frac{\bar{A_{s1}}}{\bar{A_{u1}}}))^{t(1-\alpha)}\left[\bar{q_1}\bar{A_{s1}}^{\theta(1-\alpha)}\bar{A_{u1}}^{(1-\theta)(1-\alpha)} + (1-\bar{q_1})\bar{A_{s1}}^{(1-\theta)(1-\alpha)}\bar{A_{u1}}^{\theta(1-\alpha)}\right]\\ &/\left(\mathcal{B}(1+\gamma(\frac{\bar{A_{s2}}}{\bar{A_{u2}}}))^{t(1-\alpha)}\left[\bar{q_2}\bar{A_{s2}}^{\theta(1-\alpha)}\bar{A_{u2}}^{(1-\theta)(1-\alpha)} + (1-\bar{q_2})\bar{A_{s2}}^{(1-\theta)(1-\alpha)}\bar{A_{u2}}^{\theta(1-\alpha)}\right]\right).\end{aligned}$$

Since, $(1+\gamma(\frac{\bar{A_{s2}}}{\bar{A_{u2}}})) = (1+\gamma(\frac{\bar{A_{s1}}}{\bar{A_{u1}}}))$ and $\bar{q_1} = 1-\bar{q_2}$ we obtain

$$\begin{aligned} W_t^1/W_t^2 =& \bar{q_1}\frac{\bar{A_{s1}}}{\bar{A_{u1}}}^{\theta(1-\alpha)}\bar{A_{u1}}^{(1-\alpha)} + (1-\bar{q_1})\frac{\bar{A_{u1}}}{\bar{A_{s1}}}^{\theta(1-\alpha)}\bar{A_{s1}}^{(1-\alpha)} \\ & / \left(\bar{q_1}\frac{\bar{A_{s1}}}{\bar{A_{u1}}}^{\theta(1-\alpha)}\bar{A_{s2}}^{(1-\alpha)} + (1-\bar{q_1})\frac{\bar{A_{u1}}}{\bar{A_{s1}}}^{\theta(1-\alpha)}\bar{A_{u2}}^{(1-\alpha)}\right). \end{aligned}$$

Using the fact that $\bar{A_{s1}} = \beta\bar{A_{u2}}$ and $\bar{A_{u1}} = \beta\bar{A_{s2}}$, $\beta \in \mathbb{R}^+$, one finds

$$W_t^1/W_t^2 = \beta^{(1-\alpha)}.$$

(2) Growth of welfare due to natural resource. Now, I compare the growth rate of utility due to the growth of the natural resource in each steady state.

Along any steady state $(q, \frac{A_s}{A_u})$, the dynamics of the natural resource is described by the following equation

$$G_t = (1+b)^t\left(G_0 - \frac{I(1-\alpha)^{(1-\alpha)}h(q)}{(1+b)}A_u^{(1-\alpha)}\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau\right),$$

where $h(q) = q(1-\theta)+(1-q)\theta$. To alleviate notations, I set

$$Z \equiv \frac{I(1-\alpha)^{(1-\alpha)}h(q)}{(1+b)}A_u^{(1-\alpha)}.$$

Along any steady state $(q, \frac{A_s}{A_u})$, the growth rate of the natural resource is given by

$$\begin{aligned} \frac{G_{t+1}}{G_t} =& (1+b)\frac{G_0 - Z\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau}{G_0 - Z\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau}, \\ =& (1+b)\left[1 - \frac{Z\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^t}{G_0 - Z\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau}\right]. \end{aligned}$$

The growth rate of the natural resource is positive for all $t > 0$ if and only if

$$G_0 > Z \sum_{\tau=0}^{t} \left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b} \right)^{\tau} \quad \forall t.$$

A necessary condition for this inequality to hold is $\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b} < 1$ which is true due to item (i) of Assumption (since the function $\gamma(\frac{A_s}{A_u})$ reaches a maximum at $\frac{A_s}{A_u} = 1$). Then, using a development in power series, one obtains

$$\frac{1}{1 - \frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}} > \sum_{\tau=0}^{t} \left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b} \right)^{\tau},$$

so that a sufficient condition for $\frac{G_{t+1}}{G_t} > 0 \ \forall t$ is

$$\frac{G_0}{Z} > \frac{1}{1 - \frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}},$$

which is true due to item (ii) of Assumption 1.

Now, I show that the condition for a positive growth rate of the natural resource implies that the growth rate of the natural resource is higher than the growth rate of consumption, at each t.

Indeed, this condition writes as

$$
\begin{aligned}
&(1+b)\left[1-\frac{Z\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^t}{G_0-Z\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau}\right]>(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha},\\
&\Leftrightarrow 1-\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{(1+b)}>\frac{Z\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^t}{G_0-Z\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau},\\
&\Leftrightarrow G_0-Z\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau-Z\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^t\\
&\quad -G_0\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{(1+b)}+Z\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{(1+b)}<0,\\
&\Leftrightarrow G_0-Z\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau-G_0\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{(1+b)}\\
&\quad +Z\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}\right)^\tau-Z,\\
&\Leftrightarrow \frac{G_0}{Z}>\frac{1}{1-\frac{(1+\gamma(\frac{A_s}{A_u}))^{1-\alpha}}{1+b}}.
\end{aligned}
$$

The last condition is item (ii) of Assumption 1.

Let compare the growth of natural resource in each equilibrium. To do so, I compute $\frac{G^1_{t+1}}{G^1_t}/\frac{G^2_{t+1}}{G^2_t}$. Let denote by Z_i, the value of Z in equilibrium $i\in\{1,2\}$.

$$
\begin{aligned}
&\frac{G^1_{t+1}}{G^1_t}/\frac{G^2_{t+1}}{G^2_t}=\\
&\left[1-\frac{Z_1\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^t}{G_0-Z_1\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^\tau}\right]/\left[1-\frac{Z_2\left(\frac{(1+\gamma(\frac{\bar{A}_{s2}}{\bar{A}_{u2}}))^{1-\alpha}}{1+b}\right)^t}{G_0-Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s2}}{\bar{A}_{u2}}))^{1-\alpha}}{1+b}\right)^\tau}\right],\\
&\equiv\frac{1-\mathcal{C}_1}{1-\mathcal{C}_2}.
\end{aligned}
$$

This ratio is lower than one if and only if

$$
\begin{aligned}
&\mathcal{C}_1 > \mathcal{C}_2,\\
\Leftrightarrow & Z_1 > Z_2,\\
\Leftrightarrow & \frac{\mathcal{C}h(\bar{q}_1)}{(1+b)}\bar{A_{u1}}^{(1-\alpha)} > \frac{\mathcal{C}h(\bar{q}_2)}{(1+b)}\bar{A_{u2}}^{(1-\alpha)},\\
\Leftrightarrow & h(\bar{q}_1)\beta^{(1-\alpha)}\bar{A_{s2}}^{(1-\alpha)} > h(\bar{q}_2)\bar{A_{u2}}^{(1-\alpha)},\\
\Leftrightarrow & f(\bar{q}_1)^{-1}\frac{\bar{A_{s1}}}{\bar{A_{u1}}}^{-(1-\alpha)}\beta^{(1-\alpha)} > 1. \qquad (\text{using } \ f(q) = \frac{g(q)}{h(q)} = \frac{h(1-q)}{h(q)}).
\end{aligned}
$$

Since $f(\bar{q}_1) < 1$, $\frac{\bar{A_{s1}}}{\bar{A_{u1}}} < 1$, one has $\frac{G^1_{t+1}}{G^1_t} < \frac{G^2_{t+1}}{G^2_t}$ for any $\beta > \bar{\beta}$, where $\bar{\beta} = (f(\bar{q}_1)\frac{\bar{A_{s1}}}{\bar{A_{u1}}}^{(1-\alpha)})^{\frac{1}{1-\alpha}} < 1$.

Finally, I perform the difference of welfare growth for type E-agents in each equilibrium. I omit superscript E, this difference writes as

$$
\frac{U^1_{t+1} - U^1_t}{U^1_t} - \frac{U^2_{t+1} - U^2_t}{U^2_t} = \frac{W^1_{t+1} + {G^1_{t+1}}^{\mu}}{W^1_t + G^{1\mu}_t} - \frac{W^2_{t+1} + {G^2_{t+1}}^{\mu}}{W^2_t + G^{2\mu}_t},
$$

and is negative iif

$$
\begin{aligned}
&\frac{W^1_{t+1} + {G^1_{t+1}}^{\mu}}{W^1_t + G^{1\mu}_t} < \frac{W^2_{t+1} + {G^2_{t+1}}^{\mu}}{W^2_t + G^{2\mu}_t},\\
\Leftrightarrow & W^1_{t+1}W^2_t + {G^1_{t+1}}^{\mu}W^2_t + W^1_{t+1}G^{2\mu}_t + {G^1_{t+1}}^{\mu}G^{2\mu}_t - W^2_{t+1}W^1_t - {G^2_{t+1}}^{\mu}W^1_t - W^2_{t+1}G^{1\mu}_t - {G^2_{t+1}}^{\mu}G^{1\mu}_t < 0.
\end{aligned}
$$

Note that $W^1_{t+1}W^2_t = W^2_{t+1}W^1_t$ (i.e., the growth of welfare due to consumption is the same in each steady state). Moreover, if $\beta > \bar{\beta}$, ${G^1_{t+1}}^{\mu}G^{2\mu}_t - {G^2_{t+1}}^{\mu}G^{1\mu}_t < 0$ so that a sufficient condition for the above inequality is

$$
\begin{aligned}
&{G^1_{t+1}}^{\mu}W^2_t + W^1_{t+1}G^{2\mu}_t - {G^2_{t+1}}^{\mu}W^1_t - W^2_{t+1}G^{1\mu}_t < 0,\\
&W^1_{t+1}G^{2\mu}_t - {G^2_{t+1}}^{\mu}W^1_t < W^2_{t+1}G^{1\mu}_t - {G^1_{t+1}}^{\mu}W^2_t
\end{aligned}
$$

Remind that $\frac{W^1_{t+1}}{W^1_t} = \frac{W^2_{t+1}}{W^2_t} = (1+\gamma(\frac{\bar{A_{s1}}}{\bar{A_{u1}}}))^{1-\alpha}$ and $\frac{G^1_{t+1}}{G^1_t} = (1+b)(1-\mathcal{C}_1)$, $\frac{G^2_{t+1}}{G^2_t} = (1+b)(1-\mathcal{C}_2)$ so that the inequality can be can be re-written as

$$
W^1_tG^{2\mu}_t\left((1+\gamma(\frac{\bar{A_{s1}}}{\bar{A_{u1}}}))^{1-\alpha} - (1+b)^{\mu}(1-\mathcal{C}_2)^{\mu}\right) < W^2_tG^{1\mu}_t\left((1+\gamma(\frac{\bar{A_{s1}}}{\bar{A_{u1}}}))^{1-\alpha} - (1+b)^{\mu}(1-\mathcal{C}_1)^{\mu}\right)
$$

Under Assumption 1, one has $(1+b)(1-\mathcal{C}_2) > (1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}$ as well as $(1+b)(1-\mathcal{C}_1) > (1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}$. Suppose that $\mu \geq 1-\alpha$, this implies $(1+b)^{\mu}(1-\mathcal{C}_2)^{\mu} > (1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}$ and $(1+b)^{\mu}(1-\mathcal{C}_1)^{\mu} > (1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}$. Therefore, the condition is equivalent to

$$\frac{W_t^1}{W_t^2} > \frac{G_t^{1\mu}}{G_t^{2\mu}} \frac{\left((1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha} - (1+b)^{\mu}(1-\mathcal{C}_1)^{\mu}\right)}{\left((1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha} - (1+b)^{\mu}(1-\mathcal{C}_2)^{\mu}\right)}$$

Remind that

$$1-\mathcal{C}_1 = \frac{G_0 - Z_1 \sum_{\tau=0}^{t} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - Z_1 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}},$$

$$1-\mathcal{C}_2 = \frac{G_0 - Z_2 \sum_{\tau=0}^{t} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - Z_2 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}},$$

$$\frac{G_t^{1\mu}}{G_t^{2\mu}} = \frac{\left(G_0 - Z_1 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)^{\mu}}{\left(G_0 - Z_2 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)^{\mu}}$$

Also, $\frac{Z_1}{Z_2} = f(\bar{q_1})^{-1} \frac{\bar{A_{s1}}}{A_{u1}}^{-(1-\alpha)} \beta^{(1-\alpha)}$. Let denote this function $\phi(\beta)$, i.e.,

$$\phi(\beta) \equiv f(\bar{q_1})^{-1} \frac{\bar{A_{s1}}}{\bar{A_{u1}}}^{-(1-\alpha)} \beta^{(1-\alpha)},$$

and note that ϕ is an increasing function of β. Now replace $Z_1 = \phi(\beta) Z_2$ and $\frac{W_t^1}{W_t^2} = \beta^{1-\alpha}$ in the inequality,

$$\beta^{1-\alpha} > \frac{\left(G_0 - \phi(\beta) Z_2 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)^{\mu}}{\left(G_0 - Z_2 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)^{\mu}} \times$$

$$\frac{\left((1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha} - (1+b)^{\mu} \left(\frac{G_0 - \phi(\beta) Z_2 \sum_{\tau=0}^{t} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - \phi(\beta) Z_2 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}\right)^{\mu}\right)}{\left((1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha} - (1+b)^{\mu} \left(\frac{G_0 - Z_2 \sum_{\tau=0}^{t} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - Z_2 \sum_{\tau=0}^{t-1} \left(\frac{(1+\gamma(\frac{\bar{A_{s1}}}{A_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}\right)^{\mu}\right)}$$

The left hand side of this inequality is increasing in β. Let us study the sign of the derivative of the right hand side with respect to β. Note that,

$$\frac{1}{\left(G_0 - Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)^{\mu}} \frac{1}{\left((1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha} - (1+b)^{\mu}\left(\frac{G_0 - Z_2\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}\right)^{\mu}\right)} < 0,$$

so that the sign of the derivative is the opposite sign of the following expression (i.e., the numerator of the derivative of the RHS with respect to β),

$$\mu\left(G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)^{\mu} \frac{\phi'(\beta)Z_2}{\left(G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)} \times$$

$$[-\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\left((1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha} - (1+b)^{\mu}\left(\frac{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}\right)^{\mu}\right)$$

$$+ (1+b)^{\mu}\left(\frac{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}\right)^{\mu} \frac{\left(G_0\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{t}}{\left(G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)}]$$

The term of the first line is positive. Hence, the sign of the expression is the sign of the expression in brackets:

$$-\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\left((1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha} - (1+b)^{\mu}\left(\frac{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}\right)^{\mu}\right)$$

$$+ (1+b)^{\mu}\left(\frac{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}{G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t-1}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}}\right)^{\mu} \frac{G_0\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}}{\left(G_0 - \phi(\beta)Z_2\sum_{\tau=0}^{t}\left(\frac{(1+\gamma(\frac{\bar{A}_{s1}}{\bar{A}_{u1}}))^{1-\alpha}}{1+b}\right)^{\tau}\right)},$$

which is positive given Assumption 1.

Let's go back to the inequality. At $\beta = 1$, the LHS is equal to one. The RHS is lower than one since $\phi(1)Z_2 > Z_2$. At $\beta = \bar{\beta}$, the RHS is equal to one since $\phi(\bar{\beta}) = 1$. The LHS is lower than one since $\bar{\beta} < 1$. Since the LHS (resp. RHS) is increasing (resp. decreasing) in β, we conclude that there exists a unique $\beta = \beta^* \in]\bar{\beta}, 1[$ such that $\forall \beta > \beta^*$, the inequality holds.

9.3 Proof of Proposition 4

(1) Convergence under trade integration.

Suppose that $\beta > 1$. This implies that $\frac{\hat{A_{s0}}}{\hat{A_{u0}}} = \frac{1}{\beta} < 1$. At time $t = 1$, the fraction of ethical consumers in the domestic and foreign country are respectively is given by

$$q_1 = q_0 + q_0(1 - q_0)\epsilon \ln \left(\frac{1 - q_0}{q_0} \frac{\hat{A_{s0}}}{\hat{A_{u0}}}^{(2\theta-1)(1-\alpha)} \right),$$
$$q_1^* = q_0^* + q_0^*(1 - q_0^*)\epsilon \ln \left(\frac{1 - q_0^*}{q_0^*} \frac{\hat{A_{s0}}}{\hat{A_{u0}}}^{(2\theta-1)(1-\alpha)} \right).$$

Using $q_0 = 1 - q_0^*$ (since $q_0^* = \bar{q}_1$ and $q_0 = \bar{q}_2$), one deduces that the fraction of ethical consumers in the whole economy, i.e., $\hat{q}_1$, is given by

$$\begin{aligned} \hat{q}_1 &= \frac{1}{2} q_1 + \frac{1}{2} q_1^* \\ &= \frac{1}{2} + q_0(1 - q_0)\epsilon \ln \left(\frac{\hat{A_{s0}}}{\hat{A_{u0}}}^{(2\theta-1)(1-\alpha)} \right). \end{aligned}$$

Since $\frac{\hat{A_{s0}}}{\hat{A_{u0}}} < 1$, then $\hat{q}_1 < \frac{1}{2}$ and we deduce that $\frac{\hat{A_{s1}}}{\hat{A_{u1}}} < 1$. Indeed,
(i) if $\frac{\Pi_{st}}{\Pi_{ut}} < 1$ then $\frac{\hat{A_{s1}}}{\hat{A_{u1}}} < \frac{\hat{A_{s0}}}{\hat{A_{u0}}} < 1$,
(ii) if $\frac{\Pi_{st}}{\Pi_{ut}} = 1$ then $\frac{\hat{A_{s1}}}{\hat{A_{u1}}} = f(\hat{q}_1) \left(\frac{A_{s0}}{A_{u0}} \right)^{2\lambda} < 1$,
(iii) if $\frac{\Pi_{st}}{\Pi_{ut}} > 1$ which is equivalent to $f(\hat{q}_1) \left(\frac{A_{s0}}{A_{u0}} \right)^{2\lambda} \frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} \frac{1}{1+\gamma\eta \frac{\hat{A_{s0}}}{\hat{A_{u0}}}} > 1$, then $\frac{\hat{A_{s1}}}{\hat{A_{u1}}} = (1 + \gamma\eta \frac{\hat{A_{s0}}}{\hat{A_{u0}}}) \frac{\hat{A_{s0}}}{\hat{A_{u0}}} < f(\hat{q}_1) \left(\frac{A_{s0}}{A_{u0}} \right)^{2\lambda} < 1$.

At time $t = 2$, one first easily shows that the fraction of ethical consumers in the foreign economy is such that $q_2^* < \frac{1}{2}$. Indeed,

$$\begin{aligned}
&q_1^* < \frac{1}{2} \\
\Leftrightarrow &Q(q_1^*, \frac{\hat{A_{s1}}}{\hat{A_{u1}}}) < Q(\frac{1}{2}, \frac{\hat{A_{s1}}}{\hat{A_{u1}}}) \quad \text{since the function } Q \text{ is increasind in } q, \\
\Leftrightarrow &q_2^* < Q(\frac{1}{2}, \frac{\hat{A_{s1}}}{\hat{A_{u1}}}) < Q(\frac{1}{2}, 1) = \frac{1}{2} \quad \text{since } Q \text{ is increasing in } \frac{A_s}{A_u} \text{ and } \frac{\hat{A_{s1}}}{\hat{A_{u1}}} < 1.
\end{aligned}$$

Then, regarding the fraction of ethical consumers in the domestic economy,

(i) either $q_2 < \frac{1}{2}$ and one concludes that $\hat{q}_2 = \frac{1}{2}(q_2 + q_2^*) < \frac{1}{2}$,

(ii) or $\frac{1}{2} < q_2 < q_1$ (where the latter inequality comes from $\frac{\hat{A_{s1}}}{\hat{A_{u1}}} < 1$). If $q_2^* < q_1^*$, one easily deduces that $\hat{q}_2 < \frac{1}{2}$. First, $\hat{q}_1 = \frac{1}{2}(q_1 + q_1^*) < \frac{1}{2}$ is equivalent to $q_1 - \frac{1}{2} < \frac{1}{2} - q_1^*$. Second, by assumption, one has $q_2 - \frac{1}{2} < q_1 - \frac{1}{2}$ and $\frac{1}{2} - q_1^* < \frac{1}{2} - q_2^*$. This two facts imply $q_2 - \frac{1}{2} < \frac{1}{2} - q_2^*$ that is $\hat{q}_2 < \frac{1}{2}$.

(iii) or $\frac{1}{2} < q_2 < q_1$ and $\frac{1}{2} > q_2^* > q_1^*$. In this latter case, let re-express $\hat{q}_2$ as,

$$\begin{aligned}
\hat{q}_2 =& \frac{1}{2}\left[1 + 2q_0(1-q_0)\epsilon \ln\left(\frac{\hat{A_{s0}}}{\hat{A_{u0}}}^{(2\theta-1)(1-\alpha)}\right)\right. \\
&+ q_1(1-q_1)\epsilon \ln\left(\frac{1-q_1}{q_1}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right) \\
&\left. + q_1^*(1-q_1^*)\epsilon \ln\left(\frac{1-q_1^*}{{q_1}^*}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right)\right] \equiv \hat{q}_2(\frac{\hat{A_{s0}}}{\hat{A_{u0}}}),
\end{aligned}$$

where I define $\hat{q}_2(\frac{\hat{A_{s0}}}{\hat{A_{u0}}})$ by noting that q_1, q_1^* and $\frac{\hat{A_{s1}}}{\hat{A_{u1}}}$ are all functions of $\frac{\hat{A_{s0}}}{\hat{A_{u0}}}$. The term of the first line is the sum $q_1 + q_1^*$. The two subsequent terms measure the variation of q_t between time $t = 1$ and $t = 2$ in the domestic and the foreign country. When $\frac{\hat{A_{s0}}}{\hat{A_{u0}}} = 1$, we have $q_1 = 1 - q_1^*$ and also $\frac{\hat{A_{s1}}}{\hat{A_{u1}}} = 1$ so that $\hat{q}_2(1) = \frac{1}{2}$. Therefore, if the function $\hat{q}_2$ which is continuous in $\frac{\hat{A_{s0}}}{\hat{A_{u0}}}$ is increasing in

$\frac{\hat{A_{s0}}}{\hat{A_{u0}}}$, then we have $\hat{q}_2(\frac{\hat{A_{s0}}}{\hat{A_{u0}}}) < \frac{1}{2}$ for any $\frac{\hat{A_{s0}}}{\hat{A_{u0}}} < 1$. Let compute the derivative $\frac{d\hat{q}_2}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}$,

$$
\begin{aligned}
\frac{d\hat{q}_2}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} = \frac{1}{2}\Bigg[& 2q_0(1-q_0)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} \\
& + \frac{dq_1}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\left(-\epsilon+\epsilon(1-2q_1)\ln\left(\frac{1-q_1}{q_1}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right)\right) \\
& + \frac{dq_1^*}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\left(-\epsilon+\epsilon(1-2q_1^*)\ln\left(\frac{1-q_1^*}{q_1^*}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right)\right) \\
& +\epsilon(2\theta-1)(1-\alpha)\frac{d\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\frac{1}{\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}\left(q_1(1-q_1)+q_1^*(1-q_1^*)\right)\Bigg].
\end{aligned}
$$

Note that the term of the first line, that is the derivative of $q_1 + q_1^*$ is positive. Replace $\frac{dq_1}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} = q_0(1-q_0)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}$, $\frac{dq_1^*}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} = q_0^*(1-q_0^*)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}$, and re-arrange the terms,

$$
\begin{aligned}
\frac{d\hat{q}_2}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} = \frac{1}{2}\Bigg[& 2q_0(1-q_0)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} \\
& + q_0(1-q_0)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\left(\epsilon(1-2q_1)\ln\left(\frac{1-q_1}{q_1}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right)\right) \\
& + q_0^*(1-q_0^*)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\left(\epsilon(1-2q_1^*)\ln\left(\frac{1-q_1^*}{q_1^*}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right)\right) \\
& + \epsilon(2\theta-1)(1-\alpha)\frac{d\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\frac{1}{\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}\left(q_1(1-q_1)+q_1^*(1-q_1^*)\right) \\
& -\epsilon(q_0(1-q_0)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} - q_0^*(1-q_0^*)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}})\Bigg],
\end{aligned}
$$

Hence,

$$\frac{d\hat{q}_2}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}} = \frac{1}{2}\Bigg[2q_0(1-q_0)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}$$
$$+ q_0(1-q_0)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\left(\epsilon(1-2q_1)\ln\left(\frac{1-q_1}{q_1}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right)\right)$$
$$+ q_0^*(1-q_0^*)(2\theta-1)(1-\alpha)\epsilon\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\left(\epsilon(1-2q_1^*)\ln\left(\frac{1-q_1^*}{q_1^*}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)}\right)\right)$$
$$+\epsilon(2\theta-1)(1-\alpha)\frac{1}{\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\left[\frac{d\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\frac{1}{\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}q_1(1-q_1)-\epsilon q_0(1-q_0)+\frac{d\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\frac{1}{\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}q_1^*(1-q_1^*)-\epsilon q_0^*(1-q_0^*)\right]\Bigg].$$

Due to $\frac{1}{2} < q_2 < q_1$ and $\frac{1}{2} > q_2^* > q_1^*$, one has $1-2q_1 < 0$, $1-2q_1^* > 0$, $\frac{1-q_1^*}{q_1^*}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)} < 1$ and $\frac{1-q_1^*}{q_1^*}\frac{\hat{A_{s1}}}{\hat{A_{u1}}}^{(2\theta-1)(1-\alpha)} > 1$ so that the terms of the second and third line are positive. Also due to $\frac{1}{2} < q_1 < q_0$, $\frac{1}{2} > q_1^* > q_0^*$, one has $q_1(1-q_1) > q_0(1-q_0)$ and $q_1^*(1-q_1^*) > q_0^*(1-q_0^*)$. One easily finds that $\frac{d\frac{\hat{A_{s1}}}{\hat{A_{u1}}}}{d\frac{\hat{A_{s0}}}{\hat{A_{u0}}}}\frac{1}{\frac{\hat{A_{s1}}}{\hat{A_{u1}}}} > 1$. Since $\epsilon < 1$, I deduce that the derivative is positive.

By recurrence, I deduce that $\hat{q}_t < \frac{1}{2}$ and $\frac{\hat{A_{st}}}{\hat{A_{ut}}} < 1\ \forall t$. Given Lemma 4 and following the proof of Proposition 1, one concludes that $(q_t, q_t^*, \frac{A_{st}}{A_{ut}})$ converges to $(\bar{q}_1, \bar{q}_1, \frac{\bar{A_{s1}}}{A_{u1}})$.

The symmetric reasoning allows to conclude that $(q_t, q_t^*, \frac{A_{st}}{A_{ut}})$ converges to $(\bar{q}_2, \bar{q}_2, \frac{\bar{A_{s2}}}{A_{u2}})$.