

Three Essays on Low-Skilled Migration, Sustainability and Trade in Services

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Abstract

Chapter 1 Low-skilled Migration and Altruism: Population ageing has become a common concern among welfare states, including Canada and most of the OECD countries. Immigration has been identified as a solution to help sustain labour-force growth in industrialized countries, and as the factor most able to mitigate dire predictions of future fiscal imbalances. This chapter examines the impact of low-skilled immigration in a host country where households are altruists with a pay-as-you-go pension system to support the elderly. It demonstrates that low-skilled immigration does not harm the welfare of the domestic population. We use an overlapping-generations model similar to the work of Razin and Sadka (2000) but introduce paternalistic altruism into the life-cycle framework. Within this context of inter-generational altruism and pay-as-you-go pension systems, the initial negative fiscal impact of low-skilled migrants is compensated, thus, all income groups (high and low) and all age groups (young and old) benefit from migration.

Chapter 2 Growth and Sustainability: In light of the major environmental issues experienced by several countries in the last decades, several papers have advocated the rethinking of the role of governments in environmental preservation. This chapter develops an overlapping-generations model of environmental quality and production and investigates the potential role of governmental participation in the preservation of the quality of the environment so as to achieve both economic growth and environmental sustainability. The analysis suggests that long term economic growth and environment sustainability can be

maintained with tax-funded environmental programs in a context of a negative production externality on the quality of the environment.

Chapter 3 The Incidence of Geography on Canada's Services Trade:

We estimate geographic barriers to export trade in nine service categories for Canada's provinces from 1997 to 2007 using the structural gravity model. Constructed Home, Domestic and Foreign Bias indexes capture the direct plus indirect effect of services trade costs on intra-provincial, inter-provincial and international trade relative to their frictionless benchmarks. Barriers to services international trade are huge relative to inter-provincial trade and large relative to goods international trade. A novel test confirms the fit of structural gravity with services trade data.

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General Introduction

Three chapters constitute my doctoral dissertation. The first two chapters, titled *Altruism and Low-skilled Migration* and *Growth and Sustainability* explore the dynamics of an economy in a multiple generations setting. They incorporate the notion of welfare improvement to the current generation but also to the future ones. The third chapter, *The Incidence of Geography on Canada's Services Trade*, examines the barriers to trade in services between Canada and the United States and their impact on growth.

The first chapter, *Altruism and Low-skilled Migration*, examines the role of altruistic behaviours when examining the impact of low-skilled immigration in a host country and a Pay-as-you-go pension system. Population ageing is now a common feature of welfare states and is expected to have serious economic consequences, among which are slow growth of the labour force and a higher ratio of elderly to the working age population, and to increase the burden on the productive labour force, therefore posing a serious strain on the fiscal sustainability of many countries. These countries are confronted with the choice of either increasing contribution rates or reducing pension benefits. In order to avoid this undesirable trade-off, immigration has been identified as a solution to sustaining the labour force growth of most industrialized countries and as a factor able of modifying predictions of future fiscal imbalances.

A central issue in the ongoing immigration debate has been *the fiscal impact of immigrants*. Borjas (1994a) and Auerbach and Oreopoulos (1999a) have suggested that the strain imposed on public finances by immigrants is not due to the rise in their number, but rather to the decline in their earning ability. Since then, research has turned to the *role of skills* in explaining the participation of immigrants in the labour market and in social programs.

To the best of our knowledge, no study measuring the role of skills in immigrants' fiscal contribution has challenged the saving-consumption pattern of the agents in an infinitely-lived economy. In an economy characterized by life-cycle saving behaviour, the

capital stock is generated by individuals who save during their working years to finance their consumption during retirement. Thus, the individuals end up with zero assets at the end of their lives. While the infinitely-lived nature of the economy induces links between generations, the economic planning horizon of each individual is constrained by his own lifecycle.

In this context, the agent's marginal propensity to save diminishes with age. At the same time, the introduction of a social security system further contributes to the reduction in private savings by providing insurance against the possibility of a low income shock affecting the descendants. The rate of capital accumulation falls as well as the steady state capital stock. The arrival of low-skilled migrants further reduces the per capita national product and decreases the welfare of the original inhabitants. The incorporation of paternalistic altruism into a life-cycle framework would remediate this reduction in welfare as it allows for linkages between each agent's economic planning horizons, and thus ensures the sustainability of the capital stock.

We build upon the work of Razin and Sadka (2000a) to include paternalistic altruism to the life-cycle saving framework. Within the context of inter-generational altruism and a pay-as-you-go pension system, we find that immigrants do not need to be skilled to contribute to the sustainability of the fiscal policy of the host country. The altruistic linkages and the bequest motive are sufficient to compensate for the initial negative fiscal impact of low-skilled migrants. It follows that all income ranges (high and low) and all age groups (young and old) benefit from migration. The economic intuition behind this result is partly derived from *Ricardian equivalence*: In an economy with unfunded social security and with positive existing bequests, individuals offset the change in social security contributions by modifying their bequests, such that the net transfers between generations remain unaffected (Barro, 1974). The result is also partly explained by *consumption smoothing* whereby bequests are considered as an element of the utility function. The pensioners, therefore, transmit a fraction of their wealth through end-of-life bequests in order to protect their children from any undesirable fluctuations in their levels of welfare. The presence of intergenerational transfers engenders additional savings at the aggregate level that increase the capital stock.

The second chapter, *Growth and Sustainability*, studies the dynamics of the agents' defensive protection behaviour and of governmental interventions on the preservation of the environment and on economic growth. Environment deterioration is now a common concern among economies. For the last 30 years, world conferences on the Environment like the Earth Summits have highlighted major issues: rarity of non-polluted air, clean water access, climate change etc, and have mandated serious actions to be taken. During that same period, the roles of the government, as well as the behaviour of individuals, in relation to the environment have also been revisited but the economic theory rarely analyses this evolution. It still portrays the government, when it comes to the environment, as a taxation administrator (Baumol, 1972 and 1974; Wittman, 1985; John *et al.*, 1995; Ono, 1996) or as pollution licenses issuer (Montgomery, 1972). These representations exclude the development of environmental programs introduced by governmental entities and abstract from the signalling role that governmental entity can play when it comes to informing and influencing the behaviour of individuals. It also excludes the possible reactions of myopic and self-serving individuals (reduction in consumption, maintenance, recycling etc) when it comes to environmental protection.

To the best of our knowledge, the existing literature on environment and sustainability does not look at the dynamics of the agents' defensive protection behaviour and of governmental interventions on the preservation of the environment and on economic growth. In an inter-generational context, the environmental impacts of production and consumption have been analyzed with the assumptions of pollution abatement (Jouvet *et al.*, 2000 and 2002; Brechet *et al.*, 2005) or investment in the maintenance of the environment (John and Pecchenino, 1994; John *et al.*, 1995; Ono, 1996). None of the studies have considered *the role of governmental programs* on the preservation of the environment by assuming that solely the actions of the agents can have an impact on its quality. While it is reasonable to foresee the need for agents' participation to have an influence on the preservation of the environment, we believe that they are also reacting to governmental intervention. Without infrastructures, installations and environmental programs, the impact of their participation is limited. Furthermore, the government programs and policies often act as signals for the individuals.

We extend the work of John and Pecchenino (1994) to a governmental presence and by including the agents' behaviour of defensive protection against the degradation of the environment. Our study examines the government's role in sustainability by making the strong assumption that all taxes (on income and on the use of capital) collected are exclusively used for environmental programs and by examining whether growth can still be unrelenting over generations. Aged individuals typically care about consumption and are affected, via their health, by the quality of their environment. Our model links the young agents' investment in defensive protection to the public programs by a spillover function in the spirit of Barro and Sala-i-Martin (1992 and 2004). Following Jouvét *et al.* (2000) and Gutierrez (2008), we introduce production as a source of pollution. The production of the consumable good creates ecological degradation (pollution) hence inducing a substitution effect between old-age consumption and environment preservation for each agent.

Our results suggest that economic growth and environment sustainability can be maintained in the context that production creates a negative environmental externality and in the presence of agents' defensive protection and tax-funded environmental programs. Our main finding is that both the wage income tax and the capital tax *contribute* to savings *i.e.* to the growth of the economy but without imposing additional degradation to the environment. Governmental spending create spillover effects on the agent's first period choice of investing in environmental protection, the wage income tax affects private savings through two channels: a *spillover* effect and a *substitution* effect. The mechanism at play is that the individuals perceive their own spending on the defensive goods and the governmental programs as substitutes but that governmental spending encourages them (via the spillover effect) to spend more on defensive protection. The importance of the quality of the environment when old still incite them to defend themselves against the deterioration of the environment but to a lesser degree than the effect of spillover from the governmental programs.

The third chapter titled *The Incidence of Geography on Canada's Services Trade*, coauthored with James E. Anderson and Yoto V. Yotov, investigates the trade in services between Canada and the United States. It attempts at quantifying the effects of geographic barriers to the services trade of Canada's provinces from 1997 to 2007. We thus investigate

the border effect in service trade between Canada and the United States in the post-9/11 context of increased security-related border measures. Our study draws a portrait of the border-related factors impacting the services sectors and quantifies their impact on the Canadian economy. Contrary to the merchandise trade sectors, very few studies have attempted to measure the degree of trade-related friction in services between Canada and the United States (Papadaki *et al.*, 2006; Francois *et al.*, 2007)¹ and no studies have measured the border effect on trade in services between Canada and the United States.

Services have unique features that can affect their tradability. Such characteristics include: intangibility, non-storability, differentiation and joint production as customers must participate in the production process. In order to enhance the export performance of Canadian businesses in the world and more specifically in the United States, one suggested approach is to improve the trade participation of the service providers. Harmonization of procedures, the removal or lowering of regulatory barriers to services trade and the diminishing of discrimination vis-à-vis foreign service providers can contribute to further liberalize trade in services. Taking into consideration that the facilitation of the efficient crossing could improve the participation of Canadian service providers, an analysis of barriers to trade affecting the bilateral exchanges in services is therefore an important preoccupation for trade policy.

Many studies confirm that further trade liberalization in services would bring such positive effects as increased efficiency and competitiveness of the domestic economy (Nielson and Taglioni, 2004), growth-enhancing effect in the long run (Mattoo *et al.*, 2006) and indirect effects from the services sector trade liberalization on the efficiency and output of other sectors in the economy (via inter-industry input-output relations and TFP growth) (Robinson *et al.*, 2002). Although known that little facilitation related to the flow of services exists between the United States and Canada, there is no solid evidence of how much trade in services is subjected to border and friction costs.

¹ The literature reports trade and friction costs of 20 per cent to 46 per cent in tariffs equivalents for the Canadian services sectors.

We find significant, large service border effects in each direction of service trade flows. There is evidence for changes (mostly thickening) in the border effects in the post 9/11 period. Finally, we see some directional asymmetries in both our border and thickening estimates. Such diversity arises due to differences across sectors in the ability of private agents to invest in friction-reducing activities, some linked to new border security measures and others simply as a reaction to perceived market opportunities.

The magnitude of services trade barriers found in our study suggests potential large gains from globalization over time, especially if speeded up by deliberate policy efforts to liberalize services trade. The similar Constructed Home Bias of services and goods trade suggest the potential for Constructed Foreign Bias to also be similar, implying a seven-fold potential rise in services trade across borders. Large welfare improvement for the Canadian economy would result from even a partial fall of the barriers to trade in services.

Chapter 1

Altruism and Low-skilled Migration

1.1 Introduction

In this chapter, we examine the impact of low-skilled immigration in a host country with altruistic households and a Pay-as-you-go pension system. Population ageing is now a common feature of welfare states, such as Canada and most OECD countries². As a result of the staggering lower fertility rate and of the increased longevity³, ageing is expected to last and to have serious economic consequences, among which are slow growth of the labour force and a higher ratio of elderly to the working age population. In welfare states, the economic impacts of ageing are compounded by the fact that an important share of redistributive transfers is accounted by transfers to elderly, health, and social programs. The support and provision of social services for an expanding age dependent population increases the burden on the productive labour force, and therefore poses a serious strain on the fiscal sustainability of many countries.

With the continued ageing of their populations, countries are confronted with the choice of either increasing contribution rates or reducing pension benefits. In order to avoid this undesirable trade-off, immigration has been identified as a solution to sustaining the labour force growth of most industrialized countries and as a factor able of modifying predictions of future fiscal imbalances. The rationale is that new immigrants dampen the negative effects of ageing on both contribution rates and benefits as their participation in the

² OECD reports that, in 2005, the ratio of population aged 65 and older to the total population is 13.6% in average and should increase to 17.3% in 2020 and to 26.7% in 2050 (OECD, 2008).

³ OECD reports that, in 2005, the average fertility rate was 1.60 births per woman down from 3.2 in 1960 and 2.0 in 1980 and that life expectancy at birth had reached 78.6 years old on average, up 10 years from 1960 (OECD, 2007).

labour market increases the level of aggregate contributions. Since the 1980s, various countries such as Canada, Germany and Australia have had recourse to significant immigration flows (between 0.7% and 0.9% of their population growth rate). To compensate for the ageing and decline of their domestic populations, these flows were largely composed of working age immigrants.

A central issue in the ongoing immigration debate has been *the fiscal impact of immigrants*. Borjas (1994a) and Auerbach and Oreopoulos (1999a) have suggested that the strain imposed on public finances by immigrants is not due to the rise in their number, but rather to the decline in their earning ability. Since then, research has turned to the *role of skills* in explaining the participation of immigrants in the labour market and in social programs. The finding indicates that the level of education has a direct influence on immigrants' participation in the labour market, and hence, on their participation in welfare programs.

In a static set-up, low-skilled immigration is costly to the host economy as it exacerbates imperfections in the labour market and increases the economic cost of non-lump-sum income redistribution policies (Wildasin, 1994; Razin and Sadka, 1995). However, the contribution of skilled immigrants is found to be positive as a result of the high production complementarities existing between skilled labour and other factors of production (Borjas, 1995). In a dynamic framework, immigration of low-skilled workers imposes a burden on the welfare state, while skilled migration is found to sustain fiscal policy (Lee and Miller, 1997; Bonin et al., 1998). The rationale for this is that a flow of low-skilled workers reduces aggregate savings as well as the economy's capital stock, imposing on the high-skilled workers the financing of a larger welfare state (Canova and Ravn, 1998).

Nonetheless, the negative impact of low-skilled immigrants on the economy has been challenged by Razin and Sadka (1999). Their analysis suggests that immigration of low-skilled workers in an economy with a pay-as-you-go pension system does not represent a burden and could even be a Pareto-improving measure. The central result of their paper rests on the assumption of an infinite-horizon economy à la Samuelson (1958). In such an economy, the burden of the first generation of immigrants is shifted forward indefinitely into the future, while the original inhabitants of the economy receive a one-time gain. If

immigration is repeated in each period or the gain is spread out over all consecutive periods, all descendants of the host population will gain.

Following Razin and Sadka (1999), subsequent research has relaxed the restrictive assumptions of fixed factor prices and perfect labour market conditions. In another paper, Razin and Sadka (2000a) find that when factor prices are variable, low-skilled migration decreases wages and increases the relative return of capital to that of labour. As a consequence, in the period in which migrants arrive, only old individuals gain because of a rise in their old-age pension benefit combined with an increased return to capital. All other income groups in every generation lose from migration and their loss is an increasing function of the number of immigrants. It thus appears that the relaxation of some assumptions in Razin and Sadka (1999) model refutes the conclusion that immigration of less productive workers improves public finances.

To the best of our knowledge, no study measuring the role of skills in immigrants' fiscal contribution has challenged the saving-consumption pattern of the agents in an infinitely-lived economy. In an economy characterized by life-cycle saving behaviour, the capital stock is generated by individuals who save during their working years to finance their consumption during retirement. Thus, the individuals end up with zero assets at the end of their lives. While the infinitely-lived nature of the economy induces links between generations, the economic planning horizon of each individual is constrained to his own lifecycle.

Therefore, in order to offset any shock to the economy, such as the arrival of low-skilled immigrants, no financial flow is transmitted from one generation to the next. In this context, the agent's marginal propensity to save diminishes with age. At the same time, the introduction of a social security system further contributes to the reduction in private savings by providing insurance against the possibility of a low income shock affecting the descendants. The rate of capital accumulation falls as well as the steady state capital stock. The arrival of low-skilled migrants further reduces the per worker national product as they do not bring capital with them and decreases the welfare of the original inhabitants. The incorporation of paternalistic altruism into a life-cycle framework would remediate this

reduction in welfare as it allows for linkages between each agent's economic planning horizons, and thus ensures the sustainability of the capital stock.

We believe that the main result obtained by Razin and Sadka (2000a) concerning the non-beneficial effect of low-skilled immigration for the host country in the presence of varying factor prices, is largely dependent on the life-cycle saving patterns of agents rather than on the infinitely-lived nature of the economy. The analysis could benefit from the introduction of households' wealth acquired from two sources: savings out of income earned and transfers from family members of previous generations. Empirical studies on savings and bequest motives have shown that the wide differences in preferences and in behaviour between individuals justify the inclusion of intergenerational welfare functions into a life-cycle based model (Arrondel et al., 1997). In addition, the results of Altonji et al. (1992) and Laitner and Ohlsson (2001) offer positive support for an altruistic model based on intended transfers.

Moreover, the same studies have estimated that between 18.0% and 70.0% of aggregate wealth in the United States is attributable to intended transfers and bequests rather than life-cycle savings (Kotlikoff and Summers, 1981; Gale and Scholz, 1994). Thus, bequests and intergenerational transfers illustrate the altruistic nature of agents and seem to account for an important part of individual wealth. The evidence we provide indicates that the simple life-cycle model does not explain an important component of capital accumulation and wealth distribution; thus, we believe that the inclusion of altruism would reflect more realistically the impact of low-skilled migrants on the fiscal policy of the domestic economy.

In this chapter we build upon the work of Razin and Sadka (2000a) to include paternalistic altruism to the life-cycle saving framework. Within the context of intergenerational altruism and a pay-as-you-go pension system, we find that immigrants do not need to be skilled to contribute to the sustainability of the fiscal policy of the host country. The altruistic linkages and the bequest motive are sufficient to compensate for the initial negative fiscal impact of low-skilled migrants. It follows that all income ranges (high and low) and all age groups (young and old) benefit from migration. The economic intuition behind this result is partly derived from Ricardian equivalence. In an economy with unfunded social security and with positive existing bequests, individuals offset the change in

social security contributions by modifying their bequests, such that the net transfers between generations remain unaffected (Barro, 1974). The result is also partly explained by consumption smoothing whereby bequests are considered as an element of the utility function. The pensioners, therefore, transmit a fraction of their wealth through end-of-life bequests in order to protect their children from any undesirable fluctuations in their levels of welfare. The presence of intergenerational transfers engenders additional savings at the aggregate level that increase the capital stock.

The organization of the paper is as follows. Section 1.2 provides a description of the economy, and section 1.3 develops the dynamics of the economy. Section 1.4 presents the welfare analysis. Section 1.5 concludes.

1.2 Description of the Economy

Following Razin and Sadka (2000a), we use an overlapping-generations model, where each generation lives for two periods. In the first period of his life, the individual is young, decides to get an education, works, bears $(1+n)$ children, consumes a single good and saves for retirement. In the second period of his life, the individual is now old and retired; he consumes his retirement savings and his pension benefits but also leaves bequests to his $(1+n)$ descendants. Fiscal policy consists mainly in a Pay-as-you-go (PAYG) pension system. In this section, we first discuss the decisions of the domestic agents without immigration and examine in the next section the impact of immigration on those decisions.

1.2.1 The Households

The households provide labour services in exchange for wages, receive interest income on their assets, purchase goods for consumption and save by accumulating assets. We do not allow for labour/leisure choice: each household supplies inelastically one unit of labour⁴. The

⁴ It is common in the OLG analytical literature to remove the labour/leisure choice of young agents for tractability purposes. We list Diamond (1965), Barro (1974), Blanchard (1985) and Weil (1987a) as a few.

economy is composed of identical households, each containing one adult alive for two periods, having the same preferences, facing the same wage rate and the same fertility rate. In making his plans, the optimizing agent takes into account the welfare and the resources of his descendants by leaving them an end-of-life bequest.

Ability, Schooling Decisions and Labour Productivity

Following Krieger (2004), we use a simplified version of the model of Razin and Sadka (2000a) in which we abstract from the distribution function of education of the individuals.⁵ It is presumed that there are two homogenous groups of workers in the economy; the unskilled, who represent a constant fraction N^U of the workforce, and the skilled, composing the constant fraction N^S of the same workforce; such that $N^S + N^U = 1$. Both types of workers are perfect substitutes in production. There are also two levels of labour productivity: low productivity characterizes the unskilled worker while the skilled worker has a high productivity. An unskilled worker provides $q < 1$ units of effective labour supply, per unit of time at work, whereas a skilled worker provides one full unit of effective labour supply, per unit of time at work. The wage per effective units of labour is denoted by w_t .⁶

Each individual possesses one unit of labour-schooling time endowment in the first period of his life (when young). Since every agent is born unskilled, each skilled worker must acquire skills by investing e units of time in schooling during his first period of life. The remainder of his one unit of time, $(1-e)$, is spent working as a skilled worker. Due to the homogeneousness characteristic of the skilled workers group, the individual-specific parameter e that reflects the innate ability of an individual in acquiring a work skill will be the same for all of the skilled workers, *i.e.*, the average level of ability $\bar{e}$. The individual who chooses not to acquire skills will allocate his entire unit of time endowment working as

⁵ In Razin and Sadka (2000a), the education decision parameter e ranges between 0 and 1 but follows a cumulative distribution function $G(e)$.

⁶ The wage rate is defined per effective units of labour otherwise only the skilled agents would be employed as both the unskilled and skilled workers are substitute in production.

an unskilled worker. The skilled worker, after investing e^- units of his time in schooling, earns an after tax income of $w_t \cdot (1 - \tau) \cdot (1 - e^-)$ while the unskilled worker earns $q \cdot w_t \cdot (1 - \tau)$.

Altruism, Preferences, Savings and Consumption

This economy has one single produced good that can be consumed or invested. Individuals decide how much to consume and save, partly to smooth consumption possibilities over their lifetime and partly to leave a bequest to their descendants. The agent can save by either accumulating capital or lending to other families but will end up with zero net loans at the equilibrium. Families are indifferent to the composition of their wealth, so the interest rate on loans must be equal to the rental rate on capital

Altruism and Preferences

Following Barro (1974) and Barro and Sala-i-Martin (2004), we assume that people value their children's happiness and introduce altruistic linkages across generations. Parents make intergenerational transfers to their descendants in the period in which they are retired. Assuming that transfers occur while the elderly are still alive allows for the funding of the first-period consumption of the next generation. We follow the theory developed by Becker (1974), Blinder (1974, 1976) and Modigliani (1986) and define agents as *paternalistic altruists* i.e. the amount of bequest is not based on the children's preferences but on what the parents judge might be good for their children.⁷ The bequests thus enter the utility function as any other consumption good and the economic position of the child is not taken into

⁷ Paternalistic altruism can also be referred to as 'warm glow preferences' which assume that parents derive utility from the act of giving rather than the utility or the consumption of their offspring. For further details, see Andreoni (1989) or Acemoglu (2007). Baranzini (1991) also builds a model in which bequests enter the utility function.

consideration.⁸ Young agents accumulate private savings to ensure old-age consumption and to leave some financial means to their descendants.

The agents have a log linear utility function and temporally separable preferences. An altruistic individual born in period t faces the following utility function:

$$U_t(c_{1,t}^t, c_{2,t+1}^t, b_{t+1}^t) = \log c_{1,t}^t + \beta \log c_{2,t+1}^t + \phi(1+n) \log b_{t+1}^t \quad (1.1)$$

The first two terms in the right-hand side represent the utility derived by consumption over the two periods of life with $c_{1,t}^t$ being the first-period consumption of the individual born in period t and $c_{2,t+1}^t$ being the same individual's consumption in the second period of his life. The last term in the right-hand side represents the utility (warm glow) derived from the real amount bequeathed b_{t+1}^t to each of the $(1+n)$ children.

The parameter $\beta < 1$ is the fixed subjective inter-temporal discount factor and is defined as $\beta = \frac{1}{1+\rho}$ where $\rho > 0$ is the rate of time preference or the subjective discount rate for consumption. We assume that all consumers have the same subjective discount rate otherwise the consumer whose discount factor is highest will eventually be the only one to consume. The parameter ϕ ($0 < \phi < 1$) represents the degree of altruism expressed by the agent and is defined as $\phi = \frac{1}{1+\kappa}$ where $\kappa > 0$ is the rate of preference, or the subjective discount rate, for the bequest. The stronger is the degree of paternalistic altruism ϕ , the larger will be the amount bequeathed by the individual born in period t to the individual born in period $t+1$.

⁸ Under pure altruism, the parents care about their children's welfare by weighting the children's utility in their own utility function. 'This creates strong links between each generations and lead to large savings, the steady state level of capital is the modified golden rule level with the relevant discount rate being the rate at which parents care about their children utility' (Blanchard and Fisher, 1989). For tractability purpose, and since there are no empirical proofs that either type of altruism is more frequent, we used paternalistic altruism. Empirical studies on savings and bequest motives demonstrate that the wide differences in preferences and behaviour between individuals justifies the inclusion of intergenerational welfare functions to a life-cycle based model (Arrondel *et al.*, 1997) while the results of Altonji *et al.* (1992) and Laitner and Ohlsson (2001) on saving behaviour offer positive support for an altruistic model based on intended transfers.

Altruistic individuals bring up their $(1+n)$ descendants to also be of a generous nature thus the offspring of an altruist displays the same degree of altruism as the one expressed by his parents. As we assumed that bequests reflect the parental joy of giving, accidental bequests are therefore excluded from the model. We also assume one-sided altruism by imposing that the constraint $b_{t+1+i}^{t+i} > 0$ applies for all $i \geq 0$, *i.e.* there cannot be negative transfers (transfers from children to parents)⁹.

Budget constraints

We denote first-period consumption, second-period consumption and savings by, respectively, $c_{1,t}^t$, $c_{2,t+1}^t$ and s_t . The individual born at time t faces the following inter-temporal budget constraints over the first period and the second period of his life:

$$c_{1,t}^t + s_t = \omega_t(1 - \tau) + b_t^{t-1} \quad (1.2)$$

$$c_{2,t+1}^t + (1+n)b_{t+1}^t = (1+r_{t+1})s_t + P_{t+1} \quad (1.3)$$

ω_t is the before tax wage income such that

$$\omega_t = (1 - e^-)w_t \quad \text{if skilled workers} \quad (1.4)$$

$$\omega_t = q \cdot w_t \quad \text{if unskilled workers}$$

τ is the tax rate or the rate of contribution to the social security system.

b_t is the intergenerational transfer received by each individual born at time t . The total amount transferred by each old person in period t is thus $(1+n)b_t$.

⁹ We impose the condition that parents cannot leave negative bequests to their children in order to prevent family debt from increasing exponentially. This is similar to the no-Ponzi-game condition.

¹⁰ We have fixed the price of the consumption good, in each period t , equal to 1 (numéraire). We also assumed that bequest is a real variable (quantity) and thus has the same price as the consumption good.

r_{t+1} is the interest rate on one-period loans between periods t and $t+1$ since individuals can lend and borrow from other individuals. P_{t+1} is the social security benefit paid to retirees in the second period of their life and b_{t+1}^t is the amount bequeathed by the individual born in period t to its $(1+n)$ descendants at the end of the second period of his life.

Looking at the first-period budget constraint (1.2), we can see that, since members of previous generations care about the individual born in period t , the latter will begin his life with assets transferred to him in the form of bequests (b_t). He also supplies unskilled or skilled labour when young and receives the wage income net of taxes $\omega_t(1-\tau)$. His labour income and the amount bequeathed to him will provide for his first-period consumption as well as for his savings.

The second-period budget constraint (1.3) also incorporates the notion that individuals care about their descendants' welfare as they choose not to end up with zero asset at the end of their lives. They leave part of their savings (with accrued interests) and of their pension benefits to the following generation in the form of bequests and spend the remaining amount as old-age consumption.

As previously mentioned, we assume that the constraint $b_{t+1+i}^{t+i} > 0$ applies for all $i \geq 0$, *i.e.* parents cannot require their children to provide transfers.

The Agent's Problem

Taking w_t and r_{t+1} as given, an individual born at time t chooses s_t and b_{t+1} to maximize:

$$U_t(c_{1,t}^t, c_{2,t+1}^t, b_{t+1}^t) = \log c_{1,t}^t + \beta \log c_{2,t+1}^t + \phi(1+n) \log b_{t+1}^t \quad (1.1)$$

Subject to

$$c_{1,t}^t + s_t = \omega_t(1-\tau) + b_t \quad (1.2)$$

$$c_{2,t+1}^t + (1+n)b_{t+1}^t = (1+r_{t+1})s_t + P_{t+1} \quad (1.3)$$

$$\omega_t = (1-e^-)w_t \quad \text{if skilled workers} \quad (1.4)$$

$$\omega_t = q \cdot w_t \quad \text{if unskilled workers}$$

$$b_t \text{ is given} \quad (1.5)$$

$$b_{t+1+i} > 0 \quad (1.6)$$

$$c_{1,t+i}^{t+i} \geq 0, c_{2,t+1+i}^{t+i} \geq 0 \quad (1.7)$$

The optimizing individual's maximization of (1.1) over (1.2) – (1.7) results in the following first-order conditions:

$$\frac{\partial U_t / \partial c_{1,t}^t}{\partial U_t / \partial c_{2,t+1}^t} = (1 + r_{t+1}) \quad (1.8')$$

$$\frac{\partial U_t / \partial b_{t+1}^t}{\partial U_t / \partial c_{2,t+1}^t} = (1 + n) \quad (1.9')$$

The interpretation of these conditions is as follows: from the condition (1.8'), the accumulation of capital is the only available mechanisms through which the individual can transform first-period consumption into second-period consumption. Capital will be accumulated until the marginal rate of substituting present consumption for future consumption $\left[\frac{\partial U_t / \partial c_{1,t}^t}{\partial U_t / \partial c_{2,t+1}^t} \right]$ is equal to the marginal rate of transforming present into future consumption *i.e.* $(1 + r_{t+1})$. As expected, a bequest involves a sacrifice of old-age consumption. Condition (1.9') states that the marginal utility earned from a bequest must equal the consumption utility foregone (adjusted for the number of descendants). Replacing the derivatives with their results, we obtain

$$c_{2,t+1}^t = \beta(1 + r_{t+1})c_{1,t}^t \quad (1.8)$$

$$c_{2,t+1}^t = \frac{\beta}{\phi} b_{t+1}^t \quad (1.9)$$

Euler Equations and Other First-Order Conditions

The allocation of consumption over a person's life will vary according to the following equation

$$c_{2,t+1}^t = \beta(1 + r_{t+1})c_{1,t}^t \quad (1.8)$$

As previously mentioned, savings (in the form of capital) are accumulated until the marginal rate of substituting present for future consumption is equal to the marginal rate of transforming present into future consumption. Knowing that the interest rate r_{t+1} is the rate of return to saving and the inter-temporal discount factor β is the rate at which individuals discount future consumption, we can interpret the Euler equation by assuming that individuals choose per capita consumption to equate the rate of return r to the rate of time preference ρ . A log-linear utility function thus renders the optimizing agents indifferent to the timing of consumption *i.e.* first- and second-period consumptions would be equal *i.e.* agents are indifferent at the margin between consuming and saving.

$$\frac{c_{2,t+1}^t}{c_{1,t}^t} = \frac{(1 + r_{t+1})}{(1 + \rho)} \quad (1.8'')$$

Therefore the individual's decision to defer consumption is only related to the interest rate and the rate of time preference such as in the economy described by Razin and Sadka (2000a) where individuals are selfish. Thus the agents have a pattern of consumption that falls, rises or stay constant according to the rate of return to capital being smaller, greater or equal to the rate of time preference.

We note that the relation between the two levels of consumption is independent of the degree of altruism ϕ . Due to the separability of the utility function, the optimizing agent does not take into consideration his joy of giving when choosing a consumption pattern. Looking back at the equation (1.9) and combining equation (1.8) we can identify the relationships between bequests and consumptions:

$$b_{t+1}^t = \frac{\phi}{\beta} c_{2,t+1}^t \quad (1.9)$$

$$b_{t+1}^t = \phi(1 + r_{t+1})c_{1,t}^t \quad (1.10)$$

Bequests are a positive function of first- and of second-period consumption which varies according to the degree of altruism. According to equation (1.10), the relation between bequests and first-period consumption is directly related to the degree of altruism and to the rate of return to capital. A greater rate of return to capital delays consumption and encourages savings thus increases the ratio bequests to first-period consumption. Equation (1.9) demonstrates that bequests and second-period consumption vary according to a constant fraction that depends on the rate of preference and the degree of altruism. The more importance given to the joy of giving and the greater the rate of time preference ρ , both discouraging second-period consumption, the larger the bequests will be with respect to old-age consumption. Once again, a bequest involves a sacrifice of young and old-age consumptions.

Private Savings and Bequests

The consumer's problem gives rise to the following first order conditions for the savings of, and the bequests made by, the individual born in period t ,

$$s_t = \frac{\beta}{(1+\beta)} [\omega_t(1-\tau) + b_t] + \frac{(1+n)b_{t+1}}{(1+\beta)(1+r_{t+1})} - \frac{P_{t+1}}{(1+\beta)(1+r_{t+1})} \quad (1.11')$$

and

$$b_{t+1} = \frac{\phi}{[\beta + \phi(1+n)]} [(1+r_{t+1})s_t + P_{t+1}] \quad (1.12')$$

Private savings are a positive function of wage income and of bequests made and received by the individual born at time t and are negatively impacted by the pension benefits received by the agent in the second period of his life. Intergenerational transfers made by the elderly are a constant fraction, equal to $\frac{\phi}{[\beta + \phi(1+n)]}$, of their life-cycle wealth.

The maximization of the consumer's problem by the optimizing agent born in period t therefore gives rise to the following saving and bequest functions

$$s_t = \frac{[\beta + \phi(1+n)]}{[1 + \beta + \phi(1+n)]} [\omega_t(1-\tau) + b_t] - \frac{P_{t+1}}{[1 + \beta + \phi(1+n)](1+r_{t+1})} \quad (1.11)$$

and

$$b_{t+1} = \frac{\phi}{[1 + \beta + \phi(1+n)]} [(1+r_{t+1})[\omega_t(1-\tau) + b_t] + P_{t+1}] \quad (1.12)$$

As expected, due to the assumption of separability and concavity of the utility function, which ensures that both goods are normal, the private savings of the individual born in period t are an increasing function, discounted, of his net income from wages.

$$0 < \frac{\partial s_t}{\partial \omega_t} = \frac{\beta + \phi(1+n)}{[1 + \beta + \phi(1+n)]} (1-\tau) < 1 \quad (1.13)$$

Therefore, each individual has a constant saving rate, equal to $[\beta + \phi(1+n)]/[1 + \beta + \phi(1+n)]$, out of labour income net of taxes. Looking at the derivative of bequests with respect to wages,

$$\frac{\partial b_{t+1}}{\partial \omega_t} = \frac{\phi}{[1 + \beta + \phi(1+n)]} (1+r_{t+1})(1-\tau) > 0 \quad (1.14)$$

We find that, similarly to private savings, the amount bequeathed is an increasing function of net wages which varies according to the rate of return to capital. The private savings of, and the amount bequeathed by, the agent born in period t are also function, discounted and prorated by the degree of altruism, of the amount legated by the individual born in period $t-1$ (his parents). Finally, we can observe the impact of a social security system on the savings and the bequest propensity of the agent born at time t . Taking the derivative of equation (1.11) with respect to P_{t+1} ,

$$\frac{\partial s_t}{\partial P_{t+1}} = -\frac{1}{[1 + \beta + \phi(1+n)](1+r_{t+1})} < 0 \quad (1.15)$$

Since private savings and pension benefits both allow for the second-period consumption of goods, they are thus perceived as perfect substitutes by the agent and consequently, access to social security benefits reduces the individual's marginal propensity

to save. Moreover, the pension benefits diminish the individual's savings by an inverse function of the subjective rate of preference, of the degree of altruism and of the interest rate that would be earned on these private savings. Having assumed constant rates for the subjective inter-temporal discount factor β , for the degree of altruism and for the fertility rate, any increase in the rate of return to capital, which renders savings more attractive, would mitigate the negative impact of pension benefits on private savings.

The amount bequeathed by the individual born at time t to each of his descendants is also affected by the discounted pension benefits he will receive in $t+1$ (when old). Taking the derivative of equations (1.12) with respect to P_{t+1} ,

$$\frac{\partial b_{t+1}}{\partial P_{t+1}} = \frac{\phi}{[1 + \beta + \phi(1 + n)]} > 0 \quad (1.16)$$

Pension benefits and bequests both allow for future consumption, either old-age consumption of the parent or first-period consumption of the children, therefore the social security benefits received by the agent born at period t augment his bequest capacity. Since the utility function is concave, households prefer a smooth consumption profile and would like to offset the income redistribution (from young to old) imposed by the social security system. This income redistribution is compensated by a variation in the wealth left from the elderly generation to the young generation e.g. an augmentation in pension benefits leads to an increase in bequests.

As a special case, in which the individual in period t is selfish *i.e.* $\phi = 0$, we can easily derive Razin and Sadka (2000a)'s result as equation (1.11) then collapses to $s_t = \frac{\beta}{(1 + \beta)} \omega_t(1 - \tau) - \frac{P_{t+1}}{(1 + \beta)(1 + r_{t+1})}$ thus representing the savings of a pure life cycler who does not legate financial resources to his descendants.

First- and Second-Period Consumption

Substituting equations (1.11) and (1.12) in the first-period and in the second-period budget constraints, equations (1.2) and (1.3), respectively, imply the following first-period and second-period consumption functions for the individual born at time t

$$c'_{1,t} = \frac{1}{[1 + \beta + \phi(1+n)]} \left(\omega_t(1-\tau) + b_t + \frac{P_{t+1}}{(1+r_{t+1})} \right) \quad (1.17)$$

and

$$c'_{2,t+1} = \frac{\beta(1+r_{t+1})}{[1 + \beta + \phi(1+n)]} \left(\omega_t(1-\tau) + b_t + \frac{P_{t+1}}{(1+r_{t+1})} \right) \quad (1.18)$$

First-period consumption is, as was the case for private savings, an increasing function of wage-income net of taxes and of the bequests received. Contrary to private savings, first-period consumption increases with the amount of pension benefits received in period $t+1$.

$$\frac{\partial c'_{1,t}}{\partial P_{t+1}} = \frac{1}{[1 + \beta + \phi(1+n)](1+r_{t+1})} > 0 \quad (1.19)$$

Since pension benefits represent a part of the individual's life-cycle wealth, they thus contribute to an increase of consumption in both first- and second-period. A large rate of time preference ρ , which favours present consumption, augments the contribution of any variation of pension benefits on first-period consumption. Alternatively, an increase in the interest rate (rate of return to savings) makes first-period consumption less attractive thus reduces the influence of social security benefits on young age consumption. Finally, an altruistic agent will exhibit greater preferences for bequest via a stronger degree of altruism thus will reduce his first-period consumption in order to legate more of his life-cycle income to his offspring.

Here also, the special case of the selfish agent *i.e.* $\phi = 0$, leads to Razin and Sadka

$$(2000a)'s \text{ result } c'_{1,t} = \frac{1}{(1+\beta)} \omega_t(1-\tau) + \frac{P_{t+1}}{(1+\beta)(1+r_{t+1})}.$$

Now looking at the derivative of the equation (1.18) for old-age consumption with respect to P_{t+1}

$$\frac{\partial c_{2,t+1}}{\partial P_{t+1}} = \frac{\beta}{[1 + \beta + \phi(1 + n)]} > 0 \quad (1.20)$$

The degree of altruism that characterizes the family of the individual born at time t directly translates into a reduction of the amount of good consumed in the second period of his life. Once again, the absence of altruism ($\phi = 0$), leads to the equation for second-period consumption of Razin and Sadka (2000a), $c'_{2,t+1} = \frac{\beta(1+r_{t+1})}{(1+\beta)} \left(\omega_t(1-\tau) + \frac{P_{t+1}}{(1+r_{t+1})} \right)$.

The Effective Labour Supply

At each period t , only the young generation constitutes the labour force of the economy as we assumed that individuals work when young (first period of life) and then retire *i.e.* stop working when old (second period of life). The individual who decides to get an education will work as a skilled worker for the rest of his first period of life ($1-e$), while the agent who chooses to remain unskilled will work as an unskilled worker *i.e.* the labour force participation of workers varies according to their skill levels. The workforce is divided into two homogenous groups of workers; the unskilled (N^U) who work at a productive level of $q < 1$ and the skilled (N^S) who work at a productive level of $q = 1$. We normalize the young population of period zero to unity ($N_0 = 1$) and obtain the following aggregate effective labour supply

$$L_0 = (1 - e^-)N^S + qN^U \quad (1.21)$$

The first term consists in the effective labour supply of the skilled workers and the second term is the effective labour supply of the unskilled workers: the unskilled (N^U) work their entire unit of time at a productive level of $q < 1$ and the skilled (N^S) spend the remaining portion ($1-e^-$) of their unit of time working at a productive level of $q = 1$.

With a fertility rate of n , the young population will grow to attain $(1+n)$ working individuals in period one. The total population of workers is $N_1 = (1+n)N^s + (1+n)N^u$. The $(1+n)N^s$ skilled workers spend e units of their 1 unit of time studying and $(1-e)$ units of their time working at a productive rate of $q=1$. The $(1+n)N^u$ unskilled individuals spend their full unit of time working at a productive rate of $q<1$. The effective labour supply becomes

$$L_1 = (1+n)[(1-e^-)N^s + qN^u] \quad (1.22)$$

In period t , the total population of young workers now attains $N_t = (1+n)^t N^s + (1+n)^t N^u$. The effective labour supply is

$$L_t = (1+n)^t [(1-e^-)N^s + qN^u] \quad (1.23)$$

1.2.2 The Firms

The firms produce goods, pay wages for labour input and make rental payment for the use of capital. Each firm has access to the constant-returns-to-scale production technology

$$F(K_t, L_t) = L_t F(K_t / L_t, 1) \equiv L_t f(k_t) \quad (1.24)$$

Since each young person owns one unit of time and works according to their ability, the variable L_t is the total effective labour supplied by young people in the economy. It is assumed that the capital stock in period t is productive in the same period; there is no lag in the production and use of capital.

In each period t , the firms offer the wage rate w_t for each hour of effective labour supplied by the young agents and rent the services of capital from the elderly at a rental rate of R_t per unit of capital. Since capital depreciates at the constant and positive rate δ , the net rate of return to the old individual that owns one unit of capital is $R_t - \delta$. Since families are indifferent as to the composition of their wealth, loans and capital being perfect substitutes in terms of value, we must have $r_t = R_t - \delta$ or $R_t = r_t + \delta$.

The representative firm's profit at any point in time is given by

$$\text{Max } \pi = F(K_t, L_t) - R_t K_t - w_t L_t \quad (1.25')$$

The problem of maximizing the present value of profit reduces to a problem of maximizing profit in each period without regard to the outcomes in other periods thus we can re-write profit maximization as

$$\text{Max } \pi = L_t [f(k_t) - (r_t + \delta)k_t - w_t] \quad (1.25)$$

A competitive firm, which takes r_t and w_t as given, maximizes profit for a given L_t by setting the marginal product of capital equal to its rental price.

$$f'(k_t) = r_t + \delta \quad (1.26')$$

In full-market equilibrium, the wage rate will be equal to the marginal product of labour

$$w_t = f(k_t) - k_t \cdot f'(k_t) \quad (1.27)$$

Therefore, profits will equal zero for any value of L_t . As in Razin and Sadka (2000a), we assume that capital depreciates fully after one period, *i.e.* $\delta = 1$. The factor price of capital will thus be determined by

$$f'(k_t) = 1 + r_t \quad (1.26)$$

1.2.3 The Government

The government collects taxes on the labour income of young workers in order to sustain a social security system that provides pension benefits to the elderly. Individuals make a contribution to the social security system in the first period of their life (when young) and receive payment from the system in the second period of their life (when old). The government operates an unfunded system, as a pay-as-you-go pension system, that transfers

current contributions made by the young directly to the current old so that the government budget is in equilibrium in each period.

As in Razin and Sadka (2000a) we assume that in each period t , workers pay contributions to the pension system which are transferred to the retirees as benefits P_{t+1} . Contributions take the form of a payroll tax, where τ is the exogenous tax rate per unit of income¹¹.

In each period t , for $t \geq 0$, the total contributions paid to the government by the young generation are expressed as

$$T_t = (1+n)^t \tau w_t [(1-e^-)N^S + qN^U] \quad (1.28)$$

In period t , there are $(1+n)^t$ workers which contribute a fraction τ of their labour income to the social security system and $(1+n)^{t-1}$ retired individuals who receive pension benefits from the social system. The budget equation of the PAYG pension system is therefore

$$(1+n)^{t-1} P_t = (1+n)^t \tau w_t [(1-e^-)N^S + qN^U] \quad (1.29)$$

Solving for P_t , the pension benefits for each retired individual are

$$P_t = (1+n) \tau w_t [(1-e^-)N^S + qN^U] \quad (1.30)$$

Social security systems can be run fully funded or unfunded. In a fully funded social security system, the contributions made by the young at period t are invested and returned with interest in the following period $(t+1)$ when the contributors become themselves pensioners. In each period t , the government invests the contributions paid by the young as capital thus the aggregate stock of capital of the economy is composed of private savings and of contributions. Private savings and contributions being perceived as perfect substitutes by the young agents, who only care about the rate of return r_t , the latter offset any changes in contributions by variations of their own private savings.

¹¹ In Canada and in most countries, the rate of contribution to the pension system is readjusted on a regular basis therefore is considered endogenous. We chose to follow the methodology in Razin and Sadka (2000a) in order to simplify the analysis.

On the other hand, the PAYG pension system or unfunded social security system, transfers current contributions made by the young directly to the current old therefore provide the individual with a rate of return on social security savings that is equal to n , the growth rate of population rather than r_t , the interest rate. ‘The government can pay a rate of return equal to the fertility rate of the population n because in each period there are more young individuals alive to make contributions to the social security system’ (Blanchard and Fisher, 1989). The PAYG pension system thus acts as a pure transfer mechanism hence the only source of capital for the economy consists of the individuals’ private savings.

In section 1.2.1, we previously evaluated the effects of social security on private savings and determined that, given wages and interest rates, pension benefits received from a PAYG pension system reduce the individual’s incentive to save. We now look at the effects of the contributions paid to the social security system on the propensity to save. In this economy, fiscal policy only consists of programs to provide for retirement income therefore the tax rate τ is also the rate of contribution to the PAYG pension system. By taking the derivative of equation (1.11) with respect to τ ,

$$\frac{\partial s_t}{\partial \tau} = -\frac{\beta + \phi(1+n)}{[1 + \beta + \phi(1+n)]} \omega_t < 0 \quad (1.31)$$

Any increase in the rate of contribution to PAYG pension system reduces private savings. The introduction of a PAYG pension system thus reduces private savings through two channels: first through the contribution (tax) rate and second via the pension benefits.

1.2.4 The Competitive Equilibrium

We now combine the behaviour of competitive households and firms that face given values of w_t and r_t to analyze the structure of a competitive market equilibrium. For a certain sequence of wages and rental rates, each family chooses a path of consumption and wealth accumulation by supplying both labour and capital inelastically¹². We assume a closed

¹² The stock of capital is the result of previous saving-consumption decisions and thus given at time t .

economy so that all debts within the economy must cancel therefore households' assets - all owned at the start of a period t by the members of the old generation - equal the capital stock. Aggregate net investment equals total income minus total consumption thus the economy's resource constraint is

$$K_{t+1} - K_t = F(K_t, L_t) - C_t - \delta K_t \quad (1.32)$$

The aggregate consumption C_t includes both unskilled and skilled individuals as well as young and old generations of agents.

The Aggregate Stock of Capital

Substituting first- and second-period consumption ($c_{1,t}$ and $c_{2,t}$) for both skilled and unskilled agents from the individual budget constraints (1.2) and (1.3) in equation (1.32) we get

$$K_{t+1} = s_t^S N^S + s_t^U N^U \quad (1.33)$$

The savings of the young unskilled and skilled workers make up the next period's capital stock. In each period t , the aggregate savings of the old generation (skilled and unskilled) constitutes the economy's stock of capital K_t which is used in the current period production of the consumption good. Since the PAYG pension system and the bequest motive represent transfer mechanisms from the young to the old and from the old to the young, respectively, the only source of capital for the economy is the individuals' private savings s_t .

In period zero, at the start of the economy, the aggregate stock of capital (K_0) is owned by the $\frac{1}{(1+n)}$ retired domestic-born individuals. The aggregate stock of capital in period one is composed by the savings of the retired agent. Since the 1 individual is divided in N^S skilled and N^U unskilled, the aggregate stock of capital in period one consists of the savings of the domestic-born young generation (unskilled and skilled) of period zero:

$$K_1 = \frac{[\beta + \phi(1+n)]}{[1 + \beta + \phi(1+n)]} \left[((1-e^-)N^s + qN^u)w_0(1-\tau) + b_0^s N^s + b_0^u N^u \right] - \frac{P_1}{[1 + \beta + \phi(1+n)](1+r_1)} \quad (1.34')$$

Since bequests can be expressed as function of savings as in equation (1.12'), we can re-write equation (1.34') such that

$$K_1 = \frac{1}{[1 + \beta + \phi(1+n)]} \left(\phi(1+n)(1+r_0)K_0 + [\beta + \phi(1+n)][(1-e^-)N^s + qN^u]w_0(1-\tau) + \phi P_0 \right) - \frac{P_1}{[1 + \beta + \phi(1+n)](1+r_1)} \quad (1.34)$$

In period t , the savings of the $(1+n)^{t-1}$ retired agents constitute the aggregate stock of capital. Among the $(1+n)^{t-1}$ retirees, there are $(1+n)^{t-1} N^s$ who are skilled and $(1+n)^{t-1} N^u$ who are unskilled, hence the aggregate capital stock is

$$K_t = \frac{(1+n)^{t-1}}{[1 + \beta + \phi(1+n)]} \left(\phi(1+n)(1+r_{t-1})K_{t-1} + [\beta + \phi(1+n)][(1-e^-)N^s + qN^u]w_{t-1}(1-\tau) + \phi P_{t-1} \right) - \frac{(1+n)^{t-1} P_t}{[1 + \beta + \phi(1+n)](1+r_t)} \quad (1.35)$$

The Capital-Labour Ratio

In period zero, the capital-labour ratio k_0 is given by:

$$k_0 = K_0 / L_0 \quad (1.36')$$

Since K_0 is given and L_0 is obtained by equations (1.21), we get that

$$k_0 = \frac{K_0}{((1-e^-)N^s + qN^u)} \quad (1.36)$$

In period one, the capital-labour ratio k_1 is given by

$$k_1 = K_1 / L_1 \quad (1.37')$$

Since K_1 is given by (1.34), L_1 and P_1 are obtained by equation (1.22) and (1.30), we get that k_1 is equal to

$$k_1 = \frac{1}{[1 + \beta + \phi(1+n)]} \left(\phi(1+r_0)k_0 + \frac{[\beta(1-\tau) + \phi(1+n)]}{(1+n)} w_0 \right) - \frac{\tau w_1}{[1 + \beta + \phi(1+n)](1+r_1)} \quad (1.37)$$

Henceforth, in period t , the capital-labour ratio k_t is given by

$$k_t = K_t / L_t \quad (1.38')$$

Using equation (1.35), (1.23) and (1.30), we find that the capital-labour ratio k_t becomes:

$$k_t = \frac{1}{[1 + \beta + \phi(1+n)]} \left(\phi(1+r_{t-1})k_{t-1} + \frac{[\beta(1-\tau) + \phi(1+n)]}{(1+n)} w_{t-1} \right) - \frac{\tau w_t}{[1 + \beta + \phi(1+n)](1+r_t)} \quad (1.38)$$

Assuming a Cobb-Douglas production function $f(k_t) = k_t^\alpha$, we get $1+r_t = \alpha(k_t)^{(\alpha-1)}$ and $w_t = (1-\alpha)(k_t)^\alpha$, Equation (1.38) is a non-linear difference equation in k_t for every value of k_t , the equation implicitly determines the value of k_{t+1} at the equilibrium.

Dynamics of the Economy

As we previously established, the dynamics of the economy can be deduced from equation (1.38) which can be re-written as

$$k_{t+1} = \frac{1}{[1 + \beta + \phi(1+n)]} \left(\phi(1+r_t)k_t + \frac{[\beta(1-\tau) + \phi(1+n)]}{(1+n)} w_t \right) - \frac{\tau w_{t+1}}{[1 + \beta + \phi(1+n)](1+r_{t+1})} \quad (1.38a)$$

Using $1+r_t = \alpha(k_t)^{(\alpha-1)}$ and $w_t = (1-\alpha)(k_t)^\alpha$, equation (1.38a) becomes

$$k_{t+1} = \frac{1}{[1 + \beta + \phi(1+n)]} \left[\phi \cdot \alpha \cdot k_t^{(\alpha-1)} \cdot k_t + \frac{[\beta(1-\tau) + \phi(1+n)] \cdot (1-\alpha) \cdot k_t^\alpha}{(1+n)} \right] - \frac{\tau \cdot (1-\alpha) \cdot k_{t+1}^\alpha}{[1 + \beta + \phi(1+n)] \cdot \alpha \cdot k_{t+1}^{(\alpha-1)}}$$

Which simplifies to

$$k_{t+1} = \frac{\alpha[\beta(1-\alpha)(1-\tau) + \phi(1+n)]}{(1+n)[\alpha(1+\beta) + \alpha\phi(1+n) + (1-\alpha)\tau]} \cdot k_t^\alpha \quad (1.39)$$

For any value of capital k_t , equation (1.39) determines the evolution of the capital stock from the current period to the next as a function of the parameters that characterize the economy. Having assumed a positive degree of altruism, $0 < \phi < 1$, positive rate of population growth rate, n , and rate of time preference ρ as well as a capital share, α , that is also positive but less than 1, the ratio on the right hand side will be less than 1. The convergence to the unique steady-state capital-labour ratio, k^* , is monotonic.

1.2.5 The Steady State

We have established that the future paths of capital stocks can be prescribed by the capital stock's equilibrium condition (1.38), given an initial value k_0 . In the steady state, the variables per unit of effective labour, k , c , b and y , are constant as their growth rate is zero while the level variables, K , C , B , and Y , grow at the rate of population growth (n). Using equation (1.39), we find that the steady state capital stock is equal to

$$k^* = \left(\frac{\alpha[\beta(1-\alpha)(1-\tau) + \phi(1+n)]}{(1+n)[\alpha(1+\beta) + \alpha\phi(1+n) + (1-\alpha)\tau]} \right)^{\frac{1}{1-\alpha}} \quad (1.40)$$

Once again, by assuming that the agents are purely selfish *i.e.* $\phi = 0$, the equation (1.40) reduces to the steady state capital stock per capita of the model of Razin and Sadka (2000a),

$$k^* = \left(\frac{\alpha\beta(1-\alpha)(1-\tau)}{(1+n)[\alpha(1+\beta) + (1-\alpha)\tau]} \right)^{\frac{1}{1-\alpha}} .$$

Thus as long as we have $\tau > -\alpha/(1-\alpha)$, the presence of altruism seems to lead the economy to a higher steady state, ensures the growth of the capital stock and of the output per capital. Looking at the derivative of equation (1.40) with respect to ϕ ,

$$\frac{\partial k^*}{\partial \phi} = \left(\frac{\alpha^2 \beta (1-\alpha)(1-\tau) + \alpha[\alpha(1+\beta) + (1-\alpha)\tau]}{(1-\alpha)[\alpha(1+\beta) + \alpha\phi(1+n) + (1-\alpha)\tau]^2} \right) \left(\frac{\alpha[\beta(1-\alpha)(1-\tau) + \phi(1+n)]}{(1+n)[\alpha(1+\beta) + \alpha\phi(1+n) + (1-\alpha)\tau]} \right)^{\frac{\alpha}{(1-\alpha)}} > 0 \quad (1.41)$$

With assumptions of a positive degree of altruism, $0 < \phi < 1$, positive rates of population growth rate, n , and of time preference, ρ , as well as a capital share, α , that is also positive but less than 1, we can see that the introduction of altruism contributes positively to the growth of k^* . The selfishness nature of generations leads to a lower level of capital compared to the one obtained with intergenerational transfers $k_{RandS}^* < k_{altruism}^*$. Looking back at the first-order conditions (1.8') and (1.9'), we have established that capital will be accumulated until the marginal rate of substituting present for future consumption is equal to the marginal rate of transforming present into future consumption and that the utility earned from a bequest must equal the consumption utility foregone.

The intuition here is that the optimizing agents respond to two incentives concerning private savings (capital): first, capital is the only available mechanism through which the individual can transform first-period consumption into second-period consumption and second, the existence of bequests induces sacrifices of young and old-age consumption thus augmenting savings. Young individuals not only save to ensure old-age consumption (as in Razin and Sadka (2000)) but also to ensure bequests (as illustrated by equation (1.11')). Both these optimal choices sustain the growth of the capital stock and the achievement of the higher steady state.

1.2.6 The Role of Altruism

In our model, we formulated altruism as an end of life intergenerational transfer and introduced it as another element of the utility function as in Blinder (1974) and Becker (1976). Having assumed that the amounts bequeathed reflect the parents' belief of what might be best for future generations, we can therefore see that the introduction of altruism, in the form of bequests, will consequently link each generation to the one that precedes it and to the one following it. As a result, individuals do not solely plan according to their own life (as a life-cycler) anymore, but behave as if they are part of a dynasty, *i.e.*, they have an

infinitely-lived horizon. In this context, we can explore the implications of altruism for the agents' economic behaviour and for the economy's accumulation of capital.

The Degree of Altruism

In section 1.2.1, we first introduced the degree of altruism such that $0 \leq \phi \leq 1$. We can now specify the value of this selfishness factor. Since bequests are made in the second-period of the donor's life they are, in this respect, comparable to old-age consumption. Furthermore, since we presumed that agents benefit from the amount they bequeathed through the joy of giving and are therefore impure altruists¹³, they would still prefer an additional unit of their own old-age consumption to an added unit of their children consumption, the generosity factor ϕ must then be at least as large as the inter-temporal subjective discount factor β for altruism to be strong enough to lead to actual bequests *i.e.* $\beta \leq \phi$ ¹⁴. Looking at the equation (1.12) for endogenous bequest, we can see that we need to avoid the extremes situations of pure selfishness and perfect altruism, *i.e.*, where individuals bequeath no assets or transfer their entire wealth, respectively. In that respect, we find that $0 < \frac{\phi}{[1 + \beta + \phi(1 + n)]} < 1$, thus even a degree of altruism of 1 would respect this constraint. We can conclude that the degree of altruism must be greater or equal to the inter-temporal subjective discount factor and smaller or equal to 1 *i.e.* $\beta \leq \phi \leq 1$.

Private Savings

Looking at equation (1.11) which determines private savings and comparing it to the one for private savings in Razin and Sadka (2000a), we can see that the savings of the altruistic individual born in period t incorporate one new element: the bequests received from his

¹³ Pure altruism incorporates the utility or the consumption of the children in the utility function of the parent. Paternalistic altruism is thus perceived as impure altruism as it only takes into consideration the parents' joy of giving. See Acemoglu (2007).

¹⁴ Baranzini (1991) also assumes that the rate of preference for consumption is larger than the rate of preference for bequest.

parents (individuals born in period $t-1$). Remembering that bequests received by the individual born in period t is a function of the wage income, of the bequests and of the pension benefits received by his parents, we can see that private savings in period t are influenced by the decisions of the individuals born in period $t-1$. Bequests create an intergenerational link such that the life-cycle wealth of the agent born in $t-1$ now contributes to the savings of the individual born at time t . The effects of amounts bequeathed by the previous generation on the private savings of the current young, for given wages and interest rates, will vary according to

$$\frac{\partial s_t}{\partial b_t} = \frac{[\beta + \phi(1+n)]}{[1 + \beta + \phi(1+n)]} > 0 \quad (1.42)$$

The bequest received by the individual born in period t contributes to increase his private savings in the same constant proportion as his net income earned from labour and thus mitigates the harmful effects of pension benefits. Comparing the effects of social security benefits and bequests received on the individual's private saving, we can derive the following result:

Proposition

Intergenerational transfers will have a larger effect on private savings than social security if the rate of return on capital ($1+r_{t+1}$) is larger than the inverse of the inter-temporal discount factor jointly with altruism. A higher rate of return to capital renders savings more attractive i.e. reduces the negative impact of pension benefits on savings. Whereas a high degree of altruism, which encourages bequests, linked to a small rate of time preference, which favours a shift of consumption towards the future, allow for a greater positive variation of savings.

Deriving equation (1.11) with respect to the degree of altruism:

$$\frac{\partial s_t}{\partial \phi} = \frac{(1+n)}{[1 + \beta + \phi(1+n)]^2} \left([\omega_t(1-\tau) + b_t] + \frac{P_{t+1}}{(1+r_{t+1})} \right) > 0 \quad (1.43)$$

We can see that the intergenerational transfers made by the individual born in period t to his $(1+n)$ descendants will contribute to augment his private savings. The incentive to legate some financial assets thus increases the need for private savings. Thus the individual's marginal tendency to save augments due to his parent's altruism and to his own bequest motive.

First- and Second-Period Consumptions

The bequests received also contribute to augment first- and second-period consumption as can be seen by the derivative of (1.17) and (1.18) with respect to b_t

$$\frac{\partial c_{1,t}}{\partial b_t} = \frac{1}{[1 + \beta + \phi(1+n)]} > 0 \quad (1.44)$$

and

$$\frac{\partial c_{2,t+1}}{\partial b_t} = \frac{\beta(1+r_{t+1})}{[1 + \beta + \phi(1+n)]} > 0 \quad (1.45)$$

Intergenerational transfers positively contribute to the agent's consumptions in a constant fraction inversely related to the subjective rate preference and the degree of altruism and in the same proportion as the wage income net of taxes. First-period consumption is positively influenced by income from wages, bequests received and by pension benefits but since the interest rate is positive *i.e.* $1 < 1+r_{t+1}$, the contributions of wages and bequests to first-period consumption are greater than the contribution of pension benefits. Finally, since the rate of return to capital is greater than the rate of time preference, the amount of bequests received positively contributes to old-age consumption.

Looking at the impact of the agent's own degree of altruism on his first-period consumption, we take the derivative of equations (1.17) and (1.18) with respect to ϕ

$$\frac{\partial c_{1,t}}{\partial \phi} = -\frac{(1+n)}{[1 + \beta + \phi(1+n)]^2} \left(\omega_t(1-\tau) + b_t + \frac{P_{t+1}}{(1+r_{t+1})} \right) < 0 \quad (1.46)$$

and

$$\frac{\partial c_{2,t+1}}{\partial \phi} = -\frac{\beta(1+r_{t+1})(1+n)}{[1+\beta+\phi(1+n)]^2} \left(\omega_t(1-\tau) + b_t + \frac{P_{t+1}}{(1+r_{t+1})} \right) < 0 \quad (1.47)$$

The agent born in period t reduces both his first- and second-period consumptions according to his own degree of altruism. The more altruistic is the agent, the smaller will be his levels of consumption. The degree of altruism dictates the amount of young age and old-age consumption that must be sacrificed in order to provide bequests for $(1+n)$ descendants.

The Bequest Motive

We can thus see that altruism creates intergenerational transfers which render all choices made by the individual born in period t to be directly influenced by the decisions made by his parents (the individual born in period $t-1$) via b_t and to impact the behaviour of his $(1+n)$ offspring (the individual born in period $t+1$) via b_{t+1} . Looking at equation (1.11) and (1.12'), we can observe that the bequest motive implies an accumulation effect: the bequest received by the individual born at time t increases his private savings (according to equation (1.11)), which directly augments the amount he will himself bequeath in the second-period of his life (equation (1.12')). The derivative of equation (1.11) with respect to bequest received illustrates a positive relation,

$$\frac{\partial s_t}{\partial b_t} = \frac{[\beta + \phi(1+n)]}{[1 + \beta + \phi(1+n)]} > 0 \quad (1.48)$$

While the derivative of equation (1.12') with respect to private savings also shows a positive relation,

$$\frac{\partial b_{t+1}}{\partial s_t} = \frac{\phi}{[\beta + \phi(1+n)]} (1 + r_{t+1}) > 0 \quad (1.49)$$

Both lead to a positive relation between amount bequeathed and bequests received by the agent born in period t

$$\frac{\partial b_{t+1}}{\partial b_t} = \frac{\partial b_{t+1}}{\partial s_t} \cdot \frac{\partial s_t}{\partial b_t} = \frac{\phi(1+r_{t+1})}{[1+\beta+\phi(1+n)]} > 0 \quad (1.50)$$

The higher is the interest rate, the larger will be the fraction of the bequests that the agent himself received as a young worker that will be passed along to his descendants. As a higher rate of return to capital renders private savings more attractive, it thus enables the altruistic agent to have more funds available for intergenerational transfers. The degree of altruism and the rate of preference both determine first, the amount of bequest received that will go towards private savings and second, the amount of savings that will contribute to intergenerational transfers. A stronger degree of altruism and a high rate of time preference both allow for an increase in bequests as demonstrated by the following derivatives:

$$\frac{\partial b_{t+1}}{\partial \phi} = \frac{(1+\beta)}{[1+\beta+\phi(1+n)]^2} [(1+r_{t+1})[\omega_t(1-\tau)+b_t]+P_{t+1}] > 0 \quad (1.51)$$

As expected, a greater degree of altruism leads to an increase in the amount bequeathed to the descendants.

$$\frac{\partial b_{t+1}}{\partial \beta} = -\frac{\phi}{[1+\beta+\phi(1+n)]^2} [(1+r_{t+1})[\omega_t(1-\tau)+b_t]+P_{t+1}] < 0 \quad (1.52)$$

And a greater subjective discount rate leads to a reduction of the intergenerational transfers as the agent prefers first-period consumption and will thus want to reduce bequests.

1.3 Dynamics of the Economy and Migration

We suppose that, in the period before immigration (period zero), the economy is in a steady state. Bequests exist and represent an exogenous and constant fraction of the life-cycle wealth of the elderly. The dynamics of c_t and k_t are determined by equation (1.8), the evolution of consumption over time, combined with the economy's budget constraint (1.32).

1.3.1 The Migrants' Arrival

In period zero, m altruistic migrants are admitted in the economy. It is assumed that these altruistic migrants are all young, unskilled and have no capital. Once entered into the country, they adopt the domestic norms of the natives such as fertility rate, preferences and skill distributions. Their arrival has an effect on

- 1) The effective labour supply (L_0) and;
- 2) The pension benefits (P_0).

Impact on Effective Labour Supply

The arrival of young unskilled migrants causes the total productivity of the labour force, now composed of $\frac{N^s}{(1+m)}$ skilled workers and of $\frac{N^u + m}{(1+m)}$ unskilled workers, to diminish, while the sudden inflow of young individuals in the economy, which goes from 1 up to $(1+m)$ workers, augments the effective labour supply. As a result, the effective labour supply is now

$$L_0 = (1 - e^-)N^s + q(N^u + m) \quad (1.21a)$$

And thus increases by a net proportion, defined as the productivity of unskilled workers, q , times the number, m , of unskilled migrants, compared to its steady state level L^* . The increase in effective labour supply reduces the capital-labour ratio (k_0). Since the aggregate stock of capital in period zero K_0 is not affected by immigration, as migrants don't bring any capital with them, the augmented effective labour supply L_0 reduces the capital-labour ratio with respect to its pre-migration steady state value (k^*).

$$k_0 = \frac{K_0}{L_0} = \frac{K^*}{[(1 - e^-)N^s + q(N^u + m)]} \quad (1.36a)$$

The reduction of the capital-labour ratio translates into a reduction of the wage rate and into an increase of the rental rate of capital. With private savings of the young

individuals being an increasing function of wage-income, *i.e.* $0 < \frac{\partial s_t}{\partial w_t} < 1$, the current decrease in the wage rate translates into lower income, per time spent at work, which translates into lower savings for the young agents of period zero.

The effect of an increase in the interest rate is ambiguous as it involves a substitution effect and an income effect. The substitution effect of an increase in interest rate lowers the price of second-period consumption therefore agents shift consumption from the first to the second period and augment savings. The income effect increases the feasible consumption set, augmenting the consumption in both periods. The net impact of these two effects is ambiguous on the first-period consumption but will definitely increase the second-period consumption. In a model where agents live for two periods and have a log-linear utility, the interest rate has no effect on the supply of savings as the substitution and income effect cancels each other. The private savings accumulated by the young generation will only be affected by the current wage rate which has decreased. It follows that private savings will decrease.

In period zero, the private savings of the elderly (accumulated in period -1) now constitutes the current capital stock. This increase in the value of capital positively influences the elderly generation by providing them with higher returns on their savings hence supplying them with more second-period income.

Both unskilled and skilled workers of period zero lose from the reduction in the wage rate while the elderly, who have accumulated savings from their work effort in period -1, are now receiving more income from interest earned on the capital stock they own. The reduction in the capital-labour ratio that results from the increase in effective labour supply benefits the retirees, while it penalizes the young workers.

Impact on Pension Benefits

Immigration increases the number of contributors to the social security system. Following the migrants' arrival, the number of contributors increases from 1 to $1+m$ individuals. The

fraction N^s of skilled workers still each contributes τw_0 to the social security system while the now augmented proportion $N^u + m$ of unskilled workers each contributes $\tau q w_0$. The total contributions paid in period zero by the young workers are

$$T_0 = \tau w_0 [(1 - e^-)N^s + q(N^u + m)] \quad (1.28a)$$

We can see that for a given contribution rate τ , immigration increases total contributions. Since the migrants are all young individuals, the elderly population of period zero remains at its pre-migration level of $\frac{1}{(1+n)}$ retirees. The budget equation of the PAYG pension system is therefore

$$\frac{1}{(1+n)} P_0 = \tau w_0 [(1 - e^-)N^s + q(N^u + m)] \quad (1.29a)$$

The pension benefits in period zero, following the migrants' arrival, will now take the form of

$$P_0 = (1+n)\tau w_0 [(1 - e^-)N^s + q(N^u + m)] \quad (1.30a)$$

Taking the derivative of (1.30a) with respect to migration m , we can see that an increasing number of migrants, even of low-skilled workers, raise the pension benefit by a positive factor:

$$\frac{\partial P_0}{\partial m} = (1+n)\tau w_0 q > 0 \quad (1.53)$$

On the other hand, since the migrants' arrival leads to a reduction of the wages in period zero, we must determine the net impact of immigration on pension benefits. Deriving equation (1.30) with respect to w_0 demonstrates that a decrease in wages resulting from the migrants' arrival reduces pension benefits compared to its steady state value by a constant and positive fraction:

$$\frac{\partial P_0}{\partial w_0} = (1+n)\tau [(1 - e^-)N^s + qN^u] > 0 \quad (1.54)$$

The constant numbers of retirees of period zero will therefore receive higher benefits compared to the pre-migration levels thus gain from low-skilled migration.

The Welfare of Young and Old Generations

The reduction in the wage rate, the augmentation of interest rates and the reduction of pension benefits translate into the change in the welfare of both young and the old generations of domestic born individuals. Looking at the income side of the first-period budget constraint (1.2), we can see that the reduction of the gross wages has a negative impact on both the first-period consumption and the savings of the young of period zero, *i.e.*, it reduces their welfare. The derivatives of both equations (1.11) and (1.17) illustrate the positive and fractional relationship between wages and savings and first-period consumption

$$0 < \frac{\partial s_0}{\partial \omega_0} = \frac{\beta + \phi(1+n)}{[1 + \beta + \phi(1+n)]} (1 - \tau) < 1 \quad (1.55)$$

and

$$0 < \frac{\partial c_{1,0}^0}{\partial \omega_0} = \frac{(1 - \tau)}{[1 + \beta + \phi(1+n)]} < 1 \quad (1.56)$$

The income side of the second-period budget constraint (1.3) illustrates that both the augmentation in interest rates r_0 and in pension benefits P_0 carries the following effects: the amount bequeathed (b_0) by the altruistic retirees of period zero to the young of period zero will be higher and the consumption of the elderly of period zero will also augment. Deriving equation (1.12) with respect to interest rates and pension benefits, respectively, we can see that a positive and constant¹⁵ fraction of the increase in r_0 and of P_0 will be distributed to their $(1+n)$ descendants via the bequest motive

$$\frac{\partial b_0}{\partial (1 + r_0)} = \frac{\phi}{[1 + \beta + \phi(1+n)]} (\omega_{-1}(1 - \tau) + b_{-1}) > 0 \quad (1.57)$$

and

¹⁵ The wage income earned, and the bequest received, by the old of period zero, having been determined in the period before immigration, it is thus perceived as given in period zero.

$$\frac{\partial b_0}{\partial P_0} = \frac{\phi}{[1 + \beta + \phi(1 + n)]} > 0 \quad (1.58)$$

The amount bequeathed to the young generation of period zero will be higher following the migrants' arrival compared to the amount they would have normally received (the steady state value b^*). The larger the augmentation of the pension benefits, or of the interest rates, the greater the amount legated to the young of period zero.

The second-period consumption of the old generation of period zero ($c_{2,0}^{-1}$) will also augment following the increase in pension benefits (P_0) and interest rates (r_0). By taking the derivative of equation (1.18) with respect to pension benefits and with respect to interest rates, we obtain

$$\frac{\partial c_{2,0}^{-1}}{\partial (1 + r_0)} = \frac{\beta}{[1 + \beta + \phi(1 + n)]} (\omega_{-1}(1 - \tau) + b_{-1}) > 0 \quad (1.59)$$

and

$$\frac{\partial c_{2,0}^{-1}}{\partial P_0} = \frac{\beta}{[1 + \beta + \phi(1 + n)]} > 0 \quad (1.60)$$

The second period consumption of the old generation of period zero increases following the migrants' arrival thus leading to an increase in welfare. The increase in old age income due to the rise in pension benefits, or to the rise in interest rates, will profit more the young generation (via the bequest) or the elderly generation (via old-age consumption), depending on ϕ being larger or smaller than β . We have already determined that $\beta \leq \phi \leq 1$, therefore the increase in both pension benefits and interest rates is more profitable to the young generation.

The Role of Altruism

In this economy, bequests are the unique means by which parents can transfer portion of their wealth to their offspring. Since bequests are a fraction of life-cycle wealth, in period zero, the amount bequeathed (b_0) by the retirees to their offspring is higher following the increase of their pension benefits and of the higher interests earned on savings. We demonstrated that a positive and constant fraction of these increments will be distributed by the elderly of period zero to their $(1+n)$ descendants according to their degree of altruism.

Therefore, for a positive degree of altruism *i.e.* $\phi > 0$, the amount bequeathed to the young generation of period zero will be higher following the migrants' arrival than the amounts they would have received in the pre-migration steady state. As previously demonstrated in section 1.2.6, this increase in the amount bequeathed positively influences the saving and the consumption capacities of the young generation therefore mitigates the negative impact of the falling wages and could even offset it. The derivatives of first-period consumption of the young generation with respect to the wage rate

$$0 < \frac{\partial c_{1,0}^0}{\partial \omega_0} = \frac{(1-\tau)}{[1 + \beta + \phi(1+n)]} < 1 \quad (1.61)$$

Comparing this derivative with the impact of bequest received on first period consumption,

$$\frac{\partial c_{1,0}^0}{\partial b_0} = \frac{1}{[1 + \beta + \phi(1+n)]} > 0 \quad (1.62)$$

We determine that the increases in the bequests received from the elderly generation of period zero will more than compensate the fall in wages if $1 > 1-\tau$. With a positive rate of time preference, of fertility and a degree of altruism that is smaller or equal to 1, intergenerational transfers can offset the negative impact of wage on first-period consumption and can contribute to improve the welfare of the young of period zero. As a result, altruism allows for the arrival of low-skilled migrants to benefit the unskilled and skilled workers of period zero.

1.3.2. The Aging of the Migrants

In period one ($t=1$), the m unskilled migrants are now retired and thus benefit from the PAYG pension system. Their $m(1+n)$ descendants contribute to the economy in the same manner as the $(1+n)$ descendants of the domestic-born through their labour participation (unskilled and skilled) and their contribution to the social security system. The aging of the m unskilled migrants affects

- 1) The aggregate stock of capital (K_1) and;
- 2) The pension benefits (P_1).

While the labour participation of their $m(1+n)$ descendants affects

- 1) The effective labour supply (L_1) and;
- 2) The pension benefits (P_1).

Net Impact on the Capital Labour Ratio

In the period of their arrival, the now retired migrants have accumulated private savings according to the same preference attributes as the domestic born. Despite the falling wage rate w_0 which led to a reduction in private savings s_0 , the increased number of savers $(1+m)$ and the augmented bequests b_0 result in a net growth of aggregate savings thus in an augmentation of the stock of capital for the economy K_1 . The $m(1+n)$ migrants' offspring are participating in the labour force with the same skills distribution as the domestic-born contributing to an increase of the effective labour supply in period one. Such that

$$L_1 = (1+m)(1+n)[(1-e^-)N^S + qN^U] \quad (1.22a)$$

In the period following the migrants' arrival, the per capita stock of capital monotonically increases back towards its steady state level by following the dynamics equation (1.37).

$$k_1 = \frac{(\phi(1+r_0)K_0 + [\beta(1-\tau) + \phi(1+n)]w_0[(1-e)N^s + q(N^u + m)])}{[1 + \beta + \phi(1+n)](1+m)(1+n)[(1-e)N^s + qN^u]} - \frac{\tau w_1[(1-e)N^s + q(N^u + m)]}{[1 + \beta + \phi(1+n)](1+m)[(1-e)N^s + qN^u](1+r_1)} \quad (1.37a)$$

This increase of the capital-labour ratio translates into an augmentation of the wage rate w_1 and into a reduction of the rental rate of capital r_1 . Both unskilled and skilled workers of period one gain from the increase in the wage rate while the elderly, who have accumulated savings from their work effort in period zero, are now receiving less income from interest on the capital they own. The augmentation in the capital ratio benefits the young workers while penalizing the elderly.

Impact of the aging migrants and their descendants on Pension Benefits

The total number of contributors to the PAYG pension system, which is now composed of the offspring of both domestic-born and migrants, has reached $(1+n)(1+m)$ in period one. The total contributions made by the young generation is expressed as followed

$$T_1 = (1+n)(1+m)\tau w_1((1-e^-)N^s + qN^u) \quad (1.28b)$$

As we can see, even in the period following the arrival of low-skilled migrants, immigration still contributes positively to the funds available to be distributed to the elderly.

$$\frac{\partial T_1}{\partial m} = (1+n)\tau w_1((1-e^-)N^s + qN^u) > 0 \quad (1.63)$$

Since the unskilled migrants are now retired and thus are entitled to receive pension benefits, the elderly population now translates into $(1+m)$ retirees who benefit from the social security system. The budget equation of the PAYG pension system is therefore

$$(1+m)P_1 = (1+n)(1+m)\tau w_1((1-e^-)N^s + qN^u) \quad (1.29b)$$

And the pension benefits are now equal to

$$P_1 = (1+n)\tau w_1((1-e^-)N^s + qN^u) \quad (1.30b)$$

Despite an increase in the amount of total contributions, the increase in the number of pensioners reduces the pension benefits received by the $(1+m)$ elderly of period one in comparison to the pension benefits they would have received without the arrival of the migrants. In period zero, the migrants were young workers thus contributed to the social security system as low-skilled workers. In period one, they now receive the same pension benefits as the skilled workers therefore expanding the burden on the social security system.

The pension benefits in period one P_1 decrease in comparison to the one in the previous period (P_0). They even reach a lower level than in the steady state because of the loss in pension contributions of the migrants, the decrease in wages and the increased number of retirees.

The Welfare of Young and Old Generations

The augmentation of wages in period 1, the reduction in both the pension benefits (due to the increased number of beneficiaries) and the interest rate (induced by additional savings of the aging migrants) translate into a variation of welfare of both young and old generations of domestic born individuals. The augmentation of the gross wages increases both the consumption and the savings of the young of period one *i.e.* augments their welfare.

Both the reduction in interest rates r_1 and in pension benefits P_1 diminishes the amount bequeathed (b_1) and consumed by the altruistic retirees of period one. The welfare of the elderly of period one is reduced as a result of the aging of the migrants.

With a degree of altruism such that $\beta \leq \phi \leq 1$, the decrease in old age income due to the fall in pension benefits and in interest rates impacts the young generation as well as the elderly generation. The aging of the migrants translates into an improved welfare for the young of period one and into a reduced welfare for the elderly generation.

The Role of Altruism

As previously mentioned, the intergenerational transfers received by the young of generation zero b_0 (now the elderly of period one) increased due to the positive outcomes of low-skilled migration on interest rate and on pension benefits. A constant fraction $[\beta + \phi(1+n)]/[1 + \beta + \phi(1+n)]$ of this augmentation in b_0 contributed to the private savings of the young of period zero (s_0) and was also, according to equation (9'), passed along to their $(1+n)$ offspring (the current young of period one) via the bequest motive b_1 .

$$\frac{\partial b_1}{\partial s_0} = \frac{\phi}{[\beta + \phi(1+n)]} (1 + r_1) > 0 \quad (1.64)$$

This leads to a positive relation between the amount bequeathed and the bequests received by the agent born in period 0

$$\frac{\partial b_1}{\partial b_0} = \frac{\phi(1 + r_1)}{[1 + \beta + \phi(1+n)]} > 0 \quad (1.65)$$

On the other hand, the decrease in interest rate (r_1) and in pension benefits (P_1) will also diminish the amount bequeathed (b_1) in period one by the elderly generation compared to the amount they themselves received (b_0) as young workers in period zero. The amount bequeathed to the young generation of period one will be lower than the intergenerational transfer their parents received in period zero, but will still be higher than the amount they would have normally received without the migrants' arrival (the steady state value b^*) due to the accumulation effect induced by b_0 .

As seen in section 1.2.6, the net impact of intergenerational transfers is to increase private savings and first-period consumption of the young generation of period one and to increase the old-age consumption of the elderly of period one thus contribute to an increase in welfare for both generations.

1.3.3. The Offspring of the Migrants

In period two and in the following periods, the descendants of the migrants are now fully integrated in society. The shock of immigration has been absorbed by the economy which will continue to converge back towards its previous steady state. The migrants do not affect the capital stock, the effective labour supply or the pension benefits anymore. The capital-labour ratio and the pension benefits continue to raise monotonically back to their previous steady state levels.

Each period $t=2$ and onward, the capital-labour ratio (k_t) increases monotonically back to its previous steady state level k^* following the dynamic equation (1.39). As illustrated by equation (1.40), the capital-labour ratio is unaffected by migrants anymore as the composition of unskilled versus skilled population does not depend on m . In the second period following the migrants' arrival, the number effect has completely disappeared since the immigrants' descendants have the same demographic characteristics as the domestic-born.

On the path towards the previous steady state, the wage rate w_t will increase and the rental rate r_t will decrease until they reach their pre-migration steady state values. As private savings are an increasing function of wage-income, the current increase in the wage rate translates into higher income which translates into higher savings. Since bequests allow for consumption, their presence induces a substitution effect which conduces to a reduction of savings. The net effect of higher wages, lower interest rate and lower bequests is to decrease private savings.

The bequest motive re-introduces the income and the substitution effects brought on by the interest rate which were cancelled with the log-linear utility function. The introduction of bequest renders private savings, first- and second-period consumption positively influenced by the interest rate. The increase in interest rate creates an income effect which renders both period consumption more attractive as well as a substitution effect which augments the second-period consumption thus increases private savings. As the substitution effect outweighs the income effect, savings decrease following the fall in interest rate from

the period following the migrants' arrival until the economy reaches its previous steady state level.

By looking at equation (1.30), we can see that pension benefits are affected by the descendants of the m aging migrants as they augment the number of beneficiaries. Their $(1+n)^t m$ offspring now contribute to the social security system in the same proportion as the domestic born thus the right hand side now reflects the augmented number of contributors. In each period $t \geq 2$, the pension benefits P_t increase due to the increase in the wage rate until it reaches its previous steady state value.

The bequests increase in the period of the migrants' arrival and then slowly decrease back to their pre-migration steady state value mainly due to the falling interest rates and of the decrease in private savings.

1.4. Conclusion

By extending the work of Razin and Sadka (2000a) to include paternalistic altruism, we demonstrate that immigrants do not need to be skilled to contribute to the sustainability of the fiscal policy of the host country. Within this context of inter-generational altruism and pay-as-you-go pension system, we find that for certain degrees of altruism *i.e.* $\beta \leq \phi \leq 1$, it is possible to maintain the growth of private savings, consumption and capital despite the negative impact of immigrants on wages.

It is important to note that we have ignored the situation of a very low degree of altruism, as *i.e.* $\phi < \beta$ in order to ensure the growth of the capital stock. With a very low degree of altruism, bequests represent a ratio of less than 1 of old-age consumption, according to equation (1.9), and therefore cannot mitigate the decrease in wages that result from the arrival of low-skilled migrants. We have also abstained from imposing perfect altruism *i.e.*, where individuals transfer their entire wealth, to avoid over-saving which would lead the economy to be inefficient *i.e.* growth cannot be sustained in the long term. Outside of these two extreme situations, we find that the altruistic linkages and the bequest motive

are sufficient to compensate for the initial negative fiscal impact of low-skilled migrants. Considering conventional parameter values such as an annual fertility rate of 2.0%, a rate of time preference of 5.0% and a period of 25 years, the degree of altruism would have to be at least greater than 30% and can thus be empirically supported as the literature reports that bequeathed amounts represent between 18% and 80% of life-cycle wealth.¹⁶

In the period of the arrival of the low-skilled immigrants, the current old gain from their pension benefits which increase in the number of migrants and from the higher interest rates as they own all the capital (aggregate savings). The old generation uses its net migration-induced gains to augment their second-period wealth which will then translate into increased old-age consumption and greater end-of-life bequests. In models of overlapping generations with altruistic preferences (Barro, 1974), the current generation cares about the welfare of future generations and therefore acts as a dynasty; each family smoothes their consumption over time by means of their bequests. The marginal propensity to save does not decrease when the individual gets older as his planning horizon now includes transfers to his descendants. Altruism reduces considerably the negative effect of social security on the capital stock accumulation because the altruistic parents, benefiting from a social security system funded by their children's contributions, will be more inclined to leave financial means to the subsequent generation¹⁷. Hence the reduction of the capital stock rate of accumulation is mitigated.¹⁸

Despite the penalty associated with the lower wages that resulted from the migrants' arrival, the young domestic-born generation ends up having an increased welfare thanks to the amount bequeathed by the elderly. Therefore, the domestic-born workers (both skilled and unskilled) also gain from low-skilled migration and can also afford to bequeath larger amounts to their offspring. The unskilled migrants do not benefit from intergenerational transfers when young but gain from the pension benefits when retired. Since migrants and domestic-born offspring have the same socio-economic characteristics, by the following

¹⁶ See studies by Kotlikoff and Summers (1981) and by Gale and Scholz (1994).

¹⁷ The recent empirical study of Horioka (2009) measures the average bequest received by Japanese households as approximately 15% of life cycle wealth whereas it reaches an average 17.89% for social security recipients.

¹⁸ In a framework accounting for altruism, the presence of the U.S. social security system has been found to reduce the capital stock by only 2.0% (Fuster, 1999) while the same security system reduces the economy's capital stock by 24.0% in a life-cycle framework (Auerbach and Kotlikoff, 1987).

period all generations are made better off (Pareto improving). As a result, all income (high and low) and all age (young and old) groups benefit from migration.

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Chapter 2

Growth and Sustainability

2.1 Introduction

Environmental deterioration is now a common concern among economies. For the last 30 years, world conferences on the environment like the Earth Summits have highlighted major issues: rarity of non-polluted air, clean water access, climate change etc, and have mandated serious actions to be taken. During that same period, the roles of the government, as well as the behaviour of individuals, in relation to the environment have also been revisited. Often perceived as a necessity to maintain regulation and develop programs in that most agents and firms would not otherwise engage in environmental protection, governmental entities currently play many roles. The maintenance of parks and water areas, taxation and quota policies, research and development funding, the establishment of recycling and waste management facilities, the creation of incentives programs for businesses are a few examples among several others. Individuals' involvement toward the environment has also evolved from engaging in direct actions such as recycling, composting and reducing the consumption of polluting goods to participating in indirect ones like the investment in certain private goods as a defence against negative environmental externalities.

Despite the increasing and diversified roles of governmental participation over the last decades, economic theory still portrays the government when it comes to the environment as a taxation administrator (Baumol, 1972 and 1974; Wittman, 1985; John *et al.*, 1995; Ono, 1996) or as a pollution license issuer (Montgomery, 1972). These representations exclude the development of programs that have been introduced by governmental entities as tools to slowdown, and possibly reverse, ecological degradation. Furthermore, they also abstract from the signalling role that the governmental entity can play when it comes to informing and influencing the behaviour of individuals. In the context of

environmental degradation due to firms' pollution, government signals are of importance since the actual reduction of pollution is out of the control of the agents who care about their future environment, and who are often left with modifying their behaviour to protect themselves against the negative externality.¹⁹ When faced with environmental deterioration, the possible reactions of myopic and self-serving individuals include reducing consumption, engaging in maintenance and recycling etc.²⁰ The degradation of their environment may also motivate them to adopt consumption patterns based on the use of private goods rather than on the use of free access environmental goods (Leipert, 1989; Bartolini and Bonatti, 2003).

To the best of our knowledge, the existing literature on environmental sustainability does not look at the dynamics of agents' defensive protection behaviour and of governmental interventions on the preservation of the environment and on economic growth. In an inter-generational context, the environmental impact of production and consumption has been analyzed with the assumptions of pollution abatement (Jouvet *et al.*, 2000 and 2002; Brechet *et al.*, 2005) or investment in the maintenance of the environment (John and Pecchenino, 1994; John *et al.*, 1995; Ono, 1996). None of the studies has considered *the role of governmental programs* on the preservation of the environment by assuming that solely the actions of the agents can have an impact on its quality. While it is reasonable to foresee the need for agents' participation to have an influence on the maintenance of the environment, we believe that they can also be reacting to governmental intervention. Without infrastructures, installations and environmental programs, the impact of their participation is limited. Furthermore, the government programs and policies often act as signals for the individuals. For example, we believe that a new stringent policy to reduce CO₂ emissions from cars can send the signal to individuals that their environment is not as clean as they thought and since they do not have any controls over the motor manufacturing, they modified their behaviour by buying the most efficient vehicles (a substitute), thus engaging in defensive protection. "To the extent that policy reacts to environmental problems and that environmental protection laws compel firms to reduce their emissions... there are additional

¹⁹Leiper (1989) draws similar conclusions concerning the impact on private defensive expenditures of governmental spending in the sector of order and security when it comes to protection against criminal activities.

²⁰According to Antoci *et al.* (2005), the literature of environmental economics suggests that the category of defensive environmental spending comprise a substantial range of consumptions that is derived in part from environmental degradation, but are not merely a response to it.

ecological and societal costs of an environmentally unsound style of production and consumption...which can be subdivided into four categories: (1) compensatory "defensive" expenditures; (2) the economic cost of income pensions and health insurance; (3) loss of income, output, and natural resources, and damage to property; and (4) real-partially intangible and unquantifiable-damage suffered by individuals..." p. 845-846 (Leipert, 1989).

This chapter continues the examination of models in which environmental sustainability and economic growth interact, by extending the work of John and Pecchenino (1994) to a governmental presence and by including the agents' reaction against the degradation of the environment. Our study examines the government's role in sustainability by making the strong assumption that all taxes collected are exclusively used for environmental programs and by examining whether growth can still be unrelenting over generations. In the spirit of Brechet *et al.* (2005) and Valente (2008), we assume that the government delegates the conduct of environmental policies to a central agency and thus benefits from an expertise in the management and monitoring of environmental programs, and in designing policy instruments. Aged individuals typically care about consumption and are affected, via their health, by the quality of their environment²¹. The inclusion of an index measuring the quality of the environment in individual preferences illustrates the agents' concerns regarding the degradation of their environment and induces them to invest in its protection. Our model links the young agents' investments in defensive protection to the public programs by a spillover function in the spirit of Barro and Sala-i-Martin (1992 and 2004). Following Jouvét *et al.* (2000) and Gutierrez (2008), we introduce production as a source of pollution. The production of the consumable good creates ecological degradation (pollution) hence inducing a substitution effect between old-age consumption and environment preservation for each agent.

In our model, the quality of the environment enters individual welfare positively, but it is subject to negative externalities from the aggregate effect of production activities on the environment. Faced with the deterioration of this environmental asset, households are increasingly forced to rely on defensive spending to protect themselves against this negative externality and thus to increase their welfare. In the context of overlapping generations,

²¹ See Gutierrez (2008) for a brief review of the literature on pollution and the elderly's health.

young individuals make decisions concerning their economic well-being as well as for the future quality of the environment by choosing between savings in the form of capital and investment in the protection of the environment as a defence mechanism.

The government implements programs to protect the environment, a free public good which is degraded by the activities of the production sector. We thus impose taxes on individual income and on the use of capital by the profit maximization production sector as an instrument to finance the government-led environmental programs. The agents react to the environmental deterioration by investing in the maintenance of the environment that can act both as a defensive tool and as a substitute for the deterioration of the free public good *i.e.*, their environment. The agent's consumption of the final good induces the need for economic growth whereas his concern about the quality of his environment creates the need for sustainability.

Our results suggest that economic growth and environment sustainability can be maintained in the context that production creates a negative environmental externality in the presence of agents' defensive protection and tax-funded environmental programs. Our main finding is that both the wage income tax and the capital tax *contribute* to savings *i.e.*, to the growth of the economy but without imposing additional degradation to the environment. Governmental spending creates spillover effects on the agent's first period choice of investing in environmental protection; the wage income tax contributes to savings but through two channels: a *spillover* effect and a *substitution* effect. The mechanism at play is that the individuals perceive their own spending on defensive goods and governmental programs as substitutes but that governmental spending encourages them (via spillover) to spend more on defensive protection. The importance of the quality of the environment when old still encourages them to defend themselves against the deterioration of the environment but to a lesser degree than the effect of spillover from governmental programs.

The remainder of the chapter is organized as follows: Section 2.2 provides a description of the economy constituents; Section 2.3 develops the dynamics of the economy. Section 2.4 concludes.

2.2 Description of the Economy

Using the overlapping-generations framework of Allais (1947), Samuelson (1958) and Diamond (1965), we develop a model where individuals' decisions have consequences that can outlive them. We consider an infinite-horizon economy under perfect certainty and where each generation is alive for two periods. For simplicity, we assume there is no population growth and normalize the size of each generation (young and old) to unity for each period t . The agent derives utility from old-age consumption and his health status in the second period of his life.

In the first period of his life, the individual is young and supplies a constant unit of labour. The agent spends wage earnings on private savings in the form of capital and by engaging in defensive protection against environmental deterioration (Kerry, 1991; Bartolini and Bonatti, 2003; Antoci *et al.*, 2005). In the second period of his life, the individual is now old and retired, renting capital to firms (earning real interest) and consuming the final good. Self-serving, the individual does not leave bequests to his offspring thus is non-altruistic: the elderly does not care for the young nor does the young care for the elderly.

This domestic economy has only one consumption good competitively produced by the firms with the use of labour and capital. The government collects taxes on the labour income of young workers and on the usage of capital by the firms in order to fund its programs to maintain and improve the quality of the environment. The production of consumption goods degrades the quality of the environment whereas the governmental programs and the young agent's defensive protection improve it. The quality of the environment is considered as a stock variable that directly affects the health of the old agent.

2.2.1 The Households

The young household provides labour services in exchange for wage income, invests in defensive protection and saves by accumulating capital. To make the model tractable, we do

not allow for labour/leisure choice: each household supplies a constant unit of labour.²² In making his plans, the young agent takes into account his own welfare by saving and defending himself against the deterioration of his environment.

Preferences

Following John and Pecchenino (1994), for the sake of tractability, we assume that the agents do not care about first-period consumption. The agents have a Cobb Douglas, log linear utility function and temporally separable preferences defined over second-period consumption, $c_{2,t+1}$, and their health status when old, $H(E_{t+1})$ ²³. An individual born in period t faces the following utility function:

$$U_t(c_{2,t+1}, E_{t+1}) \equiv \log c_{2,t+1} + H(E_{t+1}) \quad (2.1)$$

Removing the individual's inter-temporal decision-making (young- versus old-age consumption) from the analysis allows us to examine the choice between investment in capital and spending on a private good as a defence mechanism against the degradation of their environment. Moreover, as highlighted by Ono (2005), it makes it possible for us to examine the process of intergenerational redistribution. We assume that the young agent's health does not come into their utility as they are stronger physically and less subject to environmental factors.

The first term on the right-hand side represents the utility derived by consumption over the last period of life. The second term reflects the utility derived by the elderly's health status as a function of an index of the quality of the environment when the individual is old. For the sake of simplicity, we follow Gutiérrez (2008) and define the impact on the elderly health of the quality of the environment by $H(E_{t+1}) = \varepsilon \log E_{t+1}$. We assume that U_t is increasing in $c_{2,t+1}$ and in E_{t+1} and is twice continuously differentiable and concave such

²² It is common in the OLG analytical literature to remove the labour/leisure choice of young agents for tractability purposes. We refer to Diamond (1965), Barro (1974), Blanchard (1985) and Weil (1987a).

²³ Analyses of sustainability in an OLG setting often abstract from the inclusion of first-period consumption in the preferences of the households. Examples are John and Pecchenino (1994), John *et al.* (1995) Ono and Maeda (2002), Ono (2005), Gutiérrez (2008).

that $U_1(\cdot), U_2(\cdot) > 0$; $U_{11}(\cdot), U_{22}(\cdot) < 0$ and $U_{12}(\cdot) \geq 0$. The parameter ε is the fixed preference parameter for the quality of the environment.

Budget Constraints

We denote savings in capital, second-period consumption and defensive spending on environmental protection by, respectively, s_t , $c_{2,t+1}$ and x_t . The individual born at time t faces the following inter-temporal budget constraints over the first period and the second period of their life:

$$s_t + x_t = w_t(1 - \tau_p) \quad (2.2)$$

$$c_{2,t+1} = (1 + r_{t+1})s_t^{24} \quad (2.3)$$

where w_t is the wage income, τ_p is the income tax rate, and r_{t+1} is the interest rate earned on private savings for period t to $t+1$.

Referring to the first-period budget constraint (2.2), we can see that the agent's income net of taxes provides for his savings in the form of capital and his purchase of goods to defend themselves against environmental degradation. Despite the fact that agents are not directly responsible for the degradation of the environment brought on by the production of the goods by the firms (but indirectly as they represent the demand for the consumption goods), they invest part of their net income when young in goods to protect themselves (via spending on x_t). The rationale for this behaviour is, as in Antoci *et al.* (2005), that the agent cares for his future environment (through the impact on his health) and when faced with its degradation needs to engage in some defensive protection against it.

The second-period budget constraint (2.3) incorporates the notion that individuals do not care about their descendants' welfare as their entire revenue from savings in the form of capital is used to finance retirement consumption.

²⁴We have fixed the price of the consumption good, in each period t , equal to 1 (numéraire).

The Law of Motion of the Quality of the Environment

Environmental quality in the current period is a public good that is affected by the quality of the environment in the previous period, by the defensive actions of the individual, the behaviour of firms and the government. Environmental quality at time $t+1$ is shown as a stock variable that evolves according to²⁵:

$$E_{t+1} = (1-\eta)E_t + \theta M_t + \gamma G_t - \rho Y_t; \quad \text{where } \theta > 0, \gamma > 0, \rho > 0^{26} \quad (2.4)$$

In the absence of human activity, the quality of the environment is only affected by its own nature; the parameter $\eta \in [0,1]$ measures the speed of reversion of environmental quality to the level of the previous period, E_t . M_t is impact of private spending on the quality of the environment. The latter captures the efficiency of defensive behaviour on the quality of the environment as induced by the governmental spending. In the spirit of Barro and Sala-i-Martin (1992 and 2004) and Turnovsky (1996)²⁷, we define the technology to produce environmental protection as

$$M_t = x_t^\lambda (x_t / G_t)^{1-\lambda} = x_t G_t^{\lambda-1} \quad 1 \leq \lambda < \bar{\lambda} \quad (2.5)$$

Where G_t is the government's environmental participation funded by tax revenues, x_t is the individual' spending on defensive protection and λ parameterizes the degree of efficiency (spillover) associated with governmental spending such as $1 \leq \lambda < \bar{\lambda}$ ²⁸. Governmental spending includes, among others, policies and programs as well as infrastructures and installations to improve the quality of the environment. Using equation (2.5) to replace M_t in equation (2.4), we can easily see that government spending affects the

²⁵The law of motion for the environment is based on the one developed by John and Pecchenino (1994) with the exception that, in this context, the production of the good, the governmental programs and the defensive consumption of young agents have a direct influence on the quality of the environment.

²⁶ Conditions of rational behaviour must be imposed on θ and ρ . The restrictions are determined in the subsequent section.

²⁷ In the context of government spending and national output, these authors developed the technology to measure the utility services derived by the agent from government expenditures.

²⁸The values of λ are established such as to avoid the congestion effect induced by governmental programs ($\lambda < 1$) and the crowding out effect on the private spending on environmental protection ($\lambda > \bar{\lambda}$). There is no close form solution to the expression of $\bar{\lambda}$. Some numerical exercises suggest that its value is around 2.

quality of the environment in two ways. First it has an indirect impact on the quality of the environment through the spillover function of equation (2.5) in relation to the individual's defensive spending; second government spending affects directly the quality of the environment. The spillover function (2.5) suggests that the individual's investment in environmental protection can be linked to government expenditures on the environment. For example, a new program aiming at reducing CO₂ emissions from cars can send the signal to individuals that their environment is not as clean as they thought and since they do not have any controls over the motor manufacturing, they modify their behaviour by buying the most efficient vehicles (a substitute), thus engaging in defensive protection.

According to equation (2.5), for the spillover condition M_t to remain constant over time, the growth rate of individual spending, x_t , must be related to that of government spending G_t through the following relationship: $(\Delta x/x) = (1-\lambda)(\Delta G/G)$. In order to illustrate the spillover effects, two extreme cases may be considered for the value of λ . When $\lambda=1$, this refers to the “no spillover” situation where the young agent's investment is independent of the size of public infrastructure. At the other extreme, when $1 < \lambda < \bar{\lambda}$, x_t must increase more than the growth of G_t in order to keep the level of environmental protection M_t fixed. The agents' defensive protection is greater than the size of the governmental expenditures. Finally, ρY_t is the degradation of the environment as a result of the production of the good at period t . In order to maintain a positive quality of the environment at time $t+1$, E_{t+1} , we assume that in the absence of individual and governmental participation, ρ is not sufficiently high with respect to $(1-\eta)E_t$. Thus we must have $\rho < (1-\eta)\frac{E_t}{Y_t}$.

The Agent's Problem

Taking the wage rate, w_t , the return to savings, r_t , and the environmental quality at the beginning of period t , E_t , as given, an individual born at time t chooses $c_{2,t+1}$, s_t , and x_t to maximize:

$$U_t \equiv \log c_{2,t+1} + \varepsilon \log E_{t+1} \quad (2.1)$$

Subject to

$$s_t + x_t = w_t(1 - \tau_p) \quad (2.2)$$

$$c_{2,t+1} = (1 + r_{t+1})s_t \quad (2.3)$$

$$E_{t+1} = (1 - \eta)E_t + \theta M_t + \gamma G_t - \rho Y_t \quad (2.4)$$

$$M_t = x_t G_t^{\lambda-1} \quad (2.5)$$

$$c_{2,t+1+i}^{t+i} \geq 0, \quad s_{t+i}^{t+i} \geq 0, \quad x_{t+i}^{t+i} \geq 0 \quad (2.6)$$

Maximizing (2.1) subject to (2.2) – (2.6) yields the following first-order condition:

$$\frac{\partial U_t / \partial c_{2,t+1}}{\partial U_t / \partial E_{t+1}} = \theta \frac{\partial M_t / \partial x_t}{(1 + r_{t+1})} \quad (2.7')$$

The condition (2.7') states that along the equilibrium path, the agent chooses s_t and x_t to equate the marginal rate of substitution between old-age consumption and environmental quality to the marginal rate of transformation $(\theta \frac{\partial M_t / \partial x_t}{(1 + r_{t+1})})$.

Replacing the derivatives with their results, condition (2.7') becomes

$$\frac{E_{t+1}}{\varepsilon \cdot c_{2,t+1}} = \frac{\theta G_t^{\lambda-1}}{(1 + r_{t+1})} \quad (2.7)$$

Equation (2.7) reflects the traditional arbitrage condition that relates, in the present case, old-age consumption and the quality of the environment in the second period. It suggests that, at the margin, the individual will invest in the environment and in physical capital in the first period so as to equate the marginal rate of substitution between the consumption and the quality of the environment to the marginal rate of transformation between these two variables. It is interesting to note that, in reality the levels of consumption and the quality of the environment in the second period are chosen by the first-period decision to invest in either defensive protection or in physical capital. The numerator in the

right-hand side of (2.7), $\theta G_t^{\lambda-1}$, represents the marginal benefit (on the quality of the environment in the second period) of spending on one unit of defensive protection good. The denominator in (2.7) is the loss in consumption in the second period stemming from the decision to invest in the defensive protection good instead of investing in physical capital that would have yielded interest rate r_{t+1} in the second period.

Private Savings, Defensive Protection and Old-Age Consumption

The consumer's problem gives rise to the following functions for the optimizing individual born in period t ,

$$s_t = \frac{1}{(1+\varepsilon)\theta G_t^{\lambda-1}} \left[\theta G_t^{\lambda-1} w_t (1-\tau_p) + (1-\eta)E_t + \gamma G_t - \rho Y_t \right] \quad (2.8)$$

$$x_t = \frac{1}{(1+\varepsilon)\theta G_t^{\lambda-1}} \left[\varepsilon \theta G_t^{\lambda-1} w_t (1-\tau_p) - (1-\eta)E_t - \gamma G_t + \rho Y_t \right] \quad (2.9)$$

$$c_{2,t+1} = \frac{(1+r_{t+1})}{(1+\varepsilon)\theta G_t^{\lambda-1}} \left[\theta G_t^{\lambda-1} w_t (1-\tau_p) + (1-\eta)E_t + \gamma G_t - \rho Y_t \right] \quad (2.10)$$

As expected, due to the assumption of separability and concavity of the utility function that ensures that both goods are normal, the private savings of the individual born in period t are an increasing function of his income from wages,

$$0 < \frac{\partial s_t}{\partial w_t} = \frac{(1-\tau_p)}{(1+\varepsilon)} < 1 \quad (2.11)$$

Because the utility function is homothetic, saving is linear homogenous in wage income of the first period. Therefore, each individual has a fixed marginal propensity to save out of wage income that depends on its preference factor for the quality of the environment and on the income tax rate. Looking at equation (2.8), we can see that private savings at time t are a positive function of the net wage rate ($w_t(1-\tau_p)$), and of the quality of the

environment, (E_t) ; however, it is a negative function of the level of pollution, (ρY_t) . Thus, a higher net wage rate and better quality of the environment contribute to increasing savings. The increase in production activities that raises pollution leads the individual to spend more on defensive protection, and hence to reduce his savings. Furthermore, we can see that the governmental programs will have an impact on savings as follows:

$$\frac{\partial s_t}{\partial G_t} = \frac{1}{\theta(1+\varepsilon)G_t^\lambda} [(1-\lambda)(1-\eta)E_t + \gamma(2-\lambda)G_t - (1-\lambda)\rho Y] \quad (2.12)$$

When $\lambda=1$, the derivative becomes $\frac{\partial s_t}{\partial G_t} = \frac{\gamma}{\theta(1+\varepsilon)} > 0$, young agent's defensive protection is independent of the size of public infrastructure. The savings are positively impacted by governmental programs via the substitution effect only.

When $1 < \lambda < \bar{\lambda}$, we get $\frac{\partial s_t}{\partial G_t} = \frac{1}{\theta(1+\varepsilon)G_t^\lambda} [(1-\lambda)[(1-\eta)E_t - \rho Y_t] + (2-\lambda)\gamma G_t] \gtrless 0$ ²⁹, the young agent's defensive protection is larger than the size of public infrastructure, thus governmental spending induces a spillover effect on the agent's first period choice of defensive protection, x_t . Private savings can either benefit from the spillover effect or be reduced by it depending on $(2-\lambda)\gamma G_t \gtrless (1-\lambda)[\rho Y_t - (1-\eta)E_t]$. Savings will be negatively (positively) affected by public spending if the governmental programs' contribution to the environment is smaller (greater) than the pollution of firms (net of the environment's own regeneration function).

As per equation (2.9), the young agent's defensive spending as a reaction against environmental degradation in period t is also an increasing function of his net income from labour.

$$0 < \frac{\partial x_t}{\partial w_t} = \frac{\varepsilon(1-\tau_p)}{(1+\varepsilon)} < 1 \quad (2.13)$$

²⁹This result is obtained since we have $\rho Y_t < (1-\eta)E_t$ and $\lambda > 1$.

This illustrates that the young agent's defensive protection at time t is a positive function of his net income from labour and of the goods production whereas a negative function of the quality of the environment at period t . The pollution caused by the production of the consumption good induces individuals to spend more to protect themselves against the degradation of the environment whereas the actual quality of the environment reduces this defensive behaviour. We have already shown that the tax-funded environmental programs affect the quality of the environment via two channels: a spillover effect and a substitution effect. In what follows, we would like to assess the impact of government spending on the environment and optimal private spending on defensive protection. The impact of governmental programs affects the agent's defensive protection according to the following expression:

$$\frac{\partial x_t}{\partial G_t} = \frac{1}{\theta(1+\varepsilon)G_t^\lambda} [(1-\lambda)\rho Y_t - (1-\lambda)(1-\eta)E_t - \gamma(2-\lambda)G_t] \quad (2.14)$$

One can easily show that its sign depends on the value of the parameter λ . Let us consider the two extreme values of the degree of efficiency λ . When $\lambda=1$, the derivative becomes $\frac{\partial x_t}{\partial G_t} = \frac{-\gamma}{\theta(1+\varepsilon)} < 0$, thus when the young agent's investment in environmental protection is independent of the size of public infrastructure, the governmental programs negatively impact his defensive behaviour via the substitution effect only.

$$\text{When } 1 < \lambda < \bar{\lambda}, \quad \text{we obtain } \frac{\partial x_t}{\partial G_t} = \frac{1}{\theta(1+\varepsilon)G_t^\lambda} [(1-\lambda)(\rho Y_t - (1-\eta)E_t) - \gamma(2-\lambda)G_t] \begin{matrix} > \\ < \end{matrix} 0,$$

governmental spending induces a spillover effect on the agent's first period choice of defensive protection *i.e.*, defensive protection increases. Defensive protection can either benefit from the spillover effect or be reduced by it depending on $(1-\lambda)(\rho Y_t - (1-\eta)E_t) \begin{matrix} > \\ < \end{matrix} (2-\lambda)\gamma G_t$.

Hence the public programs will induce an increase (decrease) of defensive protection if the governmental programs' contribution to the environment is smaller (greater) than the pollution of firms (net of the environment's own regeneration function)

The agent's consumption in period $t+1$ is also an increasing function of his net income from labour

$$\frac{\partial c_{2,t+1}}{\partial w_t} = \frac{(1+r_{t+1})(1-\tau_p)}{(1+\varepsilon)} > 0 \quad (2.15)$$

Looking at equation (2.10), we can see that old-age consumption is a positive function of net income from labour, the quality of the environment and of environmental programs and a negative function of the level of pollution. Thus higher net wage income and a better quality of the environment all contribute to an increase in old-age consumption. Knowing that production of the consumption good causes pollution, hence inducing individuals to spend more on defensive protection when firms' production augments, the agents' savings decrease hence old-age consumption diminishes. Furthermore, the governmental programs also have an impact on old consumption such that

$$\frac{\partial c_{2,t+1}}{\partial G_t} = \frac{(1+r_{t+1})}{\theta(1+\varepsilon)G_t^\lambda} [(1-\lambda)(1-\eta)E_t + \gamma(2-\lambda)G_t - (1-\lambda)\rho Y_t] \quad (2.16)$$

The sign of that impact depends on the degree of spillover λ . When $\lambda=1$, the derivative becomes $\frac{\partial c_{2,t+1}}{\partial G_t} = \frac{\gamma(1+r_{t+1})}{\theta(1+\varepsilon)} > 0$. Young agent's investment is independent of the size of public infrastructures thus the old-age consumption is positively impacted by governmental programs via the substitution effect only.

$$\text{When } 1 < \lambda < \bar{\lambda}, \text{ we obtain, } \frac{\partial c_{2,t+1}}{\partial G_t} = \frac{(1+r_{t+1})}{\theta(1+\varepsilon)G_t^\lambda} [(1-\lambda)[(1-\eta)E_t - \rho Y_t] + (2-\lambda)\gamma G_t] \stackrel{>}{<} 0,$$

The young agent's defensive protection is larger than the size of public infrastructure. Governmental spending induces spillover effect on the agent's first period choice of

defensive protection thus negatively impacts his savings and his old-age consumption via both the spillover effect and the substitution effect. Second-period consumption can either benefit from the spillover effect or be reduced by it depending on whether $(2 - \lambda)\gamma G_t \stackrel{<}{>} (1 - \lambda)[\rho Y_t - (1 - \eta)E_t]$. Old-age consumption will be negatively (positively) affected by public spending if the governmental programs' contribution to the environment is smaller (greater) than the pollution of firms (net of the environment's own regeneration function).

The Role of the Income Tax

Both savings and defensive protection are funded by the agent's net income from labour. Therefore the income tax rate is expected to have a significant impact on the first-period choices made by the young agents. Taking the derivatives of equations (2.8) and (2.9) with respect to the income tax rate τ_p ,

$$\frac{\partial s_t}{\partial \tau_p} = -\frac{w_t}{(1 + \varepsilon)} < 0 \quad (2.17)$$

$$\frac{\partial x_t}{\partial \tau_p} = -\frac{\varepsilon w_t}{(1 + \varepsilon)} < 0 \quad (2.18)$$

Both first period choices are a negative function of wage income tax with private savings being *more (less)* impacted than defensive protection if the preference factor for environment quality ε is *smaller (greater)* than 1. Furthermore, looking at the derivative of equation (2.10) with respect to the income tax rate τ_p

$$\frac{\partial c_{2,t+1}}{\partial \tau_p} = -\frac{(1 + r_{t+1})}{(1 + \varepsilon)} w_t < 0 \quad (2.19)$$

Old-age consumption is also negatively affected by income taxes and to a greater extent than private savings since the interests earned on savings represent the source for retirement income and since we have $1 < (1 + r_{t+1})$. Old-age consumption will also be more affected by any change in the tax rate than defensive protection if $\varepsilon < (1 + r_{t+1})$. This implies

that the imposition of taxes on income from labour reduces the agent's capacity to invest and to protect himself against environmental degradation.

2.2.2 The Firms

The firms produce goods and pay wages for labour input and rents for the use of capital. Each firm has access to the Cobb-Douglas production function and the gross output is a function of K_t and L_t .

$$Y_t = F(K_t, L_t) = K_t^\alpha L_t^{1-\alpha} \quad (2.20)$$

The production function exhibits constant returns to scale with respect to K and L with each input displaying positive and diminishing marginal product. Since each young person works for one unit of time, the variable L_t is the total labour supplied by all the young people in the economy. It is assumed that the capital stock in period t , K_t , is productive in the same period; there is no lag in the production and use of capital. In per worker term, we obtain

$$y_t = f(k_t) = k_t^\alpha \quad (2.20a)$$

In each period t , the firms offer the wage rate w_t for each hour of effective labour supplied by the young agents and rent the services of capital from the elderly at a rental rate of R_t per unit of capital. Since the production of the goods has a direct and negative impact on the quality of the environment, the government collects a pollution tax on the use of the stock of capital in order to protect the environment; hence, the firms must pay the price of $R_t(1 + \tau_f)$ where τ_f is the tax rate per value of capital used in production. The representative firm's profit at any point in time is given by

$$\text{Max } \pi_t = F(K_t, L_t) - R_t(1 + \tau_f)K_t - w_t L_t \quad (2.21')$$

At each period t , capital depreciates at the constant and positive rate δ , the net rate of return to the retired individual who owns one unit of capital is $R_t - \delta$. Given that families are indifferent to the composition of their wealth, loans and capital being perfect substitutes in terms of value, we must have $r_t = R_t - \delta$ or $R_t = r_t + \delta$. The problem of maximizing the present value of profit reduces to a problem of maximizing profit in each period without regard to the outcomes in other periods therefore, we can re-write profit maximization as

$$\text{Max } \pi_t = K_t^\alpha L_t^{1-\alpha} - (r_t + \delta)(1 + \tau_f)K_t - w_t L_t \quad (2.21)$$

Or in per worker terms

$$\text{Max } \pi_t = k_t^\alpha - (r_t + \delta)(1 + \tau_f)k_t - w_t \quad (2.21a)$$

The firms hires labour and rents capital such that

$$\frac{\partial \pi_t}{\partial L_t} = (1 - \alpha)K_t^\alpha L_t^{-\alpha} - w_t = 0 \quad (2.22)$$

$$\frac{\partial \pi_t}{\partial K_t} = \alpha K_t^{\alpha-1} L_t^{1-\alpha} - (r_t + \delta)(1 + \tau_f) = 0 \quad (2.23)$$

With profit maximizing firms, the factor prices will therefore equal their respective private marginal product.

$$w_t = (1 - \alpha)K_t^\alpha L_t^{-\alpha} \quad (2.24)$$

$$(r_t + \delta)(1 + \tau_f) = \alpha K_t^{\alpha-1} L_t^{1-\alpha} \quad (2.25)$$

Re-writing the equations in per worker terms, we get

$$w_t = f(k_t) - (r_t + \delta)(1 + \tau_f)k_t = (1 - \alpha)k_t^\alpha \quad (2.24a)$$

$$(r_t + \delta)(1 + \tau_f) = f'(k_t) = \alpha k_t^{\alpha-1} \quad (2.25a)$$

The individual firm hires labour until the marginal product of labour equals the wage and rents capital until the net marginal product of capital equals the rental rate. By looking at equation (2.25a), we can see that a higher capital tax τ_f raises the required marginal product of capital, $f'(k_t)$, for a given r . The result arises because the rental payments on capital (including depreciation) are not deductible from the tax base as defined by equation (2.21). Looking at equations (2.24a) and (2.25a), we can see that the tax on the use of capital will affect wages, *i.e.*, via the demand for labour, and the rental rate *i.e.*, via the demand for capital, in the following way

$$\frac{\partial w_t}{\partial \tau_f} = -(r_t + \delta)k_t < 0 \quad (2.26)$$

$$\frac{\partial r_t}{\partial \tau_f} = -\frac{f'(k_t)}{(1 + \tau_f)^2} < 0 \quad (2.27)$$

As expected, for a given level of capital supplied, both the wage and the rental rate of capital are negatively affected by the tax rate on the use of capital *i.e.*, competitive firms' decrease their demands for labour and capital. With the growth of the stock of capital, the assumption that the Inada conditions are respected insures that the marginal product of capital $f'(k)$ will decrease as k increases leading to a smaller impact of the tax rate on the rental of capital than on wages. In this context, both derivatives with respect to the capital tax rate show that variations in the rate cause a greater negative impact on wages than on interest rates: the burden of the tax will fall more on the wage rate paid to labour than on the renting of capital.³⁰ As intended, the capital tax indirectly promotes the quality of the environment by reducing the level of factors used, thus of output produced, by the firms.

2.2.3 The Government

The government collects taxes on the labour income of young workers and on the usage of capital by the firms in order to fund its programs to maintain and improve the quality of the

³⁰The reason for this stems partially from the fact that labour is inelastically supplied by the workers, who are ready to accept any level of wage rate for their fixed quantity of labour supplied.

environment. As in John *et al.* (1995), we assume that the government is a one-period-lived agent whose planning horizon is shorter than the environment.³¹ The taxes collected go exclusively towards the environmental programs and services thus do not fund any other public services or goods.³² The governmental intervention and participation in environmental preservation can be in the form of public recreation services such as parks and water area, regulation and programs development, research and development funding, the establishment of recycling and waste management facilities, incentives programs for businesses and individuals. The governmental programs allow for the individuals' tax contributions (income tax) in the first period of their life (when young) to with a certain level of environmental quality in the second period of their life (when aged). The taxes imposed on the firms' usage of the capital act as a mechanism to prevent the degradation of the environment through the reduction in output produced. The government's budget is in equilibrium in each period t .

The contributions by the young take the form of an income tax where τ_p is the tax rate per unit of income, while the firms' contribution takes the form of a pollution tax for which τ_f is the tax rate per value of capital used in production. In each period t , the total contributions paid to the government by the young generation and by the firms are expressed by

$$T_t = \tau_p w_t L_t + \tau_f R_t K_t \quad (2.28')$$

which becomes

$$T_t = \tau_p w_t L_t + \tau_f (r_t + \delta) K_t \quad (2.28)$$

The governmental expenditure G_t in each period t consists of governmental programs to improve the quality of the environment. The balanced-budget equation for the environmental programs is therefore

$$G_t = T_t \quad (2.29')$$

³¹John *et al.* (1995) find that short-lived government provides the optimal level of capital and of the public good.

³²This type of strong hypothesis is also somewhat formulated by Marini and Scaramozzino (1995) who assume the government spends its income exclusively on programs of pollution abatement. Contrarily to our model, their expenditures are financed by raising lump-sum taxes.

$$G_t = \tau_p w_t + \tau_f (r_t + \delta) K_t \quad (2.29)$$

2.2.4. The Competitive Equilibrium

We now combine the behaviour of optimizing households, competitive firms and of the government that face given values of w_t , and r_t to analyze the structure of the competitive market equilibrium. For a certain sequence of wages and returns to capital, each agent chooses wealth accumulation (in the form of capital) and defensive environmental protection by supplying constant labour.

A competitive equilibrium for this economy is a sequence of prices $\{w_t, r_t\}_{t=0}^{\infty}$ and a sequence of allocations $\{y_t, k_t, c_{2,t}, m_t, s_t, x_t, G_t, E_t\}_{t=0}^{\infty}$, given initial values for the state variables $\{k_0, E_0\}$ ³³, the policy parameters $\{\tau_p, \tau_f\}$ and the law of motion of the quality of environment, such that,

- i) Agents maximise (2.1) subject to (2.2) - (2.6)
- ii) Firms maximise profits
- iii) Government satisfies its budget constraint
- iv) Markets (labour, capital, credit and output) clear

at each period $t \geq 0$.

2.2.4.1. Markets Clearing

We assume a closed economy so that all debts within the economy must cancel; therefore, households' assets - all owned at the start of a period t by the members of the old generation - equal the capital stock.

³³We assume that there is an initial elderly generation which is endowed with capital stock in the first period of the economy (period zero). These aged agents supply their capital (k_0) to firms and spend the proceeds ($c_{2,0} = (1 + r_0)k_0$). At the initial period of the economy, the quality of the environment E_0 is a public good.

2.2.4.1.1 Equilibrium in the Goods Market

The economy produces a unique good that is invested in physical capital, used as a defence mechanism, spent on governmental programs or consumed by the old individuals. The goods market equilibrium requires that the demand for goods in each period t be equal to the supply or, equivalently, that aggregate output equals the total consumption of the old agents, the total spending on the defensive good, governmental programs and investment in the stock of capital. Knowing that the elderly and the young population in period t are each normalized to one, we have

$$C_{2,t} + X_t + G_t + I_t = F(K_t, L_t) \quad (2.30)$$

The economy's gross investment can be expressed as

$$I_t = F(K_t, L_t) - C_{2,t} - X_t - G_t \quad (2.31)$$

Where $C_{2,t}$ is the aggregate consumption of the retired agents in period t (born in period $t-1$) and X_t is the total spending on environmental protection by the young. Therefore, aggregate net investment (defined as gross investment minus the replacement investment) equals total income minus old-age consumption, defensive environmental protection, governmental programs and depreciated capital such that

$$K_{t+1} - K_t = F(K_t, L_t) - C_{2,t} - X_t - G_t - \delta K_t \quad (2.32)$$

Substituting for w_t and r_t from equations (2.24a) and (2.25a) and using equation (2.29) to replace G_t into equation (2.32), we get the economy's resource constraint

$$K_{t+1} - K_t = w_t(1 - \tau_p) + r_t K_t - C_{2,t} - X_t \quad (2.33)$$

The economy's resource constraint corresponds to the aggregated budget constraints for the two generations alive at time t . In per worker terms,

$$k_{t+1} - k_t = w_t(1 - \tau_p) + r_t k_t - c_{2,t} - x_t \quad (2.33a)$$

The Aggregate Stock of Capital

Substituting second-period consumption ($c_{2,t}$) and defensive environmental protection (x_t) from the individual budget constraints (2.2) and (2.3) in equation (2.33a) we get

$$k_{t+1} = s_t \quad (2.34)$$

The savings of the young agents make up the next period's capital stock. Since we have assumed that the elderly ignore their descendants' welfare, they will not want to retain assets when they die, and will therefore sell all their capital to the young generations. All the capital owned by the old plus any net increase in capital must be purchased by the young with their savings. Equation (2.34) becomes, by using equation (2.8) to substitute for s_t

$$k_{t+1} = \frac{1}{(1+\varepsilon)\theta G_t^{\lambda-1}} \left[\theta G_t^{\lambda-1} w_t (1-\tau_p) + (1-\eta)E_t + \gamma G_t - \rho Y_t \right] \quad (2.35)$$

When $\lambda=1$, equation (2.35) becomes

$$k_{t+1} = \frac{1}{\theta(1+\varepsilon)} \left[\theta w_t (1-\tau_p) + (1-\eta)E_t + \gamma G_t - \rho Y_t \right] \quad (2.35a)$$

When $1 < \lambda < \bar{\lambda}$, we obtain

$$k_{t+1} = \frac{1}{(1+\varepsilon)\theta G_t^{\lambda-1}} \left[\theta G_t^{\lambda-1} w_t (1-\tau_p) + (1-\eta)E_t + \gamma G_t - \rho Y_t \right] \quad (2.35b)$$

Governmental spending induces spillover effect on the agent's first period choice of defensive protection thus negatively impacts his savings. In period zero, at the start of the economy, the aggregate stock of capital (K_0) is given and owned by the retired individual. In each following period t , the aggregate savings of the aged generation constitutes the economy's stock of capital K_t that is used in the current period production of the consumption good.

2.2.4.1.2 Equilibrium in the Labour Market

For each period t , the labour market clearing condition requires that the demand of labour by the firms be equal to its supply provided by the one young individual, such that $L_t = 1$.

2.3 Dynamics of the Economy

2.3.1. Dynamics of the Economy in Equilibrium

The dynamics of our economy can be determined by combining the behaviour of the representative agent, of the competitive firm and of the government and by ensuring that all markets stay in equilibrium. We thus look at the intra and inter-temporal dynamics of capital and the environment. Beginning with the laws of motion of both capital and the quality of the environment,

$$k_{t+1} = \frac{1}{(1+\varepsilon)\theta G_t^{\lambda-1}} \left[\theta G_t^{\lambda-1} w_t (1-\tau_p) + (1-\eta)E_t + \gamma G_t - \rho Y_t \right] \quad (2.35)$$

$$E_{t+1} = (1-\eta)E_t + \theta x_t G_t^{\lambda-1} + \gamma G_t - \rho Y_t \quad (2.4)$$

Using equations (2.24a) and (2.25a) to substitute out for w_t and r_t , in equations (2.4) and (2.35), we get

$$k_{t+1} = \frac{(1-\eta)E_t + \theta(1-\alpha)(1-\tau_p) \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right)^{(\lambda-1)} k_t^{\alpha\lambda} + \left[\gamma \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right) - \rho \right] k_t^\alpha}{\theta(1+\varepsilon) \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right)^{(\lambda-1)} k_t^{\alpha(\lambda-1)}} \quad (2.36)$$

$$E_{t+1} = (1-\eta)E_t + \theta \left((1-\alpha)k_t^\alpha (1-\tau_p) - k_{t+1} \right) \left[\left((1-\alpha)\tau_p + \alpha \frac{\tau_f}{(1+\tau_f)} \right) k_t^\alpha \right]^{\lambda-1} + \left[\gamma \left((1-\alpha)\tau_p + \alpha \frac{\tau_f}{(1+\tau_f)} \right) - \rho \right] k_t^\alpha \quad (2.37)$$

We thus have two dynamic equations: 1) the stock of capital at time $t+1$ which is function of both the stock of capital and the quality of the environment at time t : $k_{t+1} = (k_t, E_t)$

and 2) the quality of the environment at time $t+1$, a function of the stock of capital at both periods t and $t+1$ and of the quality of the environment at time t : $E_{t+1} = (k_t, k_{t+1}, E_t)$

Substituting for k_{t+1} in equation (2.37) from equation (2.36), we get

$$E_{t+1} = \frac{\varepsilon(1-\eta)}{(1+\varepsilon)} E_t + \frac{\varepsilon}{(1+\varepsilon)} \left[\theta(1-\alpha)(1-\tau_p) \left[\left((1-\alpha)\tau_p + \alpha \frac{\tau_f}{(1+\tau_f)} \right) k_t^\alpha \right]^{\lambda-1} + \gamma \left((1-\alpha)\tau_p + \alpha \frac{\tau_f}{(1+\tau_f)} \right) - \rho \right] k_t^\alpha \quad (2.38)$$

We thus have two dynamic equations both function of the stock of capital and of the quality of the environment at time t : $k_{t+1} = (k_t, E_t)$ and $E_{t+1} = (k_t, E_t)$

$$k_{t+1} = \frac{(1-\eta)E_t + \theta(1-\alpha)(1-\tau_p) \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right)^{(\lambda-1)} k_t^{\alpha\lambda} + \left[\gamma \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right) - \rho \right] k_t^\alpha}{\theta(1+\varepsilon) \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right)^{(\lambda-1)} k_t^{\alpha(\lambda-1)}} \quad (2.36)$$

$$E_{t+1} = \frac{\varepsilon(1-\eta)}{(1+\varepsilon)} E_t + \frac{\varepsilon}{(1+\varepsilon)} \left[\theta(1-\alpha)(1-\tau_p) \left[\left((1-\alpha)\tau_p + \alpha \frac{\tau_f}{(1+\tau_f)} \right) k_t^\alpha \right]^{\lambda-1} + \gamma \left((1-\alpha)\tau_p + \alpha \frac{\tau_f}{(1+\tau_f)} \right) - \rho \right] k_t^\alpha \quad (2.38)$$

These equations determine the dynamic behaviour of the capital stock (output, consumption good, defensive protection) and of the quality of the environment, respectively, along an equilibrium path.

2.3.2 The Steady State

We have established that the future paths of the stock of capital and of the quality of the environment can be prescribed by the law of motion of capital and the law of motion of environment, given an initial values k_0 and E_0 . In the steady state, the variables per unit of

labour, k , c and y , are constant as their growth rate is zero hence allocations per worker are stationary. This will allow us to illustrate the economy in an E - k space.

To compute the steady state, we impose that $E_{t+1} = E_t = E^*$ and $k_{t+1} = k_t = k^*$ thus in steady state, we get

$$k^* = \frac{(1-\eta)E^*k^{*\alpha(1-\lambda)}}{\theta(1+\varepsilon)\left(\tau_p(1-\alpha)+\alpha\frac{\tau_f}{(1+\tau_f)}\right)^{(\lambda-1)}} + \frac{(1-\alpha)(1-\tau_p)k^{*\alpha}}{(1+\varepsilon)} + \frac{\left[\gamma\left(\tau_p(1-\alpha)+\alpha\frac{\tau_f}{(1+\tau_f)}\right)-\rho\right]k^{*\alpha(2-\lambda)}}{\theta(1+\varepsilon)\left(\tau_p(1-\alpha)+\alpha\frac{\tau_f}{(1+\tau_f)}\right)^{(\lambda-1)}} \quad (2.39)$$

$$E^* = \frac{\theta\varepsilon(1-\alpha)(1-\tau_p)}{(1+\eta\varepsilon)}\left((1-\alpha)\tau_p+\alpha\frac{\tau_f}{(1+\tau_f)}\right)^{(\lambda-1)}k^{*\alpha\lambda} + \frac{\varepsilon}{(1+\eta\varepsilon)}\left[\gamma\left((1-\alpha)\tau_p+\alpha\frac{\tau_f}{(1+\tau_f)}\right)-\rho\right]k^{*\alpha} \quad (2.40)$$

Case 1: $\lambda = 1$

Assuming $\lambda=1$, where the young agents investment is independent of the public programs, we can re-write the two functions (2.39) and (2.40) such as

$$k^* = \frac{(1-\eta)E^*}{\theta(1+\varepsilon)} + \frac{(1-\alpha)(1-\tau_p)k^{*\alpha}}{(1+\varepsilon)} + \frac{\left[\gamma\left(\tau_p(1-\alpha)+\alpha\frac{\tau_f}{(1+\tau_f)}\right)-\rho\right]k^{*\alpha}}{\theta(1+\varepsilon)} \quad (2.39a)$$

$$E^* = \frac{\theta\varepsilon(1-\alpha)(1-\tau_p)}{(1+\eta\varepsilon)}k^{*\alpha} + \frac{\varepsilon}{(1+\eta\varepsilon)}\left[\gamma\left((1-\alpha)\tau_p+\alpha\frac{\tau_f}{(1+\tau_f)}\right)-\rho\right]k^{*\alpha} \quad (2.40a)$$

We can find a steady state by intersecting the two functions (2.39a) and (2.40a) such that the stock of capital is determined by

$$k^* = \left(\frac{\left[(1-\alpha)\theta - \rho\right] + \left[(1-\alpha)(\gamma - \theta)\tau_p + \gamma\alpha\frac{\tau_f}{(1+\tau_f)}\right]}{\theta(1+\eta\varepsilon)} \right)^{1/(1-\alpha)} \quad (2.41)$$

Hence there exists a steady state. Equation (2.41) illustrates that the steady state level of capital is a positive function of the labour share of income $(1-\alpha)$ times the agent's direct (via spending on the protection good) and indirect (via the tax-funded programs) participation to the quality of the environment and of the capital share of income (α) times the firms' indirect participation in the quality of the environment (via the tax-funded programs). It is also a negative function of the factor of environmental deterioration caused by the firm's production of the good, ρ .

At the steady state, in order for the stock of capital to be positive, we must have this sufficient condition hold $(1-\alpha)\theta - \rho > 0$ which implies that $(1-\alpha)\theta > \rho$. Intuitively, it means that the contribution of the agent to the environment must be greater than the factor of environmental deterioration caused by the firm's production. Furthermore, equation (2.41) shows that both taxes collected by the government on wage income and on the use of capital by the firms would contribute positively to the level of the steady state stock of capital if the government's environmental program can have more impact on the quality of the environment than the agents' defensive protection *i.e.* $\gamma > \theta$. If this is not the case, then only the capital tax contributes positively to the capital stock and the tax imposed on wage income reduces the steady state level of capital. A γ larger than θ could be explained by the fact the government not only provides installations, funding and programs to improve the environment but that it also sends a signal to agents that influence their behaviour when it comes to their need of protection against environmental degradation.

Without governmental participation to the quality of the environment, the stock of capital would be obtained by

$$k^*_{no\ gov} = \left(\frac{(1-\alpha)\theta - \rho}{\theta(1+\eta\varepsilon)} \right)^{1/(1-\alpha)} \quad (2.41a)$$

Therefore, by assuming $\gamma > \theta$, the tax system ($\tau_p > 0$ and $\tau_r > 0$) allows the economy to reach a higher level of capital.

At the steady state, the quality of the environment is determined by

$$E^* = \theta \varepsilon k^* \quad (2.42')$$

$$E^* = \theta \varepsilon \left(\frac{(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho}{\theta(1+\eta\varepsilon)} \right)^{1/(1-\alpha)} \quad (2.42)$$

As per equation (2.42'), we can see that at the steady state, the quality of the environment is positively related to the steady state's capital stock k^* via the agents' preference factor for the environment when old, ε , and the contribution of defensive protection (contingent on governmental programs) to the quality of the agent's environment, θ . Once again, by assuming that the government's environmental program can have more impact on the quality of the environment than the agents' defensive protection i.e. $\gamma > \theta$, equation (2.42) shows that both taxation systems would contribute positively to the quality of the environment at the steady state. Not only does taxation allow the economy to reach a higher the level of capital, but it permits a greater quality of the environment.

Case 2: $1 < \lambda < \bar{\lambda}$

Assuming $1 < \lambda < \bar{\lambda}$, the case where the young agent's defensive protection is subject to spillover effects from the governmental programs G_t . The steady state stock of capital is solution to the equation (2.43) below. It can be shown that equation (2.43) has a solution given the restrictions imposed on the parameters namely on the value of λ . Indeed, when λ is larger than 1 the right-hand side of (2.43) decreases when the capital stock and tends toward zero when the capital stock tends to infinity. Yet, the left-hand side of equation (2.43) is positively sloped in k (45 degree line). It is straightforward to show that the curves representing both sides will intersect as soon as the y -intercept of the right-hand side equation is larger than zero. The latter is true equal to the first term in the parenthesis of the right-hand side of (2.43).

$$k^* = \left(\frac{\theta(1-\alpha)(1-\tau_p) + \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right)^{(1-\lambda)} \left[\gamma \left(\tau_p(1-\alpha) + \alpha \frac{\tau_f}{(1+\tau_f)} \right) - \rho \right] k^{*\alpha(1-\lambda)}}{\theta(1+\eta\varepsilon)} \right)^{1/(1-\alpha)} \quad (2.43)$$

Looking at equation (2.43) and comparing it with equation (2.41), we can see that the stock of capital in the case where public programs induce a spillover effect on agents' defensive protection ($1 < \lambda < \bar{\lambda}$) is larger than the stock of capital for which the defensive protection is independent of public programs ($\lambda=1$).

On measuring the impact of taxation on the steady state level of capital, we can re-write equation (2.43) without governmental participation to the quality of the environment, the stock of capital would be obtained by

$$k^*_{no\ gov} = \left(\frac{(1-\alpha)}{(1+\eta\varepsilon)} \right)^{1/(1-\alpha)} \quad (2.43a)$$

Once again we can see that the tax system ($\tau_p > 0$ and $\tau_f > 0$) allows the economy to reach a higher level of capital. Further, looking at equation (2.43a) and comparing it with equation (2.41a), we can see that the stock of capital in the case where agents' defensive protection is conditional on public programs ($1 < \lambda < \bar{\lambda}$) is greater than the stock of capital for which the defensive protection is independent of public programs ($\lambda=1$).

2.3.2.1 The Stability of the Steady State

For the sake of tractability we will only discuss the stability of the steady state for the case where λ is equal to 1. Linearly approximating equations (2.39a) and (2.40a) around the long run equilibrium (k^*, E^*) , we find that

1) The law of motion of the stock of capital, equation (2.39a), becomes

$$[k_{t+1} - k^*] = \frac{1}{\theta(1+\varepsilon)} \left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1} \cdot [k_t - k^*] + \frac{(1-\eta)}{\theta(1+\varepsilon)} [E_t - E^*]$$

2) The law of motion of the quality of the environment, equation (2.40a), becomes

$$[E_{t+1} - E^*] = \frac{\varepsilon}{(1+\varepsilon)} \left((1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right) \alpha k^{\alpha-1} \cdot [k_t - k^*] + \frac{(1-\eta)\varepsilon}{(1+\varepsilon)} \cdot [E_t - E^*]$$

3) Linearization of both equations can be summarized by the following matrix specification.

$$\begin{bmatrix} k_{t+1} - k^* \\ E_{t+1} - E^* \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} k_t - k^* \\ E_t - E^* \end{bmatrix}$$

where

$$A = \frac{1}{\theta(1+\varepsilon)} \left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1} \begin{matrix} < 0 \\ > 0 \end{matrix}$$

$$B = \frac{(1-\eta)}{\theta(1+\varepsilon)} > 0$$

$$C = \frac{\varepsilon}{(1+\varepsilon)} \left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1} \begin{matrix} < 0 \\ > 0 \end{matrix}$$

$$D = \frac{(1-\eta)\varepsilon}{(1+\varepsilon)} > 0$$

4) Following Azariadis (1993) and Gutierrez (2008), a steady state (k^*, E^*) is a sink if the following inequalities hold:

$$\text{i) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix} < 1$$

$$\text{ii) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix} + T + 1 > 0$$

$$\text{iii) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix} - T + 1 > 0$$

We show in the Appendix that the steady state is a sink *i.e.*, is asymptotically stable.

2.3.3 The Impact of Taxes on the Stock of Capital and on the Quality of the Environment

For the sake of simplicity and tractability, we will restrict our attention to the case with $\lambda=1$ in our discussions on the impact of taxes on the capital stock and the quality of the environment. We have established that the governmental programs are funded by two taxation systems which do not contribute in the same manner to the stock of capital and to the quality of the environment. We first look at the derivative of the equation (2.41) for the steady state capital stock with respect to the income tax,

$$\frac{\partial k^*}{\partial \tau_p} = \frac{(\gamma - \theta)}{\theta(1 + \eta\varepsilon)} \cdot \left(\frac{(1 - \alpha)[\theta(1 - \tau_p) + \gamma\tau_p] + \alpha\gamma\frac{\tau_f}{(1 + \tau_f)} - \rho}{\theta(1 + \eta\varepsilon)} \right)^{\alpha/(1 - \alpha)} \begin{matrix} < 0 \\ > 0 \end{matrix} \quad (2.47)$$

The wage income tax rate will have a positive or a negative impact on the steady state stock of capital depending on if $\theta < \gamma$ or $\theta > \gamma$, respectively. Having already identified that the government's environmental program can have more impact on the quality of the environment than the agents' own defensive behaviour against the negative environment externality *i.e.*, $\gamma > \theta$, the wage income tax is hence perceived as contributing positively to the capital stock via an increase in private savings.

Hence, contrary to the usual impact of a non-distorting³⁴ tax (and contrary to our previous derivative with respect to personal income tax in section 2.2.1), the imposition of an income tax on the young agent's income would contribute positively to the accumulation of savings as long as $\gamma > \theta$. It is easy to see that income taxation contributes to private savings because the government offers an environmental protection service that is perceived as a substitute for the agents' defense against the deterioration of environmental resources thus allowing the latter to invest less (more) in defensive protection (savings). Further, if

³⁴In our economy, the wage tax is perceived as a non-distorting tax since we assume that there is no labour leisure choice *i.e.*, the agents work for a fixed amount of time.

government spending is more efficient than private spending on the protection of the environment, taxation is preferable.

The derivative of equation (2.41) with respect to the tax imposed on the use of capital is

$$\frac{\partial k^*}{\partial \tau_f} = \frac{\alpha \gamma}{(1-\alpha)\theta(1+\eta\varepsilon)(1+\tau_f)^2} \left(\frac{(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \alpha \gamma \frac{\tau_f}{(1+\tau_f)} - \rho}{\theta(1+\eta\varepsilon)} \right)^{\alpha/(1-\alpha)} > 0 \quad (2.48)$$

The government imposes a tax on the use of capital by the firms as an attempt to reduce their level of pollution via an additional cost, a tax, on the use of this input to production. A variation in the capital tax rate therefore has a positive impact on the steady state stock of capital. By looking at equation (2.48), we can see that there are two effects here: an increase in the tax rate τ_f will create a decrease in the marginal rate of capital hence the stock of capital will be negatively affected. But it will also increase government revenue which augments governmental spending and by a substitution effect translates into an increase in private savings thus the investment in the stock of capital, unless the elasticity of capital to the tax rate is so high that government revenue decreases and private savings falls as well. Furthermore, we can see that the speed of reversion of environment quality, η , and the agent's rate of preference for the environment, ε , reduce the steady state capital labour ratio. The factor of environmental degradation created by the production of the output, ρ , and the parameter of environmental improvement due to the agents' defensive behaviour, θ , both decrease the capital stock at the steady state. The additional cost imposed by the tax on the usage of capital reduces the firms' profits and diminishes their demand for the old agents' capital.

With the government's active contribution to the improvement of the quality of the environment, equation (2.42a) shows that there is a positive relation between the quality of the environment and the stock of capital at the steady state and that that relation is a direct

function of the agents' preference factor for the environment when old, ε , and of the contribution to the quality of the environment of agents defensive protection, θ .

On the quality of the environment, as defined by equation (2.42), the taxation system yields the following effects

$$\frac{\partial E^*}{\partial \tau_p} = \frac{(\gamma - \theta)\varepsilon}{(1 + \eta\varepsilon)} \left(\frac{(1 - \alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1 + \tau_f)} - \rho}{\theta(1 + \eta\varepsilon)} \right)^{\alpha/(1 - \alpha)} \begin{matrix} > 0 \\ < 0 \end{matrix} \quad (2.49)$$

and

$$\frac{\partial E^*}{\partial \tau_f} = \frac{\varepsilon\alpha\gamma}{(1 - \alpha)(1 + \eta\varepsilon)(1 + \tau_f)^2} \left(\frac{(1 - \alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1 + \tau_f)} - \rho}{\theta(1 + \eta\varepsilon)} \right)^{\alpha/(1 - \alpha)} > 0 \quad (2.50)$$

Once again, with the assumption that the contribution of governmental programs to the quality of the environment is greater than the contribution of the defensive behaviour of the agents, $\gamma > \theta$, the wage income tax increases the quality of environment. Furthermore, since the tax on the use of capital was imposed with the objective to reduce the negative externality of production on the quality of the environment, thus any variations of the tax rate will bring a positive impact on the quality of the environment.

As expected, since tax revenues go exclusively towards the government's participation in environmental protection, both the wage income and the capital tax systems contribute positively to the quality of the environment at the steady state via the law of motion of the environment. The growth of the stock of capital is therefore positively affected by the wage income tax whereas the quality of the environment is protected by both tax systems. The presence of such a taxation system leads to an environment of *greater* quality.

2.4 Conclusion

This chapter has shown that, under certain conditions, economic growth and the quality of the environment can be sustained even in the presence of non-altruistic agents who do not take into consideration other generations' interests. Both the steady state stock of capital and the quality of the environment can benefit from a tax scheme on wage income. At the equilibrium, assuming that the marginal contribution of the government programs in the preservation of the quality of the environment is greater than the contribution of the agents' environmental defensive spending, the wage tax allows the economy to reach a higher stock of capital and a better quality of the environment. The rationale for this is that the increase in the tax can pay for increased government spending in environmental preservation that reduces private environmental defensive spending. Individuals can thus increase their saving and enjoy a higher stock of capital in a new steady state.

Our results suggest that economic growth and environmental sustainability can be maintained in the context that production creates a negative externality on the quality of the environment when agent's defensive protection is affected by tax-funded environmental programs. Our main finding is that *both* the wage income tax and the capital tax *contribute* to savings *i.e.*, to the growth of the economy, but without imposing additional degradation to the environment. Governmental spending creates spillover effects on the agent's first period choice of investing in environmental protection: the wage income tax contributes to savings but through two channels: a *spillover* effect and a *substitution* effect. The mechanism at play is that the individuals perceive their own spending on the defensive goods and the governmental programs as substitutes but that governmental spending encourages them (via spillover) to spend more on defensive protection. The importance of the quality of the environment when old still incite them to defend themselves against the deterioration of the environment but to a lesser degree than the effect of spillover from the governmental programs.

Our finding supports the result of John *et al.* (1995) which demonstrate that when a one-period-lived government sets the wage tax to maximize the utility of the generation alive during its term in office, the economy is better able to maintain the quality of the environment and enjoys a higher capital stock in the steady state.

Appendix 2.A The Stability of the Steady State

For the sake of tractability we will only discuss the stability of the steady state for the case where λ is equal to 1. Linearly approximating equations (2.39a) and (2.40a) around the long run equilibrium (k^*, E^*) , we find that

1) The law of motion of the stock of capital, equation (2.39a), becomes

$$[k_{t+1} - k^*] = \frac{1}{\theta(1+\varepsilon)} \left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{*\alpha-1} \cdot [k_t - k^*] + \frac{(1-\eta)}{\theta(1+\varepsilon)} [E_t - E^*]$$

2) The law of motion of the quality of the environment, equation (2.40a), becomes

$$[E_{t+1} - E^*] = \frac{\varepsilon}{(1+\varepsilon)} \left((1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right) \alpha k^{*\alpha-1} \cdot [k_t - k^*] + \frac{(1-\eta)\varepsilon}{(1+\varepsilon)} [E_t - E^*]$$

3) Linearization of both equations can be summarized by the following matrix specification.

$$\begin{bmatrix} k_{t+1} - k^* \\ E_{t+1} - E^* \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} k_t - k^* \\ E_t - E^* \end{bmatrix}$$

where

$$A = \frac{1}{\theta(1+\varepsilon)} \left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{*\alpha-1} \begin{matrix} < 0 \\ > 0 \end{matrix}$$

$$B = \frac{(1-\eta)}{\theta(1+\varepsilon)} > 0$$

$$C = \frac{\varepsilon}{(1+\varepsilon)} \left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{*\alpha-1} \begin{matrix} < 0 \\ > 0 \end{matrix}$$

$$D = \frac{(1-\eta)\varepsilon}{(1+\varepsilon)} > 0$$

4) Following Azariadis (1993) and Gutierrez (2008), a steady state (k, E) is a sink if the following inequalities hold:

$$\text{i) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix} < 1$$

$$\text{ii) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix} + T + 1 > 0$$

$$\text{iii) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix} - T + 1 > 0$$

where T is the trace of our matrix. Using the results of our linearization around the steady state, we find that

$$\text{i) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix} = 0$$

Hence the determinant of our matrix is smaller than 1, the first condition is fulfilled.

ii) The trace is the sum of the diagonal items of our matrix and is also equal to the sum of the eigenvalues. The trace is

$$T = A + D = \frac{(1-\eta)\varepsilon}{(1+\varepsilon)} + \frac{\left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1}}{\theta(1+\varepsilon)}$$

therefore we have that

$$\left| \begin{bmatrix} A & B \\ C & D \end{bmatrix} \right| + T + 1 = 0 + \frac{(1-\eta)\varepsilon}{(1+\varepsilon)} + \frac{\left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1}}{\theta(1+\varepsilon)} + 1$$

$$\left| \begin{bmatrix} A & B \\ C & D \end{bmatrix} \right| + T + 1 = \left[(1-\alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1} + \theta[1 + (2-\eta)\varepsilon]$$

Knowing that $\theta < \gamma$ and by assuming that $\alpha < 1$, it is easy to see that

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix}_{+T+1} = \left[\frac{2}{3} [\theta + (\gamma - \theta)] + \frac{\gamma}{6} - \rho \right] \alpha k^{\alpha-1} + \theta [1 + (2 - \eta)\varepsilon] > 0$$

The second condition is fulfilled at the steady state.

$$\text{iii) } \det \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{-T+1} > 0$$

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix}_{-T+1} = 0 - \frac{(1-\eta)\varepsilon}{(1+\varepsilon)} - \frac{\left[(1-\alpha) [\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1}}{\theta(1+\varepsilon)} + 1$$

$$= \theta(1+\eta\varepsilon) - \left[(1-\alpha) [\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1}$$

Knowing that $\theta < \gamma$ and by assuming that $\alpha < 1$, it is easy to see that

$$= \theta(1+\eta\varepsilon) - \left[(1-\alpha) [\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1+\tau_f)} - \rho \right] \alpha k^{\alpha-1} > 0$$

So the third condition is fulfilled at the steady state.

The steady state is thus a sink *i.e.* no matter what the two initial conditions k_0 and E_0 are, the steady state can be reached.

5) Finally, the stability of our steady state can also be proven if the Eigenvalues are negative.

We can find the Eigen values by equating the determinant to zero.

$$\det[A - \lambda I] = \begin{vmatrix} A & B \\ C & D \end{vmatrix} - \lambda \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} = 0$$

$$\det[A - \lambda I] = \begin{vmatrix} A - \lambda & B \\ C & D - \lambda \end{vmatrix} = 0$$

which becomes, $\det[A - \lambda I] = (A - \lambda)(D - \lambda) - BC = 0$

$$\det[A - \lambda I] = AD - BC - \lambda(A + D) + \lambda^2 = 0$$

Since $AD - BC = 0$, we get $\det[A - \lambda I] = \lambda[\lambda - (A + D)] = 0$ which simplifies to

$$\lambda = A + D = \frac{(1 - \eta)\varepsilon}{(1 + \varepsilon)} + \frac{\left[(1 - \alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1 + \tau_f)} - \rho \right] \alpha k^{\alpha-1}}{\theta(1 + \varepsilon)}$$

It can thus be shown that the equilibrium is saddle point stable if the following condition is satisfied

$$A + D = \frac{(1 - \eta)\varepsilon}{(1 + \varepsilon)} + \frac{\left[(1 - \alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1 + \tau_f)} - \rho \right] \alpha k^{\alpha-1}}{\theta(1 + \varepsilon)} < 1$$

$$\left[(1 - \alpha)[\theta + (\gamma - \theta)\tau_p] + \gamma\alpha \frac{\tau_f}{(1 + \tau_f)} - \rho \right] \alpha k^{\alpha-1} < \theta(1 + \eta\varepsilon)$$

Once again, as long as we have $\theta < \gamma$ and $\alpha < 1$, the equilibrium is saddle point stable for any value of θ , γ , ρ and for any tax rates τ_p and τ_f and every capital share α .

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Chapter 3

The Incidence of Geography on Canada's Services Trade

3.1 Introduction ³⁵

Fog lying over services trade volumes and barriers has impeded progress in understanding services trade, how policies affect it and how trade negotiations can liberalize it. This chapter pushes back some of the fog by quantifying the effects of geographic barriers to the services trade of Canada's provinces from 1997 to 2007. New and exceptionally high quality bilateral services trade data from Statistics Canada are used to estimate structural gravity equations for nine service sectors. Novel Constructed Bias indexes combine the bilateral and multilateral effects of geographic barriers on services trade. A test based on the Constructed Bias indexes confirms the validity of the restrictions of structural gravity for services trade.

Constructed Foreign Bias (CFB) is the ratio of predicted to hypothetical frictionless foreign trade. CFB in services trade is huge, on average some 800 times smaller than Constructed Domestic Bias (CDB), the ratio of predicted to hypothetical frictionless inter-provincial trade. Constructed Home Bias (CHB), the ratio of predicted to frictionless internal trade, measures the localization of trade. CHB is very large and varies much more by province than does CDB, provincial localization is considerably damped on inter-provincial services trade. In contrast, powerful forces other than localization suppress international trade in services as measured by CFB.

The ratio of the CFB and CDB indexes is a power function of the relative sellers' incidence of foreign and domestic trade costs. Relative incidence complements the direct bilateral border trade cost inferred from estimated gravity equations. The implied sellers'

³⁵ This chapter is coauthored with James E. Anderson and Yoto V. Yotov. We all contributed equally.

incidence of foreign trade costs is 2 to 4 times that for domestic trade costs, assuming an elasticity of substitution between 6 and 10 (as standard in the literature) to infer trade costs from the trade displacing effects of geographic barriers. This measure of the full effects of geography on relative services sellers' incidence is a multiple of the overall bilateral direct border effect on trade costs estimated from gravity below. A border cost factor equivalent of between 1.52 and 2.11 is inferred for elasticity of substitution between 6 and 10.

The foreign trade-reducing forces of gravity are much stronger for services than for goods - Canada's provinces have lower CFB in services than in goods by a factor exceeding 7. (The CFB calculations for goods use Anderson and Yotov's (2010) data for 19 manufacturing and primary goods industries of Canada's provinces from 1992 to 2003). Services on the whole do not exhibit greater Constructed Home Bias (CHB) than do goods, where CHB measures the excess localization of trade in goods and in services, the ratio of predicted to frictionless within-province trade. In other words, localization forces operate about equally on goods and services, so they do not explain the much lower CFB in services than in goods. (On net a higher CDB in services offsets the lower CFB in meeting the requirement that a weighted average of CDB, CFB and CHB must always sum to 1).

Over time, though less than for the goods sectors, CHB in services is mostly falling for Canada's provinces; CFB rises dominate CDB falls. Aggregating across provinces and sectors, CHB falls, CDB falls and CFB rises: Canada's service sector is becoming more outward oriented.

Our method is to proxy trade barriers with geographic variables, including the effect on provincial trade of crossing international borders. The variation across provinces in their trade with the US allows an international border effect on services trade to be identified, overcoming a limitation of previous gravity model work on services using national data (Francois and Hoekman, 2010, review the literature). An important subtlety is that the size of the barrier is partly endogenous since private agents can invest in reducing the impact of governmentally imposed regulatory and security barriers. Thus our reduced form approach to barrier measurement risks focusing on an unstable relationship between geographic proxies and bilateral trade patterns. Despite the risk, our results indicate that gravity works well in

the case of services disaggregated into 9 sectors, yielding stable coefficients over the period 1997-2007.

We explore whether the security-related measures implemented since September 11, 2001 have led to border thickening/thinning by estimating border coefficients before and after 9/11. Direct evidence from a survey of Canadian service providers (Vance, 2007) reports additional border-related obstacles. (More complete survey evidence on regulatory barriers along with direct measures of all other border barriers could in principle be used in gravity modeling to convert implied security barriers into tariff equivalents.) We find significant, large service border effects in each direction of service trade flows. There is evidence for changes (mostly thickening) in the border effects in the post 9/11 period. Finally, we see some directional asymmetries in both our border and thickening estimates. Such diversity arises due to differences across sectors in the ability of private agents to invest in friction-reducing activities, some linked to new border security measures and others simply as a reaction to perceived market opportunities. We attempt to interpret the differences in this chapter with some success.

The Constructed Bias indexes provide the basis for a novel test of the structural gravity model applied to services data. Recently, for manufactured goods trade Anderson and Yotov (2011a) provide a striking confirmation of structural gravity by showing the very close fit of estimated fixed effects to their theoretically predicted structural gravity values. A related test is developed and applied here using two different implied estimates of the Constructed Bias indexes, potentially allowing differences to emerge in the model's performance on domestic vs. foreign services trade. The data instead essentially show no difference in the estimates, confirming that the restrictions of structural gravity apply quite precisely to services trade as they do for manufactures trade.

The chief caveat about our results concerns aggregation and its effects. Due to the mixed nature of most of the nine service categories in our sample it is still hard to interpret our findings of directional and sectoral differences in border thickening/thinning. The magnitude and directional symmetries of our border and thickening estimates point to the need for further investigation of the factors behind these effects. Disaggregation to firm level data is also important for better understanding services trade barriers. Regulatory barriers are

likely to pose important fixed costs on potential exporters. The sector-province data used in this chapter does not permit the identification of selection of heterogeneous firms from sectoral data developed by Helpman, Meltiz and Rubinstein (2008), but firm level data might be able to shed light on the importance of fixed trade costs.

The success of our methods in this chapter suggests they are likely to be useful on services trade more broadly. Since bilateral trade data is rife with measurement error in any case, the good performance of the gravity model here suggests that more dispersed measurement error in trade flows need not preclude reasonably precise and reliable results.

The chapter is organized as follows: Section 3.2 reviews the structural gravity model. Section 3.3 presents the empirical analysis. Section 3.4 concludes.

3.2 Theoretical Foundation

The theoretical development of the gravity model reviewed here follows Anderson and Yotov (2010). Their Constructed Home Bias index is complemented here by two new general equilibrium trade cost indexes, Constructed Foreign Bias (CFB) and Constructed Domestic Bias (CDB), measuring the ratio of predicted (Foreign and Domestic) trade to hypothetical frictionless trade.

Assume identical preferences or technology across countries for national varieties of services differentiated by place of origin for every service category k , represented by a globally common Constant Elasticity of Substitution (CES) sub-utility or production function. The structural gravity model that is implied is written as:³⁶

$$X_{ij}^k = \frac{E_j^k Y_i^k}{Y^k} \left[\frac{t_{ij}^k}{P_j^k \Pi_i^k} \right]^{1-\sigma_k} \quad (3.1)$$

³⁶ See Anderson (2011) for details and discussion of two other theoretical foundations for (3.1)-(3.3). For services, a plausible alternative foundation models buyers with heterogeneous preferences over varieties that make choices distributed as in the CES 'love of variety' representative buyer model.

$$(\Pi_i^k)^{1-\sigma_k} = \sum_j \left(\frac{t_{ij}^k}{P_j^k} \right)^{1-\sigma_k} \frac{E_j^k}{Y^k} \quad (3.2)$$

$$(P_j^k)^{1-\sigma_k} = \sum_i \left(\frac{t_{ij}^k}{\Pi_i^k} \right)^{1-\sigma_k} \frac{Y_i^k}{Y^k} \quad (3.3)$$

where X_{ij}^k denotes the value of shipments at destination prices from origin i to destination j in services class k . E_j^k is the expenditure at destination j on services in k from all origins. Y_i^k denotes the sales of services k at destination prices from i to all destinations, while Y^k is the total output, at delivered prices, of services k . $t_{ij}^k \geq 1$ denotes the variable trade cost factor on shipment of commodities from i to j in class k , and σ^k is the elasticity of substitution across services in k .

The right hand side of (3.1) comprises two parts, the frictionless value of trade $E_j^k Y_i^k / Y^k$ and the distortion to that trade induced by trade costs $(t_{ij}^k / \Pi_i^k P_j^k)^{1-\sigma_k}$. In the hypothetical frictionless equilibrium, i 's share of total expenditure by each destination j is equal to Y_i^k / Y^k , i 's share of world shipments in each sector k , the pattern of a completely homogenized world. "Frictionless" and "trade costs" are used here for simplicity and clarity, but the model can also reflect local differences in tastes that shift demand just as trade costs do, suggesting "resistance" rather than costs.

Π_i^k and P_j^k in (3.1)-(3.3) are multilateral resistance (MR) terms. Π_i^k is the outward multilateral resistance, which consistently aggregates the incidence of all bilateral trade costs born by the producers of services k in origin i . It is as if producers of a given commodity class from a given region are shipping to a unified world market at markup Π_i^k . P_j^k is the inward multilateral resistance (also the CES price index of the demand system), which consistently aggregates the bilateral buyers' resistances on flows from i to j in class k . It is as if buyers at j pay a uniform markup P_j^k for the bundle of services purchased on the world market.

Anderson and Yotov (2010) define an index of the general equilibrium effects of the world-wide system of trade costs on local trade. Constructed Home Bias (CHB) measures the ratio of predicted to hypothetical frictionless internal trade within any given region i . For a generic service:

$$CHB_i = \frac{\hat{X}_{ii}}{Y_i E_i / Y} = \left[\frac{t_{ii}}{\Pi_i P_i} \right]^{1-\sigma} \quad (3.4)$$

Theory posits that the unobserved true bilateral trade flow is equal to the right hand side of (3.1) while the econometric estimate of the right hand side gives an unbiased predicted value. Using (3.1) the middle expression in (3.4) is the predicted value of internal trade, $\hat{X}_{ii}$, relative to the theoretical value of internal trade in a frictionless world, $Y_i E_i / Y$, and the rightmost expression gives the direct plus indirect effect of all trade costs acting to increase each province's trade with itself above the frictionless benchmark. Note that two regions i and j with the same internal trade cost $t_{ii} = t_{jj}$ may have quite different CHB's due to the general equilibrium incidence of trade costs, because $\Pi_i P_i \neq \Pi_j P_j$.

Aggregation of constructed bias across sectors or regions is convenient for describing results below. For aggregation across regions in sector k ,

$$CHB^k = \sum_i \hat{X}_{ii}^k / \sum_i (Y_i^k E_i^k / Y) = \sum_i \left(\frac{t_{ii}^k}{\Pi_i^k P_i^k} \right)^{1-\sigma_k} \frac{Y_i^k E_i^k}{\sum_i Y_i^k E_i^k}$$

For aggregation across sectors in region i

$$CHB_i = \sum_k \hat{X}_{ii}^k / \sum_k (Y_i^k E_i^k / Y) = \sum_k \left(\frac{t_{ii}^k}{\Pi_i^k P_i^k} \right)^{1-\sigma_k} \frac{Y_i^k E_i^k}{\sum_k Y_i^k E_i^k}$$

Both aggregates are weighted averages of the region-sector CHBs of (3.4).

The constructed bias idea extends readily to a family of constructed bias indexes composed of subsets of bilateral trades that are of interest. This chapter focuses on Constructed Foreign Bias (CFB) for province-international exports and Constructed Domestic Bias (CDB) for inter-provincial (domestic) exports. (The parallel measures for domestic and foreign import trade are suppressed here for brevity). Constructed Foreign Bias (CFB) is defined for each province and sector as the predicted volume of international export trade relative to the hypothetical frictionless volume of trade, both for given sales and expenditures. Constructed Domestic Bias (CDB) is analogously defined as the ratio of fitted to predicted inter-provincial export trade, excluding internal trade. CFB and CDB complement CHB by focusing on that part of non-internal trade that is respectively outside and inside Canada.

Let $\bar{C}$ denote the set of destinations outside Canada. Constructed Foreign Bias is defined for a generic service for region i as

$$CFB_i = \frac{\sum_{j \in \bar{C}} \hat{X}_{ij}}{Y_i E_{\bar{C}} / Y} \quad (3.5)$$

Here, $E_{\bar{C}} = \sum_{j \in \bar{C}} E_j$. Using the right hand side of (3.1) for the predicted value of bilateral trade we have

$$CFB_i = \sum_{j \in \bar{C}} \frac{t_{ij}^{1-\sigma}}{\Pi_i^{1-\sigma} P_j^{1-\sigma}} \frac{E_j}{E_{\bar{C}}}$$

Recognizing that t_{ij}/P_j is the i th sellers' incidence of bilateral trade costs on sales to j , we define the (average) sellers' incidence in province i on sales outside Canada:

$$\Pi_{i\bar{C}}^{1-\sigma_k} = \sum_{j \in \bar{C}} \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{E_{\bar{C}}}, \forall i, \quad (3.6)$$

Then,

$$CFB_i = \frac{\Pi_{i\bar{C}}^{1-\sigma}}{\Pi_i^{1-\sigma}} \quad (3.7)$$

Expression (3.7) is intuitively appealing: CFB is determined by the ratio of sellers' average incidence externally to sellers' average incidence overall. Notice that we can explain the time series behaviour of the CFB's decomposed into external and overall sellers' incidence (in power transforms), and further decompose the changes in the (power transforms of) sellers' incidence into that due to border thickening vs. other changes (such as expenditure and supply changes over time).

Turning to CDB, it is written as:

$$CDB_i = \sum_{j \in C; j \neq i} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \frac{E_j}{E_C},$$

where C denotes the set of provinces of Canada. Then, analogous to (3.6) and (3.7),

$$CDB_i = \frac{\Pi_{iC}^{1-\sigma}}{\Pi_i^{1-\sigma}} \quad (3.8)$$

Π_{iC} is called Domestic Trade Cost by Anderson and Yotov (2011a). Substitutability exists among the Constructed Bias indexes because the adding up condition implies that a weighted average of CHB, CFB and CDB must always equal 1, $CHB_i \cdot E_i/E + CDB_i \cdot E_C/E + CFB_i \cdot E_{\bar{C}}/E = 1$. The adding up condition also implies substitutability among i 's sellers' incidences to various destinations. $t_{ii}/P_i = \Pi_{ii}$, the sellers' incidence on local sales, so $CHB_i = \frac{\Pi_{ii}^{1-\sigma}}{\Pi_i^{1-\sigma}}$, the same form as in (3.7) and (3.8).

Aggregation of CFBs and CDBs has the same simple structure as aggregation of CHBs. Two further properties of Constructed Bias indexes are very appealing: (i)

independence of the normalization needed to solve system (3.2)-(3.3);³⁷ and (ii) independence of the elasticity of substitution σ , because they are constructed using the $1-\sigma_k$ power transforms of t 's, Π 's and P 's.

The constructed bias indexes below use (3.2)-(3.3) to calculate multilateral resistances and then use (3.6) and its analog to calculate the sellers' resistance on the subset of trades, all as inputs into the right hand sides of (3.4), (3.7) and (3.8). A test of the performance of structural gravity applied to services trade is based on comparing these Constructed Bias indexes with an alternative measure that would ordinarily differ. In particular, gravity equations estimated with fixed effects imply constructed bias as the ratio of predicted to hypothetical frictionless trade. For example, CFB calculated using (3.5) will differ from calculation using (3.7). In theory the two should be identical, so the calculating the closeness of the two provides a test of the theory. (This test complements a test reported in Anderson and Yotov (2011a) for manufacturing trade.)

3.3 Empirical Analysis

3.3.1 Econometric Specification

We start our empirical analysis by estimating the gravity equation (3.1),

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left(\frac{t_{ij}^k}{P_j^k \Pi_i^k} \right)^{1-\sigma_k} \quad (3.9)$$

Several steps complete the transformation of (3.9) into an econometric model. First, to provide structure behind the unobservable bilateral trade costs, we adapt the standard approach in the literature (of proxying the t_{ij} 's with a set of observable variables) to the specific features of Canadian trade and geography. For a generic service category, we define:

³⁷ Note that (3.2)-(3.3) solves for $\{\Pi_i^k, P_j^k\}$ only up to a scalar. If $\{\Pi_i^0, P_j^0\}$ is a solution then so is $\{\lambda \Pi_i^0, P_j^0 / \lambda\}$. Therefore, in the empirical section, we need to impose a normalization in order to solve for the multilateral resistances. CHB and CFB are independent of this normalization

$$t_{ij}^{1-\sigma} = e^{\gamma 1 \cdot DISTANCE_{ij} + \gamma 2 \cdot CONTIG_PR_PR_{ij} + \gamma 3 \cdot CONTIG_PR_ST_{ij} + \gamma 4 \cdot SAME_REGION_{ij} + \gamma 5 \cdot BRDR_CA_US + \gamma 6 \cdot BRDR_US_CA + \gamma 7 \cdot BRDR_ROW_CA + \gamma 8 \cdot BRDR_ROW_US + \gamma 9 \cdot THICK_CA_US + \gamma 10 \cdot THICK_US_CA} \quad (3.10)$$

Here, $DISTANCE_{ij}$ is the logarithm of bilateral distance between trading partners i and j . $CONTIG_PR_PR_{ij}$ takes a value of one when two provinces share a common border and is set to zero otherwise. $CONTIG_PR_ST_{ij}$ is equal to one when a Canadian province neighbours a US state.³⁸

$SAME_REGION_{ij}$ takes a value of one when $i = j$ and it is equal to zero otherwise. Most of the existing gravity studies ignore $SAME_REGION$, however, we include it for the following reasons. First, the few studies that do include some variant of this covariate always obtain large, positive and significant coefficient estimates.³⁹ In addition, $SAME_REGION$ and its coefficient estimate are key components (along with internal distance) of internal trade costs, the t_{ii} 's, which are needed for meaningful and consistent calculation of the multilateral resistances and the constructed bias (CB) indexes. Finally, from an econometric perspective, including $SAME_REGION_{ij}$ facilitates the analysis of our results by allowing us to interpret the estimates of all other border variables as deviations from interprovincial trade.

$BRDR_CA_US$ takes a value of one for Canadian exports to US and $BRDR_US_CA$ equals to one when US exports to Canada.⁴⁰ It is important to emphasize that the interpretation of the estimates on $BRDR_CA_US$ and $BRDR_US_CA$ in the case of services could be very different (in fact even opposite) as compared to the corresponding analysis of the same two variables in the case of merchandise. For example, consider the estimate $\hat{\gamma}_6$ of

³⁸ Previous gravity studies investigating non-service trade suggest that trade between contiguous provinces and states is much larger as compared to inter-provincial trade, while there is little evidence for significant differences in the volume of bilateral trade between contiguous provinces as compared to inter-provincial trade in general. We test these predictions for services.

³⁹ For example, Wolf (2000) finds evidence of US state border effects. Anderson and Yotov (2010) find that internal provincial trade is higher than interprovincial and international trade in the case of Canadian commodity trade. Finally, Jensen and Yotov (2011) and Anderson and Yotov (2011a) confirm a significant $SAME_REGION$ impact for important agricultural commodities and for world manufacturing, respectively.

⁴⁰ Previous studies employing aggregate data, e.g. Brown and Anderson (2002), and disaggregated manufacturing data, e.g. Anderson and Yotov (2010), find that the border between Canada and US is asymmetric. We test for asymmetric services border by splitting the Canada-US border dummy into its directional components.

BRDR_US_CA, capturing US exports to Canada, for Health. Under this scenario, *BRDR_US_CA* will mostly account for the obstacles faced by Canadian patients going to US to obtain health care and one should interpret a negative and significant estimate of γ_6 as a US border effect. Compare with trade in Health merchandises, where a negative and significant estimate of $\hat{\gamma}_6$ would be interpreted as a *Canadian* border effect.⁴¹

The broad implication is that the characteristics of the main services in a given category (a detailed description of each category is in the Appendix) condition the interpretation of the gravity border estimates. It might not always be possible to provide a meaningful interpretation of directional borders for some composite service sectors. Aggregation bias contaminates all gravity estimates to some degree (Anderson and van Wincoop, 2004) but for some services it blurs interpretation.

BRDR_ROW_CA and *BRDR_ROW_US* capture border effects between Canada and ROW and between US and ROW, respectively. In principle, it is possible for these borders to be directional as well. However, due to the rich fixed effects structure of our empirical specification (needed to account for the unobservable multilateral resistances), and because US and ROW are aggregated regions in our study, we are not able to include all directional border dummies due to collinearity and identification concerns.

The next two variables in (3.10), *THICK_CA_US* and *THICK_US_CA*, should be of particular interest to the Canadian policy makers, because they are intended to pick up any post 9/11 'thickening' of the border between Canada and the US. As in the case of borders in general, we allow for asymmetric thickening effects. Accordingly, *THICK_CA_US* is an indicator variable that takes a value of one for post 9/11 Canadian service exports to US. Similarly, *THICK_US_CA* is a dummy variable equal to one for post-9/11 US exports to Canada.

The econometric gravity specification is completed by substituting (3.10) for the power transform of t_{ij} into (3.9) and then expanding the equation with an error term. The

⁴¹ In contrast, the broad category of Health services contains the visits of Canadian doctors to perform important surgeries or to teach in the US. In that case, the interpretation of γ_6 will be similar for merchandise and services.

error structure and implied estimation must address several econometric challenges. First, to account for the zeros and for the presence of heteroskedasticity in trade data, we follow Santos-Silva and Tenreyro (2006) who advocate the use of the Poisson pseudo-maximum-likelihood (PPML) estimator for simultaneously addressing both of the above-mentioned challenges. Second, we add a time dimension to the data in order to be able to gauge any thickening effects and we use *time-varying*, directional, country-specific fixed effects to account for the unobservable multilateral resistance terms.⁴² Finally, "[f]ixed-effects estimations are sometimes criticized when applied to data pooled over consecutive years on the grounds that dependent and independent variables cannot fully adjust in a single year's time." (Cheng and Wall 2002, p.8).⁴³ To avoid this critique, we use 2- and 3-year lags.

Taking all of the above considerations into account and applying the definition of bilateral trade costs, from (3.10), for each service category in our sample, we use the PPML technique to estimate a panel version of (3.9) with time-varying, directional, country-specific fixed effects. We present the service gravity results after we describe our data.

3.3.2 Data Description

We put significant effort in the construction of a comprehensive and reliable data set for Canadian provincial service trade at the sectoral level, and we are extremely grateful to Denis Caron at Statistics Canada without whose assistance this project would not have been possible. Our study covers trade in services for the period 1997-2007. Trading partners include all Canadian provinces and territories,⁴⁴ the United States (defined here as an aggregated region of all the fifty US states and the District of Columbia) and the rest of the

⁴² See Olivero and Yotov (forthcoming) for formal discussion of the treatment of the MR terms in a panel setting. It should be noted that, in addition to controlling for the multilateral resistances, the fixed effects in our econometric specification will also absorb regional output and expenditures. Using disaggregated manufacturing data, Anderson and Yotov (2011a) show that the multilateral resistance component explains about 32.3% of the variance of the fixed effects, while the size effect terms (output and expenditures) account for about 57.7% of the fixed effects variability.

⁴³ Treffer (2004) also criticizes trade estimations pooled over consecutive years. He uses three-year lags. Olivero and Yotov (forthcoming) experiment with various lags to find that estimates obtained with 3-year and 5-year lags are very similar, but the yearly estimates produce suspicious gravity parameters.

⁴⁴ We treat the Northwest Territories and Nunavut as one unit, even though they are separate since April 1st, 1999.

world (ROW), which is an aggregated region consisting of all other countries in the world. Data availability allowed us to investigate 9 services sectors.⁴⁵ We also obtain aggregate gravity estimates by combining all service categories.

In order to estimate the gravity model and to construct the trade cost indexes of interest in this study, we use data on bilateral trade flows, output and expenditures for each trading partner, all measured in current Canadian dollars for the corresponding year. It should be noted that using real trade flows in the gravity estimates will not change our results. The reason is that the time-varying, country-specific fixed effects employed in our estimations in effect absorb any deflator index (as well as exchange rate changes) that could affect trade values.⁴⁶

Trade data comes from two sources. Statistics Canada is the major one. It provides data on intra- and inter-provincial trade flows as well as province-World and province-US bilateral trade flows. Data on US-World bilateral trade flows are from the US Bureau of Economic Analysis (BEA). We construct trade between ROW and US as the difference between US-World trade and US-Canada trade and trade between ROW and Canada as the difference between Canada-World trade and Canada-US trade. Finally, internal trade for each of the two aggregate regions (US and ROW) is obtained as the difference between domestic output and total exports.

We need production data for two reasons. First, as indicated above, we use production data in order to construct internal trade for each of the regions in our sample. Second, more importantly, we need output data to calculate the multilateral resistance terms

⁴⁵ The services sectors selection was based on (but is not completely identical to) the S-level of aggregation as classified in the Statistics Canada's Hierarchical Structure of the I-O Commodity Classification (Revised: November 3, 2010). The 9 services categories include (Abbreviated labeling used throughout the text is in parentheses): Transportation and Storage Services, including transportation margins (Transportation); Communication Services (Communication); Wholesale Services, including Wholesale Margins (Wholesale); Finance, Insurance and Real Estate services (Finance); Professional, Scientific, Technical, Computer, Administrative, Support, and Related Services (Business); Education Services (Education); Health Care and Social Assistance Services (Health); Accommodation Services and Meals (Accommodation); and, Miscellaneous Services (Other). Detailed description of each of the service categories in our sample are presented in the Appendix.

⁴⁶ Baldwin and Taglioni (2006) discuss in length the implications of inappropriate deflation of nominal trade values, which they call "the bronze-medal mistake" in gravity estimations. Their most preferred econometric specification is one with un-deflated trade values and appropriate treatment of the multilateral resistance terms, the method we employ here.

and to construct the Constructed Bias indexes. Statistics Canada provides provincial outputs. The US Bureau of Economic Analysis is our source for US service production data. Finally, we construct output for ROW from the GTAP database. GTAP has two limitations: First, data are only available for 2004 and 2007. This predetermined the years for which we will construct and analyze the Constructed Bias indexes.⁴⁷ Second, the GTAP service classification is more aggregated as compared to ours. In particular, GTAP aggregates the categories of Wholesale and Accommodation as well as those of Health and Education. Given the nature and the importance of each of these subcategories, we split the GTAP data in order to study them separately. To do this, we use actual output levels for US and Canada and we assume homogeneity, resulting in constant expenditure shares.⁴⁸

Given the specific geography and relationships among the regions in our study, we are only able to include two of the standard gravity covariates in our estimations: bilateral distance and contiguity. To calculate bilateral distances we adopt the procedure from Mayer and Zignago (2006), which is based on Head and Mayer (2000). The most appealing argument for the use of this particular approach in constructing bilateral distance is that the same procedure obtains consistent measures of internal distances and bilateral distances for each pair of regions, including ROW. We apply the following formula to generate weighted distances: $d_{ij} = \sum_{k \in i} \frac{pop_k}{pop_i} \sum_{l \in j} \frac{pop_l}{pop_j} d_{kl}$. Here pop_k is the population of agglomeration k in trading partner i , and pop_l is the population of agglomeration l in trading partner j . To calculate population weights, we take the biggest 30 agglomerations (in terms of population) in each trading partner when the partner is a province or a territory, the 300 biggest cities when the partner is US, and the biggest 100 cities when the partner is ROW.⁴⁹ Finally, d_{kl} is the distance between agglomeration k and agglomeration l , measured in kilometers, and

⁴⁷ We experiment by interpolating and extrapolating the GTAP data to cover the whole period of investigation. This adds a single sectoral observation for each year in our sample. While our sensitivity experiments reveal that the gravity estimates are not sensitive to whether we use ROW data for 2004 and 2007 only, or ROW data for the whole period, we find that the constructed bias numbers are quite sensitive to the interpolation procedures. Therefore, we limit our CB analysis to the years of 2004 and 2007, for which we do have actual data.

⁴⁸ As will become clear from our gravity estimates below, it is particularly important to separate Health and Education because the post 9/11 border response for these two categories is quite heterogeneous.

⁴⁹ In the few instances when data were not available for 30 agglomerations within a single trading partner (NT, PE and YT, for example), we included all the cities for which data were available.

calculated by the Great Circle Distance Formula.⁵⁰ All data on latitude, longitude, and population are from the World Gazetteer web page.

We also generate a series of indicator variables that pick up contiguity (*CONTIG_PR_PR_{ij}* and *CONTIG_PR_ST_{ij}*), regional borders (*BRDR_CA_US*, *BRDR_US_CA*, *BRDR_ROW_CA* and *BRDR_ROW_US*), internal trade (*SAME_REGION_{ij}*), and directional post-9/11 thickening of the Canada-US borders (*THICK_CA_US* and *THICK_US_CA*). Each of the above mentioned covariates was defined in the previous section.

3.3.3 Gravity Estimation Results

Panel PPML gravity estimates are reported in Table 1. The first column, TOTAL, presents aggregate estimates for all services, and the next nine columns report results at the sectoral level. To allow for trade adjustment, while at the same time keeping the number of degrees of freedom sufficiently large, we use 2-year lags.⁵¹ All results are obtained with time-varying, directional, country-specific fixed effects.

Distance. Bilateral distance is a significant impediment to trade in services. Without any exception, all coefficient estimates on *DISTANCE* are negative and significant. The services distance elasticity estimates are on average somewhat smaller in absolute value than those for goods sectors in Anderson and Yotov (2010), as is intuitive. The sectoral variation of services distance elasticities makes intuitive sense for the most part. The lowest estimate of -0.3 (std.err. 0.163) is for Communication, where the core of services (telecommunication, radio and television broadcasting and cable programming) are provided through wireless channels, and are therefore not subject to transportation costs. The largest estimates of -1.01 (std.err. 0.205) and -1.42 (std.err. 0.187) are for Education and Health services, respectively. In both cases, pronounced localized consumption explains the large numbers.

⁵⁰ Following Mayer and Zignago (2006), we use 32.19 kilometers as inner-city distance.

⁵¹ Estimates obtained with 3-year lags, available upon request, are virtually identical to the ones presented and discussed here.

Contiguity. Contiguity matters, but only when the common border is between a province and a state: The only positive and (marginally) significant estimate on *CONTIG_PR_PR*, capturing the presence of a common border between provinces, is for Wholesale. In contrast, all coefficient estimates on *CONTIG_PR_ST*, capturing contiguity between a province and a state, are positive, large and significant. The explanation is that almost every province is contiguous to at least one US state, and this is likely to be a major trade and business partner as well. Our province-state contiguity estimates resemble but are smaller than those for goods in Anderson and Yotov (2010), who study 19 non-service Canadian sectors. See also Brown and Anderson (2002), who use aggregate Canadian data. The absence of a province-province contiguity effect is more notable for services where we might anticipate informal arrangements that mitigate regulatory barriers.

Internal Trade (Provincial Borders). Given the structure of the border dummies employed in our estimations, the coefficient estimate on *SAME_REGION* should be interpreted as deviation from interprovincial trade. In volume terms, the coefficient of 1.4 (std.err 0.629) on *SAME_REGION* for total services, for example, implies that internal provincial trade is about 3.06 ($\exp(1.4)-1$) times larger as compared to interprovincial trade, ceteris paribus. We estimate very significant (economically and statistically) provincial borders. The largest estimates are for Health, Communication, Other services and Education. In the case of Health and Education this means that, in addition to the large distance barriers, there are other, province-specific incentives for internal trade. Possible candidates include provincially issued and managed health insurance and education credential recognition. The category of Other services includes the subcategories of beauty and personal care, funeral, child care, household, automobile repairs to recreation. Thus, the large estimate that we obtain is intuitive and reflects the fact that consumption in this category is strongly locally biased, probably due to the frequent usage that this type of services requires but also because of their personalized nature. The large estimate for Communication may be due to high volume of local radio and television broadcasting. On average, the provincial border barrier is higher in services than for goods as reported in Anderson and Yotov (2010).

Business is the only category with a small and not statistically significant estimate. Even though the estimate for Business as a whole is insignificant, it is possible that intra-provincial trade is different than inter-provincial trade for some of heterogeneous services (Professional, Scientific, Technical, Computer, Administrative, etc.) included in this category. This points to the potential benefits and need for analysis based on more disaggregated services data. Overall, the internal trade estimates for services presented in this section are in accordance with the findings from several recent studies, described in footnote 12, and our results reinforce the need and importance of accounting for internal trade in gravity-type estimations.

International Borders. Our estimates show that international borders have a strong depressing impact on Canadian trade in services. For every service category, the point estimates of the coefficients on *BRDR_CA_US* and *BRDR_US_CA*, capturing directional Canadian borders with US, and *BRDR_ROW_CA*, standing for Canadian border with the rest of the world, are economically large, negative and statistically significant at any level. The trade cost factor implied by the border coefficients is exemplified by the point estimate for *BRDR_CA_US* in column (1) of Table 1. The implied border tax factor is equal to $\exp[-3.744/(1-\sigma)]$ for σ evaluated at 6 and 10, yielding 1.52 and 2.11, a tax rate between 52% and 111%.

The estimated magnitude of the Canadian-US border effect on services is larger (in absolute value) on average than those for goods in Anderson and Yotov (2010). Canadian border effects with the rest of the world are similar in magnitude, slightly smaller for most categories.⁵² Finally, we estimate the border between US and the rest of the world to be significantly smaller for each service category, even insignificant in the case of Education. The latter reflects the large numbers of foreign students and scholars in US.

The estimates of the Canada-US border vary at the sectoral level. Accommodation stands out with lower, in each direction, but still large and significant, CA-US border estimates, while Wholesale is the category with clearly larger CA-US border estimates. In

⁵² Finance is a notable exception, where the CA-ROW border is significantly lower as compared to the CA-US border.

addition, we do find some evidence for directional border asymmetries between Canada and US.⁵³ With only the exception of financial services, all *BRDR_US_CA* estimates are lower, in absolute value, as compared to their *BRDR_CA_US* counterparts. Health is the category for which the difference between the *BRDR_CA_US* estimate and its *BRDR_US_CA* counterpart is most pronounced.

These findings should be interpreted with caution. Given the nature of services trade, the fact that the coefficient on the dummy variable standing for the border on Canadian exports to US is larger should, in most cases, be interpreted as evidence of a thicker border facing Canadian exports. To illustrate, we consider the case of Health services. Canadian exports of Health services consist mostly of US patients going to Canada. Thus, a larger *BRDR_CA_US* estimate (as compared to *BRDR_US_CA* estimate) suggests that it is significantly harder for a US citizen to cross the border in order to obtain health care in Canada. This result is intuitive, given the differences between the health systems in the two economies. On the one hand, the substantial waiting time for non-life threatening surgeries and for access to most new technologies, combined with limited access to specialists (which is only by referral and may take months), have lead Canadians to look for alternatives to the services offered by their provincial health system. Given its proximity and high quality, the US offers both an attractive substitute and a much needed complementary option. In contrast, as noted by the Bureau of Consular Affairs, U.S. Department of State, Canada's medical care is of a high standard but government-controlled and rationed. Access to ongoing medical care is very difficult for anyone who is not a member of the government-run, provincial health care plans, and no Canadian health care provider would accept U.S. domestic health insurance. Furthermore, Medicare coverage does not extend outside the United States. In combination, these facts may explain the disproportional border estimate on the Canadian side in the case of Health services.

Overall, the estimates from this section suggest that there are large and significant international borders in services trade. On the one hand, based on the nature of production and supply of services, this should be expected. On the other hand however, the magnitude

⁵³ Note that the TOTAL estimates from column one do not capture any asymmetries. This points to (i) aggregation bias in the total service estimates, and (ii) the need for even more disaggregated service data.

of the border estimates presented here is striking. This suggests that there are significant opportunities for globalization gains in the services area. In addition, our results emphasize the importance of knowing well the specific nature of a traded service when analyzing it, and to the need for more disaggregated data that will allow for better understanding of the main causes behind the large border effects in services trade.

Post 9/11 Thickening. Many business owners, especially on the Canadian side, have indicated that the CA-US border has 'thickened' as a result of stricter post 9/11 security-related measures. Our estimates provide reasonable empirical evidence that the US border has indeed thickened for some services in the post 9/11 period. We obtain negative and significant coefficient estimates on *THICK_US_CA* for five of the nine service categories in our sample, which add up to a negative and significant TOTAL estimate on *THICK_US_CA* for services trade (see column 1 of Table 1). The opposite is true on the Canadian side, where we estimate border 'thinning' for four of the nine services in our sample and an overall 'thinning' for all services. Education and Finance are the only two categories for which our estimates suggest thinning of the US border and thickening of the Canadian border after 2001. We discuss possible explanations next.

We offer two explanations for the negative and significant estimate on *THICK_CA_US* for Education. First, it may reflect the trend that it is harder (or less attractive) for American students to obtain higher education in a Canadian University. Second, it may be driven by the fact that Canadian scholars working temporarily (less than 1 year) in the US are facing additional security requirements imposed since 2001 on all foreigners entering the US. While both sources are potentially reasonable candidates to explain this result, we believe that the former has more weight. The positive estimate on *THICK_US_CA* suggests that, all else equal, it is easier for American scholars to provide services on Canadian soil and/or that it is easier for Canadian students to obtain Education services in the US after 2001. The latter reflects an overall trend of relatively easier access for foreign students, as compared to any other constituencies, to the US.⁵⁴

⁵⁴ According to the Bureau of Consular Affairs, U.S. Department of State, before applying for visa, all student applicants are required to be accepted and approved for their program. When accepted, educational institutions and program sponsors provide each applicant the necessary approval documentation for the visa. This process

We attribute our findings for Financial services (thinning on the US side and thickening on the Canadian side) to (i) the disproportionate progress in the provision of these services that was made in the US over the past decade. At the same time, (ii) border security and other impediments to trade that apply to physical crossing of the border, as in the case of Health and Education services for example, do not apply to most services included in the Finance category.

We view our results as modest support of the claims of Canadian businessmen for significant increase in the efforts to cross the US border,⁵⁵ and we attribute the small thickening estimates to joint and unilateral efforts on behalf of the US and the Canadian governments to facilitate bilateral trade in the post 9/11 period. Examples of unilateral efforts on each side of the border include the US Homeland Security in 2002 and the Canadian Border Services Agency in 2003 as well as some border measures such as the U.S. Customs and Border Protection's cargo enforcement strategy. Joint programs include the Container Security Initiative (CSI), the Customs-Trade Partnership Against Terrorism (C-TPAT)/Partners in Protection and the Nexus program.⁵⁶

3.3.4 Constructed Bias Results

All three provincial CB indexes are useful to understanding the economic effects of Canadian political and geographic structure. CFB is the ratio of predicted foreign shipments to the frictionless foreign shipments benchmark for each province. CHB is the ratio of predicted internal shipments to the frictionless internal benchmark, a measure of excess

significantly reduces the additional security requirements and impediments faced by foreign students entering the US. In addition, the Student and Exchange Visitor Information System (SEVIS) was created in 2003 as a web-accessible database used by the Department of Homeland Security to collect, track and monitor information regarding exchange visitors, international students and scholars who enter the United States on visas. This further simplified the application and entering process for foreign students in the US.

⁵⁵ The category of Transportation services (rail, bus, truck and air), where trade only takes place through one mode of supply, *cross border supply*, is a good representative example with an insignificant thickening estimate of -0.076 (std.err 0.064) on the Canadian side and a statistically significant but economically small estimate of -0.134 (std.err 0.054) on the US side.

⁵⁶ CSI was set up, based on reciprocity between partners, shortly after 9/11 to address threats posed by a potential terrorist use of a maritime container to deliver a weapon. C-TPAT/PIP are partnerships between the American and the Canadian governments, respectively, and the private sector to protect supply chains from concealment of terrorist weapons. Finally, the Nexus program is a collaboration of the CBSA and the Custom and Border Protection in order to simplify the border-crossing process for members while enhancing security.

localization, while CDB is the ratio of predicted inter-provincial shipments to frictionless inter-provincial shipments, a measure of excess domestic trade.

Services trade has some seven times smaller CFB on average across sectors and provinces than does goods trade (the latter based on new calculations for this chapter from the data used in Anderson and Yotov, 2010). In contrast, the CHBs for goods and services trade are broadly similar because services' higher CDBs than in goods trade offset their lower CFBs. This means that the lower CFB in services relative to goods trade is not due to greater localization forces in services. Equations (3.7) and (3.8) imply that the results are mainly due to differences in the direct and indirect effects of trade costs on sellers incidence on inter-provincial (Π_{iC}) as compared to international trade ($\Pi_{i\bar{C}}$).

In turn, we show below that the difference in CFB results are mainly due to direct effects of differences between services and goods in the estimated coefficients for *SAME_REGION* (home bias) and *CA_US_BORDER* (the international border barrier). Finally, services CDBs have smaller variation across provinces than CHBs, localization is damped within the Canadian confederation.

3.3.4.1 Constructed Home Bias (CHB)

Table 2 presents constructed home bias indexes and their evolution over time for each region and each service category in our sample. Standard errors are suppressed for brevity, but due to the precision of gravity coefficients they are sufficiently small to ensure that all indexes and relationships discussed in this section are statistically significant.⁵⁷ Sectoral CHB indexes are presented in columns (1)-(9) of Table 2, while column (10) reports CHB numbers for all services. Regional CHB numbers for 2004, the year for which these indexes are constructed, are reported in the rows labeled '2004'. CHB percentage changes over the

⁵⁷ Extended tables, including standard errors (SEs) for each of the CB indexes reported in Tables 2-4, are available by request. The SEs are obtained from one hundred bootstraps of the PPML gravity estimates. See Anderson and Yotov (2010) for further details.

period 2004-2007 are in rows ‘%Δ04/07’.⁵⁸ Toward the bottom of the table (row ‘All’), we aggregate CHBs across all regions for each category to obtain constructed home biases for the world. Finally, the last two rows of Table 2 report aggregate Canadian CHBs and their percentage changes, respectively.

Overall, we find significant home biases in services trade. The CHB indexes vary across regions and across service categories in a sensible way. Several clear patterns stand out. Most prominently, we estimate massive home biases for each province and territory and each service category in our sample. The implication is that internal provincial trade is significantly larger as compared to the theoretical value of internal trade in a frictionless world. At the province-service level, the CHB numbers vary between 40.8, for Wholesale services in the case of Ontario, and 163,852, for Health services in the case of the Yukon Territories. As compared to the provincial indexes, the estimates for U.S. and ROW are significantly smaller (varying between 1.2 and 5.8), and much more homogeneous across the sectors. These differences are due to size (outward multilateral resistance falls and thus CHB rises with size on average; see Anderson and Yotov, 2010) and aggregation (the U.S. states and the ROW are very large composites relative to any of Canada's provinces).

There is large, but intuitive, variation of the CHB numbers across the Canadian provinces and territories. The remote regions of the Yukon Territories (YT), the Northwest Territories and Nunavut (NT) and Newfoundland and Labrador (NL), and the small region of Prince Edward Island (PE), with overall CHB estimates ranging from 1685 (for NL) to 8897 (for YT), are the four regions with the largest CHB numbers. See column (10) of Table 2, where we aggregate CHBs across all sectors for each province or territory. On the opposite side of the CHB spectrum, we find the central, most industrialized and economically diversified regions of Ontario (ON) and Quebec (QC). These are the two provinces with the lowest CHB numbers of 75 for Ontario and 145 for Quebec (see column 10), revealing the

⁵⁸ The reason for choosing the period 2004-2007 to construct and to analyze the CB numbers is that 2004 and 2007 are the only two years for which we have actual output data for the rest of the world. As discussed in the data section, our gravity estimates are not at all sensitive to interpolating and extrapolating the ROW data, needed to construct internal trade in order to obtain a complete trade data set. However, the general equilibrium indexes (MRs and CBs) showed significant sensitivity (probably due to the large size of the ROW region) and, therefore, we decided to only use the years for which we have actual ROW data.

least, but still very large, deviation of predicted internal trade from predicted frictionless internal trade.

Our CHB indexes for services as a whole are close to the results from Anderson and Yotov (2010), who construct provincial CHB indexes for the resource and manufacturing sectors of the Canadian economy. On average, provincial home bias is around 9% larger for services (with much of this difference due to the outlying provinces) while the correlation of services and goods CHBs across provinces is 0.95. The somewhat surprisingly small difference between services and goods CHBs arises because some gravity coefficient estimates are larger in absolute value for goods (distance, contiguity between province and state) while others are smaller for goods (provincial border, international border). In the calculations of CHBs the differing distribution of sales and expenditure shares also plays a role.

CHB variation across service categories is large but intuitive. As expected, we estimate the largest home biases for Health and for Education services. As can be seen from the last panel of Table 2, we obtain an overall, across all provinces, CHB index of 367 for Education and a corresponding number of 732 for Health. The explanation is in the nature of these services (personalized and credential related) and could be due to province-based regulations (such as health insurance and learning curriculum). Wholesale is the service category with the smallest CHB estimates for each province, which translate into an overall index of 60 for Canada. Transportation services follow closely with low provincial estimates and an overall CHB number of 129. The fact that the regulations for Wholesale and for Transportation services are mostly nationally (as opposed to locally) imposed, combined with significant international interdependence, coordination and regulation in these sectors, may explain our findings.

Most service sectors experience falls in CHB over the 2004-2007 period. Accommodation, Finance and Health services are the categories with the largest overall CHB decrease of 33.3% , 10.4% and 10.1%, respectively, across all Canadian regions. See the last row of Table 2. Since the main gravity coefficients are constant (and the border thickening

for Canadian services exports is offset by border thinning for Canadian imports), the CHB changes are due to reallocation of shipment and expenditure shares. As in Anderson and Yotov (2010) these have shifted consistently with lowering the overall trade cost bill

Wholesale is the only category with CHB increase in each province, which translates into an overall increase of 26.3% for Canada as a whole. This suggests that the Wholesale industry has not been subject to the intense 'globalization' forces experienced in other industries. A contributing factor is the large CHB increase for the U.S., which is the main Canadian trading partner.

At the provincial aggregate level, CHB changes over the period 2004-2007 are relatively small according to rows '%Δ04/07' of column 10. One explanation is that the period of investigation is too short to reflect larger effects in a period when there were no major changes in the Canadian economy nor in its main trading partner U.S..⁵⁹ Alberta (AB) and British Columbia (BC) are the two provinces that experience the largest overall CHB decrease of 11% and 6%, respectively. The economic growth of these regions may explain our findings. Newfoundland and Labrador (NL) and Nova Scotia (NS) are the two regions with largest CHB increase. Notably, the most developed provinces, Ontario and Quebec, have the most stable CHB indexes. An interesting regional pattern is that the West Canada provinces enjoy CHB decrease during the period 2004-2007, whereas the East-Canadian provinces see their CHBs increase.

The world as a whole enjoyed a CHB decrease in all service sectors but Accommodation and Finance. See panel 'All' of Table 2. Our results indicate that the increase in the case of Accommodation services is driven by the index for the rest of the world, while the increase in Finance is due to the U.S..

⁵⁹ In contrast, Anderson and Yotov (2010) report larger drops in CHB but over a longer horizon, 1992-2003.

3.3.4.2 Constructed Foreign Bias (CFB)

Table 3 presents Constructed Foreign Bias indexes and their evolution over time for each region and each service category in our sample. Sectoral CFBs are presented in columns (1)-(9) of Table 3. Column (10) reports aggregate CFB numbers for all services. Regional indexes for 2004 are reported in the rows labeled '2004', and CFB percentage changes over the period 2004-2007 are presented in rows '%Δ04/07'. Toward the bottom of the table (row 'All'), we aggregate CFBs across all regions for each category to obtain constructed foreign biases for each service in the world. Finally, the last two rows of Table 3 report aggregate Canadian CFBs and their percentage changes, respectively.

Overall, our estimates suggest significant provincial biases in services trade that vary across regions and across service categories. Several patterns stand out. First, we obtain very small CFB numbers for each province and territory in each service category in our sample. The interpretation is that provincial international trade is much smaller than its frictionless value, *i.e.* much of the provincial international trade *is missing* in each service industry. At the province-service level, the CFB numbers vary between 0.001, for Health in the case of Quebec, and 0.586, for Accommodation in the case of the Yukon Territories.⁶⁰

Our CFB indexes for services are on average around 7 times smaller overall than CFBs for the agricultural, mining and manufacturing sectors of the Canadian economy constructed from data in Anderson and Yotov (2010). The explanation is mainly in the direct effects of the differences in coefficient estimates: services have larger *SAME_REGION* and *CA_US_BORDER* coefficients. Use the definition of CFB⁶¹ and the notation (*G*) and (*S*) to denote Goods and Services. Suppose (falsely) that all coefficients other than those affecting borders are equal for services and goods. Then $t_{ii}^{1-\sigma}(G)/t_{ii}^{1-\sigma}(S) = \exp \gamma_5(G)/\exp \gamma_5(M)$. Taking the arithmetic average of point estimates of γ_5 reported for goods in Anderson and Yotov (2010) and the average estimate for services reported here,

⁶⁰ The two aggregate regions in our sample (US and ROW) also register significant foreign biases.

⁶¹ CFB is defined as the ratio of predicted international trade to hypothetical frictionless international trade.

Repeating (3.7) for a generic sector and region *i*, $CFB_i = \frac{\Pi_{i\bar{C}}^{1-\sigma}}{\Pi_i^{1-\sigma}}$

$t_{ii}^{1-\sigma}(G)/t_{ii}^{1-\sigma}(S)=1/4.8$. The empirical finding that $CHB(S)=1.09CHB(G)$ implies that for a representative province and generic sector $1.09t_{ii}^{1-\sigma}(G)/t_{ii}^{1-\sigma}(S)=\Pi_i^{1-\sigma}(G)/\Pi_i^{1-\sigma}(S)=1.09/4.8$. Turning to CFB, its definition implies

$$\frac{CFB_i(G)}{CFB_i(S)} = \frac{\Pi_{i\bar{C}}^{1-\sigma}(G) \Pi_i^{1-\sigma}(G)}{\Pi_{i\bar{C}}^{1-\sigma}(S) \Pi_i^{1-\sigma}(S)} = \frac{\Pi_{i\bar{C}}^{1-\sigma}(G)}{\Pi_{i\bar{C}}^{1-\sigma}(S)} \frac{4.8}{1.09}$$

Attributing all difference in the sellers incidence on foreign sales to difference in the average estimated CA-U.S. border coefficients (exponentiating as before to obtain 1.83 as the relative difference), the right hand side of the equation yields the value 8.06, close to the actual estimated value of around 7.

To focus on the variation across sectors, we construct overall CFBs by sector for Canada. As can be seen from the last panel 'CAN' of Table 3, Accommodation and Transportation are among the service sectors with the largest CFB estimates. We find these results intuitive because many of the Accommodation services are sold to foreigners, who use various Transportation modes to come to Canada. On the other side of the CFB spectrum are Health and Wholesale services with CFB estimates that are close to zero. Local consumption and government regulations can explain our findings in the case of Health services, and there is plenty of anecdotal evidence for huge price differences and price discrimination between Canada and U.S., for example, which are reflected in the low CFB index for Wholesale services.

Sectoral CFBs have increased for most service categories in our sample during the period 2004-2007.⁶² Accommodation, Other services and Transportation services experience the largest increases of 27 percent, 24 percent and 18 percent, respectively. See the last row of Table 3. A possible explanation for these results could be the tightening of the U.S. border in the post 9/11 period. Note that Accommodation, Other and Transportation were three of the industries for which we estimate significant 'thickening' on the U.S. side.

⁶² Note that a negative change in the CFB index, *i.e.*, a smaller 2007 value, implies an increase in the foreign bias.

Notably, Health and Education are the two service categories with the largest foreign bias decreases (captured by increases in the CFB index over time) of 16 percent and 14 percent, respectively, during the 2004-2007 period. Combined with the estimated fall in the constructed home biases for each of these sectors, our CFB results suggest that the increase in the inflows of foreign patients and foreign students have been much larger as compared to the inflow of Canadian patients and students from other provinces and territories. It is also worth noting that while the increase in the Health CFB index is more or less homogeneous across provinces (Alberta is the only province suffering a CFB fall), the increase in the overall constructed foreign bias for Education is driven almost exclusively by Ontario and Quebec. Industry concentration is the natural cause for these differences.

The last column of Table 3 focuses on CFB variation across provinces. The indexes for the more remote and the smaller provinces and territories are larger than the corresponding numbers for the more developed regions. For example, YT and NT are the territories with the largest CFB estimates of 16 percent and 12 percent, respectively. PE has the fourth largest index of 8 percent. Quebec is the province with the smallest CFB estimate of 3.8 percent, followed by Alberta, British Columbia and Ontario with 4.1 percent each. Combined with the CHB estimates from the previous section, the CFB findings from this section imply that the more developed regions are trading more actively with the rest of Canada, while the more remote regions are relatively more open to the rest of the world. CFB changes are consistent with this result. As can be seen from the last column of Table 3, the more remote and the smaller regions experience further increase in CFB, while the more developed regions suffer CFB falls. Ontario is a notable exception with an overall CFB increase of 5 percent, mainly due to the large increase in the Education index for this province.

For comparison, Tables 6 and 7 from Appendix B report CFBs for goods trade constructed using the data of Anderson and Yotov (2010). Goods CFBs are well below 1; foreign trade is less than in the frictionless benchmark equilibrium, but much larger than for services trade, by an average factor greater than 7 based on comparing the bottom right hand cells of the two tables. In other words the services trade of Canada's provinces on the whole

would be more than 7 times larger if it were to be only as biased against foreign trade as is Canada's goods trade. Moreover, over time CFB is rising considerably faster in goods trade as well, by a factor greater than 10 over a period only about 3 times longer.

Another interesting experiment is to break the provincial foreign biases into CFBs with the U.S. and CFBs with ROW. Tables 8 and 9 from Appendix B report provincial CFBs and their percentage changes over the period 2004-2007 against the rest of the world and against U.S., respectively. Several findings stand out. First, the difference in the CFBs varies per product. As one would expect, the U.S. indexes are larger (i.e. less foreign bias toward the U.S.) for most services. The difference is most pronounced for Accommodation and Transportation. An interesting result is that the CFB indexes for ROW are larger, i.e. the foreign bias to the rest of the world is smaller, for two categories, namely Finance and Education. Second, there is a pattern in the CFB differences across provinces. In particular, we find that the ROW CFB numbers are larger relative to the U.S. CFBs for the more remote and the smaller regions, i.e. these regions are relatively more open to trade with the rest of the world. Finally, the difference in CFB changes also varies per product, but we do not find an overall pattern.⁶³ In sum, the results from this experiment suggest heterogeneous response and/or treatment in the foreign biases against U.S. and ROW, which might be of interest to policymakers.

Overall, the constructed foreign bias indexes, presented in this section, and the constructed home bias indexes, discussed in the previous section, reveal significant opportunities for gains from more internal trade with the rest of Canada and from more international trade for each Canadian province and territory.

⁶³ For example, the foreign bias against the US has risen faster for Transportation, Finance and Communication, and has fallen slower for Health. The foreign bias against ROW increased by more for Communication and decreased by less for Business.

3.3.4.3 Constructed Domestic Bias (CDB)

Domestic bias raises inter-provincial services trade in Canada to more than six times its frictionless benchmark value overall as revealed in our CDB results. Domestic bias is much smaller than home (intra-provincial) bias CHB but some 800 times larger than foreign bias CFB.

Constructed Domestic Bias indexes along with their evolution over time are presented in Table 4 for each Canadian province and territory and each service category in our sample. Sectoral CDBs are presented in columns (1)-(9) of Table 4. Column (10) reports aggregate CDB numbers for all services. Provincial indexes for 2004 are reported in the rows labeled '2004', and CDB percentage changes over the period 2004-2007 are presented in rows '%Δ04/07'. In the last two rows of the table report aggregate CDBs for Canada and their percentage changes, respectively.

The large ratio of CDB to CFB comes from the large ratio of sellers' incidence of trade costs for foreign vs. domestic sales. Using (3.7) and (3.8), solve for relative incidence as a function of relative CBs using elasticities of substitution σ ranging from 6 to 10. The results from column (10) of Table 4 imply that overall services sellers' incidence on foreign sales is 2 to 4 times larger than sellers' incidence on domestic sales. This relative sellers' incidence comparison is a useful complement to the direct bilateral estimate of the international border effect inferred from the estimated gravity equation. Section 2.3 reports the trade cost factor equivalent of the border as ranging from 1.52 to 2.11. The difference is attributable to the relative incidence measure (i) including relative distance and contiguity as components of bilateral relative trade costs and (ii) general equilibrium multilateral effects of trade costs.

Notably, CDB variation across provinces is much lower than is the variation of CHB, provincial localization is damped on inter-provincial trade. Compare column (10) of Table 4 with column (10) of Table 2. The considerable variation of CDB across provinces in column (10) of Table 4 is not due to direct inter-provincial barriers (our gravity estimates find no province-province contiguity effects) but to the other direct influences of geography along

with general equilibrium effects that affect provinces differently. Some remote (e.g. YT) and small (e.g. PE) provinces are the regions with the highest domestic bias. Over time, CDB has fallen for each of the provinces except NB, though overall considerably less than the fall in CHB (2.6% vs. -7.2% using on the bottom right figures in Tables 2 and 4), both changes reflecting Canada's outward turn also shown in the rise in overall CFB of 1.3%, the bottom right figure in Table 3.

Turning to variation across sectors, the aggregate sectoral indexes toward the bottom of Table 4 reveal that the ratio of predicted to frictionless inter-provincial trade ranges from Business and Communication on the upper bound with CDB estimates of 12 and 11.5 to Health at 1.9 on the lower bound. This is a much smaller range than for CHB reported above.

Constructed domestic bias fell for most service categories between 2004 and 2007. Wholesale and Education are the two exceptions, but while the increase in the Wholesale CDB is across all provinces, the increase in the average Canadian index for Education is driven by Quebec and, especially, by Ontario. One interpretation of these findings is that more and more students from the rest of Canada choose to go to ON and QC to obtain higher education (Note that the CDBs for education have fallen for the rest of the Canadian provinces and territories). Concentration of good quality higher education services in ON and QC may explain our results. Accommodation is the sector that experiences the largest aggregate fall of 36.6 percent, which is consistent across all provinces.

Interestingly, Accommodation was the sector with the largest, across all provinces, CHB and CFB falls as well. The simultaneous decrease in all CB indexes seems odd at first sight, because, as suggested by our theory, the weighted sum of the three bias indexes should always be equal to one for each province and for each service category. As a check on calculations, we confirmed this restriction for each province-service combination. This implies that the expenditure weights on the CBs should have moved significantly and in opposite directions between 2004 and 2007. Table (5) shows this for Accommodation in the case of Ontario.⁶⁴ As can be seen from the table, Canadian expenditures and Ontario's own expenditures have risen during the period 2004-2007, but the rest of the world, including

⁶⁴ The numbers for the rest of the provinces are qualitatively identical.

U.S., has spent significantly less on Ontario's accommodation services. This is what makes the simultaneous decrease in all three constructed bias numbers possible and, at the same time, consistent with our theory.

3.3.4.4 Test of Structural Gravity

As discussed in the theoretical section 3.2, Constructed Bias indexes can be calculated in two ways. The one reported above calculates buyers' and sellers' incidences from (3.2)-(3.3) and then calculates the relevant subset of sellers incidences using (3.6) and its analogs. The ratio of the subset of sellers incidences to the overall sellers' incidence (raised to the power $1-\sigma$) gives the Constructed Bias. The alternative measure is based on the ratio of predicted to predicted frictionless trade on any bilateral flow, $\hat{X}_{ij} = (E_j Y_i / Y)$, where $\hat{X}_{ij}$ is the predicted value from the econometric estimation of the gravity equation using fixed effects to control for $E_j / P_j^{1-\sigma}$ and $Y_i / \Pi_i^{1-\sigma}$. The fixed effect procedure is in principle agnostic about whether the restrictions of structural gravity hold, and one might anticipate that the very different characteristics of services trade would make structural gravity fit less well so that the fixed effects pick up other forces. The Constructed Bias indexes based on the $\hat{X}_{ij} = (E_j Y_i / Y)$ s were calculated to see if they differed from the indexes based on terms such as the right hand side of (3.7). In practice the two sets of estimates are essentially identical, both overall and subdivided into CHBs, CFBs and CDBs; and the correlation coefficient is equal to 1.

3.4 Conclusion

This chapter measures the major geographic impediments to Canadian service trade by sector and province during the period 1997-2007. Border fixed effects for local, interprovincial and international trade reflect differential treatment of outsiders by regulators as well as a host of other policy and non-policy barriers to trade. These and other geographic determinants deflect trade from its hypothetical frictionless benchmark, measured by Constructed Bias indexes defined using the structural gravity model.

Constructed Foreign Bias (CFB) is some 7 times lower on average for services than for goods trade, quantifying the widely held qualitative judgment that the direct and indirect effects of barriers to trade in services are much larger than for goods. Constructed Home Bias (CHB) is large for all services, on the whole only slightly larger than for goods, drawing on the results of Anderson and Yotov (2010). Thus the lower CFB in services is not due to greater home bias at the provincial level. Instead, Constructed Domestic Bias is higher for services than for goods, accounting for the lower CFB. There is large variation in Constructed Bias across sectors, much of it intuitively explained by the characteristics of the various service sectors.

Our results indicate that disaggregated gravity works well in the case of services and we view the service gravity estimates presented here as interesting and useful. In some cases, our results are similar to commodity-level estimates, while in other instances we see that the specific characteristics of service trade play an important role. Overall, we find the estimates to be reasonable and intuitive.

Several results stand out in regard to the Canada-U.S. border effects and their changes in the post 9/11 period. We find significant and large service border effects that are present in each direction of service trade flows. We also provide evidence for changes (mostly thickening) in the border effects in the post 9/11 period. Finally, we see some directional asymmetries in both our border and thickening estimates. Even though our data is at the sectoral level, it is still hard to interpret our directional findings due to mixed nature for most of the nine service categories in our sample. This points to the need for analysis of more disaggregated service data that will not only enhance better qualitative understanding of the border effects, but could also allow for more rigorous qualitative analysis.

The magnitude and directional symmetries of our border and thickening estimates point to the need for further investigation of the factors behind these effects. In particular, with the use of firm level data it may be possible to separate the effects of service trade barriers on fixed and variable trade costs.

The magnitude of services trade barriers found in our study suggests potential large gains from globalization over time, especially if speeded up by deliberate policy efforts to liberalize services trade. The similar CHBs of services and goods trade suggest the potential for CFBs to also be similar, implying a seven-fold potential rise in services trade across borders. Large welfare improvement for the Canadian economy would result from even a partial fall of the services border barrier toward that for goods. With more understanding of border barrier reductions achievable by policy liberalization, it would be straightforward to simulate changes in the terms of trade and gains from trade following Anderson and Yotov (2011b).

Table 1: PPML Panel Gravity Estimates, Services, 1997-2007

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	TOTAL	TRNSP	CMNCN	WHLSL	FNCE	BUSNS	EDCTN	HELTH	ACMDN	OTHER
DISTANCE	-0.671 (0.191)**	-0.617 (0.160)**	-0.297 (0.163)+	-0.563 (0.162)**	-0.678 (0.276)*	-0.928 (0.226)**	-1.010 (0.205)**	-1.420 (0.187)**	-0.927 (0.168)**	-0.724 (0.168)**
CONTIG_PR_PR	-0.034 (0.264)	0.084 (0.235)	0.216 (0.251)	0.341 (0.171)*	-0.328 (0.401)	-0.420 (0.337)	-0.394 (0.278)	-0.228 (0.295)	0.008 (0.246)	0.129 (0.248)
CONTIG_PR_ST	1.144 (0.213)**	1.128 (0.267)**	0.665 (0.191)**	0.482 (0.283)+	1.336 (0.298)**	1.069 (0.235)**	0.835 (0.265)**	0.792 (0.307)**	0.757 (0.225)**	1.287 (0.172)**
SAME_REGION	1.405 (0.629)*	1.044 (0.532)*	2.377 (0.551)**	1.199 (0.505)*	1.653 (0.944)+	0.333 (0.794)	1.823 (0.549)**	2.536 (0.586)**	1.134 (0.574)*	1.886 (0.541)**
BRDR_CA_US	-3.744 (0.295)**	-3.569 (0.276)**	-3.719 (0.221)**	-5.302 (0.389)**	-4.045 (0.460)**	-3.777 (0.365)**	-3.551 (0.344)**	-5.099 (0.500)**	-2.236 (0.215)**	-2.893 (0.313)**
BRDR_US_CA	-3.416 (0.231)**	-3.014 (0.279)**	-3.013 (0.194)**	-5.124 (0.344)**	-4.351 (0.301)**	-3.009 (0.270)**	-2.409 (0.293)**	-1.408 (0.338)**	-1.878 (0.221)**	-2.586 (0.231)**
BRDR_ROW_CA	-2.433 (0.279)**	-2.786 (0.261)**	-3.170 (0.217)**	-4.839 (0.246)**	-1.750 (0.323)**	-2.648 (0.310)**	-1.268 (0.343)**	-3.233 (0.330)**	-1.041 (0.227)**	-2.212 (0.316)**
BRDR_ROW_US	-0.908 (0.238)**	-0.676 (0.204)**	-2.530 (0.222)**	-0.041 (0.181)	-0.312 (0.334)	-1.705 (0.314)**	0.297 (0.216)	-0.717 (0.230)**	-0.865 (0.220)**	-1.236 (0.234)**
THICK_CA_US	0.161 (0.019)**	-0.076 (0.064)	0.091 (0.075)	0.224 (0.197)	-0.175 (0.046)**	0.306 (0.048)**	-0.170 (0.037)**	1.028 (0.083)**	0.416 (0.049)**	0.513 (0.114)**
THICK_US_CA	-0.138 (0.037)**	-0.134 (0.054)*	0.023 (0.042)	-0.244 (0.200)	0.330 (0.030)**	-0.348 (0.096)**	0.390 (0.033)**	-1.119 (0.078)**	-0.502 (0.056)**	-0.540 (0.113)**
_cons	6.241 (1.746)**	4.094 (1.532)**	0.584 (1.835)	3.172 (1.608)*	4.789 (2.372)*	6.211 (2.026)**	2.635 (1.549)+	6.724 (1.237)**	5.236 (1.350)**	4.565 (1.393)**
N	1173	1173	1173	1173	1173	1173	1173	1173	1173	1173
ll	-259346.535	-36914.246	-14931.003	-150530.828	-80497.699	-53542.761	-3518.936	-3260.472	-25835.737	-28734.000

Notes: + $p < 0.10$, * $p < .05$, ** $p < .01$. Huber-Eicker-White robust standard errors (clustered by country pair) are reported in parentheses. Dependent variable is always nominal trade. Each estimation is performed with directional (source and destination), time-varying fixed effects. Fixed effects estimates are omitted for brevity. The years employed in the estimations are 1997, 1999, 2001, 2003, 2005 and 2007. See main text for further details.

Table 2: Constructed Home Bias (CHB) Indexes and Their Evolution Over Time

RGN	Year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AB	2004	178.2	384.6	123.6	264.2	367.4	851.4	1725.2	522	263.7	232.7
	% Δ 04/07	-14.1	-16.7	7.3	-17.2	-16.3	-7	-13.1	-39.5	-15.1	-11.1
BC	2004	187.8	363	135.6	229.1	468.1	664.8	1292.9	470.5	262.2	239.7
	% Δ 04/07	-10.1	-11.8	18.5	-13.4	-15.1	-4.8	-13.8	-35.6	-10.3	-5.5
MB	2004	472	1030.9	322.8	873.2	1595.2	3235.7	5195.8	1767.7	1017.4	667.4
	% Δ 04/07	-9.7	-11.3	19.9	-10.8	-9	-2.1	-7.1	-31	-7	-1.7
NB	2004	563.3	1305	338	1180.6	1265.1	3946.4	8651.1	1708.6	1215.5	811.4
	% Δ 04/07	-5.2	-8.5	24.6	-9.1	-4	3	-10.5	-27.9	-5	4.6
NL	2004	1268.5	1926.9	692.5	2370.6	3159.1	7552.3	13761.5	4017.6	2358.1	1685.2
	% Δ 04/07	-6.4	.7	24.4	-11.3	-4.6	-2	-8.8	-27.3	-3.2	5
NS	2004	744.6	1265	398.5	1107.8	1596.8	2553.8	6553.2	1997.6	1169.2	910.7
	% Δ 04/07	-3.8	-14.4	26.6	-9.2	-4.4	3.6	-12	-28.4	-1.2	5.8
NT	2004	1414.8	3586.8	969.2	4325.7	5140.4	28621.3	67085.3	5596.3	4803.3	2981.4
	% Δ 04/07	-8.5	-7.2	16.7	-11.2	-12.7	-11	-11.5	-22.7	-2.3	-5.2
ON	2004	87.1	112.8	40.8	70.2	119.1	226.2	436	190.5	86.2	75.3
	% Δ 04/07	-2.7	-9.2	26.1	-10.8	-8.5	-4.8	-10.4	-34.3	-4.9	1.3
PE	2004	2039.5	4063.6	1153.5	4231.6	4450.6	15990.8	40101.7	6774.4	5426.1	3739.7
	% Δ 04/07	-6.2	-10.2	23.3	-10	-7.2	-4.4	-9.5	-25.2	-2.7	3.1
QC	2004	150.2	208.4	71.8	157.5	247.1	567.7	1016	359.8	159.5	144.7
	% Δ 04/07	-4	-7	23.3	-10	-7.4	-3.8	-7	-30.9	-4.1	1.8
ROW	2004	1.2	2	1.5	2.8	1.3	1.2	1.2	1.2	1.2	1.3
	% Δ 04/07	-2.2	-8	-15	-6.7	-9	-1.8	-2.1	6.6	-2	-2.2
SK	2004	433.5	1078.7	297.3	902.4	1412.9	3268.2	6657.8	1600.1	977	609.8
	% Δ 04/07	-6.2	-7.9	13.6	-15.4	-15.9	4	-11.9	-31.4	-13.4	-2.4
USA	2004	5.2	2	2.9	1.6	4.1	5.8	5.6	5.4	5.7	2.5
	% Δ 04/07	13	9.8	50.5	4.7	3.6	11.1	11.4	-20.5	12.5	7
YT	2004	3774.3	6345.2	2753	10921.8	13836.8	89625.5	163852	13333.6	12479.3	8897.1
	% Δ 04/07	-9.7	-9.4	17.7	-12.3	-11.6	-6.6	-13.9	-23.9	-7	-3.9
All	2004	1.4	2.1	1.8	1.9	1.6	1.4	1.4	1.4	1.5	1.6
	% Δ 04/07	-3.4	-3	-17.3	3.3	-1	-2.8	-3.2	9.6	-3.1	-2
CAN	2004	129.4	167.7	60.2	107.7	177	366.9	732.4	293.6	134	161.8
	% Δ 04/07	-3.8	-8.6	26.3	-10.4	-8	-5.3	-10.1	-33.3	-4.8	-7.2

Notes: This table reports Constructed Home Bias (CHB) indexes by region and service sector in 2004. It also lists the CHB percentage changes over the period 2004-2007. See text for description of the CHB index and discussion of results. An extended table, including standard errors for each of the CB indexes reported here, is available by request.

Table 3: Constructed Foreign Bias (CFB) Indexes and Their Evolution Over Time

RGN	Year	(1) TRNSP	(2) CMNCN	(3) WHLSL	(4) FNCE	(5) BUSNS	(6) EDCTN	(7) HELTH	(8) ACMDN	(9) OTHER	(10) ALL
AB	2004	.083	.05	.007	.034	.104	.07	.003	.222	.081	.041
	% Δ 04/07	-15.2	-6.2	-3	-6	-13.6	-7.8	-3.9	-28.7	-27.7	-5.1
BC	2004	.095	.049	.007	.033	.124	.068	.002	.21	.072	.041
	% Δ 04/07	-16.6	-13.3	1.8	-10.2	-2.2	-6.3	22.7	-18.3	-22.9	-4.1
MB	2004	.129	.087	.011	.065	.179	.107	.003	.276	.106	.065
	% Δ 04/07	-18.5	-5.1	7.1	-9.1	-4.6	-7.5	1.6	-19.9	-24	-1.5
NB	2004	.158	.114	.013	.102	.259	.164	.004	.385	.162	.091
	% Δ 04/07	-16.1	-6.3	9.4	-8	-1	6.9	30.1	-18.1	-23.4	4.3
NL	2004	.12	.092	.012	.08	.173	.174	.002	.369	.11	.069
	% Δ 04/07	-9.9	-3.7	19.1	-3.9	8	-7.1	27.8	-17.2	-20.7	7.8
NS	2004	.103	.072	.011	.064	.158	.106	.002	.313	.09	.058
	% Δ 04/07	-12.7	-4.8	17.8	3	4.8	4.3	33.1	-18.7	-24.3	7.9
NT	2004	.163	.127	.017	.149	.301	.407	.005	.583	.175	.123
	% Δ 04/07	-11.2	-7.7	14.2	-3	-3.8	-8.1	27.8	-14.1	-15.9	1.7
ON	2004	.075	.043	.007	.04	.13	.053	.003	.137	.077	.041
	% Δ 04/07	-20	-10	8.1	4.2	1.9	25.7	14	-32.4	-23.5	4.8
PE	2004	.128	.118	.014	.093	.179	.182	.002	.369	.156	.082
	% Δ 04/07	-13.1	-5.8	16	3	1.4	5	28.6	-16.6	-24.3	7.5
QC	2004	.081	.048	.006	.034	.122	.055	.001	.141	.07	.038
	% Δ 04/07	-19.3	-5.7	9	-6.5	-2	15.7	22.1	-21.3	-23.3	-5
ROW	2004	.111	.008	.127	.047	.024	.025	.007	.038	.01	.049
	% Δ 04/07	-5.4	0	-4.7	-6.4	0	12	0	-26.3	10	8.9
SK	2004	.135	.094	.012	.076	.2	.153	.004	.358	.127	.069
	% Δ 04/07	-14.2	-8.3	2.7	-11.2	-9.1	-11.4	1.9	-19.2	-27.2	-3.7
USA	2004	.087	.01	.145	.067	.046	.093	.002	.045	.048	.057
	% Δ 04/07	16.1	10	31	6	4.3	-4.3	0	33.3	6.3	8.2
YT	2004	.26	.194	.025	.203	.374	.404	.003	.586	.309	.164
	% Δ 04/07	-14.5	-7.7	8.4	-6.2	-4.4	-9.1	5	-12.3	-18.8	3.8
All	2004	.107	.009	.13	.062	.028	.031	.005	.04	.013	.052
	% Δ 04/07	-2.4	.3	-7	.8	-5	6.8	-1	-15.4	8	7.4
CAN	2004	.084	.048	.007	.039	.127	.06	.002	.161	.077	.042
	% Δ 04/07	-17.9	-8.8	6.7	-1.8	-1.4	13.9	16.3	-27.1	-23.9	1.3

Notes: This table reports Constructed Foreign Bias (CFB) indexes by region and service sector in 2004. It also lists the CFB percentage changes over the period 2004-2007. See text for description of the CFB index and discussion of results. An extended table, including standard errors for each of the CFB indexes reported here, is available by request.

Table 4: Constructed Domestic Bias (CDB) Indexes and Their Evolution Over Time

RGN	Year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AB	2004	9.456	10.413	5.985	3.467	9.575	3.955	2.186	10.353	4.569	5.743
	% Δ 04/07	-3.4	-5.8	12.7	-10.2	-18.7	-10.3	-24.2	-38.3	-10.2	-4.3
BC	2004	9.37	9.369	4.862	3.029	9.763	3.526	.992	7.66	3.126	4.752
	% Δ 04/07	-5.8	-15.6	22	-15.5	-3	-7.4	5.7	-25.3	-3	-5.4
MB	2004	14.564	18.469	8.901	6.941	16.78	6.545	1.806	12.706	5.422	9.604
	% Δ 04/07	-8.3	-6.2	23.9	-14.5	-8.2	-11	-17.9	-28.4	-5.8	-1.2
NB	2004	20.553	25.619	12.797	12.326	31.323	15.846	7.317	26.709	10.678	15.542
	% Δ 04/07	-5	-8.5	21.6	-8.8	-11.9	-4.5	-4.8	-28.9	-6.2	.6
NL	2004	18.555	26.058	11.027	10.095	20.159	9.55	2.5	19.043	7.248	13.232
	% Δ 04/07	-3.6	-9	22	-15.3	-2.6	-16.2	-12.6	-30.6	-3.6	-1.8
NS	2004	18.518	20.545	10.356	10.118	25.224	8.533	5.847	22.614	7.479	12.288
	% Δ 04/07	-6.4	-9.6	22.1	-11.4	-6.2	-7.2	-8.9	-32.1	-8.2	-.4
NT	2004	25.872	39.273	17.261	17.288	30.849	16.207	3.868	26.245	11.519	21.158
	% Δ 04/07	-5.9	-12.4	21.1	-13.1	-10.6	-13.1	-5.6	-27.6	3.1	-3.9
ON	2004	8.017	11.142	6.241	4.966	12.068	4.275	2.164	6.939	4.435	6.383
	% Δ 04/07	-10.5	-12.8	22.5	-1.5	-7	17.4	-14.3	-43	-7.6	-.4
PE	2004	28.607	36.534	16.065	20.01	45.798	28.239	10.429	36.664	17.532	21.52
	% Δ 04/07	-6.7	-10.7	21.1	-11.4	-10.9	-4.9	-12.7	-30	-7.9	-.4
QC	2004	10.638	11.457	6.485	3.69	12.721	4.866	1.3	9.959	4.537	6.163
	% Δ 04/07	-8.2	-7.5	23.7	-15.1	-10.1	1.4	-7.6	-27.5	-6.8	-3.9
SK	2004	16.353	20.651	10.467	8.727	21.434	10.239	3.089	17.939	7.104	11.476
	% Δ 04/07	-3.5	-10.4	21	-16.9	-12.8	-14.5	-16.2	-27.8	-10	-2.6
YT	2004	24.947	39.113	17.088	18.549	30.445	15.564	1.981	19.174	13.291	20.513
	% Δ 04/07	-5.7	-9.5	20.9	-12.8	-8.1	-10.7	-19.4	-24.5	-8	-.2
CAN	2004	9.59	11.5	6.394	4.464	12.076	4.546	1.894	8.529	4.465	6.362
	% Δ 04/07	-7.6	-11.2	21.3	-8.1	-9.5	6.1	-11.6	-36.6	-7.5	-2.6

Notes: This table reports Constructed Domestic Bias (CDB) indexes by region and service sector in 2004. It also lists the CDB percentage changes over the period 2004-2007. See text for description of the CDB index and discussion of results. An extended table, including standard errors for each of the CB indexes reported here, is available by request.

Table 5: CBs, Accommodation-Ontario

Index	Year	CB	Expenditures
CDB	2004	6.939	28096.36
	2007	3.957	34429.68
CFB	2004	.137	4447077
	2007	.092	3401265
CHB	2004	190.488	19383.64
	2007	125.121	24053.15

Appendix 3.A Service Sectors Description

Transportation and Storage Services: Air, water and rail passenger and freight transportation; Bus (including school), ambulance and truck transportation; Urban transit and taxi transportation; Pipeline transportation of natural gas and oil; Grain and other storage; Warehousing. *Communication Services:* Radio, television broadcasting; Cable programming; Telephone and telecommunication; Postal and courier. *Finance, insurance and real estate services:* Paid charges to financial institutions; commissions and investment banking; Mutual funds, Other securities and royalties; Real-estate commissions; Life and non-life insurance; Pension funds; Paid residential and non-residential rent and lodging. *Professional Services:* Architect, engineering, scientific, accounting, legal, advertising and other professional services; software, computer lease, data processing and other information services; Investigation and security services; Other administrative and personal services. *Education Services:* Elementary, Secondary, College and University fees and tuition. Other education fees. *Health care and Social assistance Services:* Private hospital, private residential care and other health and social services; Child care outside the home; Laboratory, physician and dental services; Other health practitioner services. *Accommodation Services and Meals:* Hotel, motel and other accommodation; Meals outside the home; Board paid. *Wholesale Services:* Wholesale trade and wholesaling margins. *Miscellaneous Services:* Beauty and other personal care services; Funeral services; Child care in the home; Private household services; Photographic, laundry and dry cleaning, services to building and dwellings; Automotive and other repair and maintenance; Rental of office, machinery, equipment, automobile and truck; Trade union and other membership organization dues and political parties contribution; Motion picture production, exhibition and distribution; Lottery, gambling and other recreation services.

Appendix 3.B Constructed Foreign Bias Goods

The data used to construct the goods CFB numbers from Tables 6 and 7 are from Anderson and Yotov (2010a). Their study covers the period 1992-2003 for 19 commodities.⁶⁵ The trading partners in their sample include all Canadian provinces and territories, the fifty U.S. states and the District of Columbia, and the rest of the world (ROW). See Appendix A from Anderson and Yotov (2010a) for a detailed description of the data, the data sources, and the data procedures.

⁶⁵ Commodity selection is based on (but is not completely identical to) the S-level of aggregation as classified in the Statistics Canada's Hierarchical Structure of the I-O Commodity Classification (Revised: January 3, 2007). The 19 commodity categories include: Agriculture (crop and animal production); Mineral Fuels (coal, natural gas, oil); Food; Leather, Rubber and Plastic Products; Textile Products; Hosiery, Clothing and Accessories; Lumber and Wood Products; Furniture, Mattresses and Lamps; Wood Pulp, Paper and Paper Products; Printing and Publishing; Primary Metal Products; Fabricated Metal Products; Machinery; Motor Vehicles, Transportation Equipment and Parts; Electrical, Electronic, and Communications Products; Non-metallic Mineral Products; Petroleum and Coal Products; Chemicals, Pharmaceutical, and Chemical Products; Miscellaneous Manufactured Products. The few commodities missing from the complete S-level I-O Commodity Classification spectrum are Forestry Products, Fish, Metal Ores, and Tobacco and Beverages. Reliable bilateral trade data were not available for those products.

Table 6: Constructed Foreign Bias (CFB) Indexes and Their Evolution Over Time

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AB	1996	.311	.805	.259	.071	.049	.025	.566	.104	.456
	% Δ 92/03	-57.7	187.7	-11.4	50.1	86.8	402.5	-26.6	-40.5	32.4
BC	1996	.306	.861	.318	.267	.108	.16	.706	.241	.737
	% Δ 92/03	7.2	716.7	38.3	146.3	153.4	697.8	-22.5	51.4	53.4
MB	1996	.411	.76	.31	.2	.067	.102	.562	.272	.495
	% Δ 92/03	-5.3	240.5	-6.4	117.8	88.4	756.4	-23.5	8.1	42.7
NB	1996	.35	.47	.386	.24	.114	.111	.582	.27	.607
	% Δ 92/03	-7.4	191.1	-16.8	143.6	64.5	649.5	-39.6	-45.3	34.3
NL	1996	.619	.337	.478	.213	.099	.043	.692	.294	.671
	% Δ 92/03	1	126.6	-14.2	99.2	60.3	338.4	-26.6	-52	48.6
NS	1996	.352	.388	.365	.144	.063	.036	.563	.18	.52
	% Δ 92/03	-14.5	173.2	-23.3	87.4	52.8	269.4	-25.1	-37.3	28.8
NT	1996	.879	.682	.575	.285	.128	.049	.805	.499	.795
	% Δ 92/03	3.2	178.2	.3	140.5	63.3	513.3	-23	-65.1	58.9
ON	1996	.116	.553	.218	.198	.071	.101	.413	.312	.452
	% Δ 92/03	7.5	400.4	-2.3	184.6	123.1	735.2	-9.5	-1	29.5
PE	1996	.405	.057	.427	.127	.057	.041	.576	.195	.435
	% Δ 92/03	-21.3	77.4	-32	62.3	24.4	176.9	-26.1	-47.2	9.4
QC	1996	.109	.562	.213	.158	.067	.155	.437	.261	.495
	% Δ 92/03	-6.6	324.4	-1	133.6	124.9	581.2	-24.4	-32.4	24
ROW	1996	.057	.348	.296	.331	.426	.738	.187	.194	.089
	% Δ 92/03	30.9	115.6	-6.8	245.4	103.1	1229	92.5	75.4	58
SK	1996	.505	.711	.349	.125	.067	.078	.618	.137	.529
	% Δ 92/03	-25.3	166.9	-10.6	89.3	54.4	741.7	-28.5	-10.9	45.1
USA	1996	.278	.022	.387	.224	.471	.619	.277	.091	.249
	% Δ 92/03	-9.2	2.8	-34.7	6	55.1	74.4	-52.5	-82	47.8
YT	1996	.817	.76	.623	.387	.153	.123	.799	.356	.74
	% Δ 92/03	1.6	176.6	2.5	179.2	78.9	831.2	-51.3	-76.8	44.6
All	1996	.091	.03	.31	.299	.423	.701	.227	.137	.165
	% Δ 92/03	29.9	43.5	-11.5	78	89.4	500.4	-10.6	-58.4	91.1
CAN	1996	.195	.792	.241	.186	.069	.131	.577	.28	.527
	% Δ 92/03	-15.3	259.2	-7	161.2	124.7	648	-27.9	-6.5	29.7

Notes: This table reports Constructed Foreign Bias (CFB) indexes by region and commodity in 1996. It also lists the CFB percentage changes over the period 1992-2003. See text for description of the CFB index and discussion of results.

Table 7: Constructed Foreign Bias (CFB) Indexes and Their Evolution Over Time

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
AB	.178	.036	.047	.072	.231	.094	.4	.23	.012	.295
% Δ 92/03	-12.6	-1.4	86.6	-12.9	-49.3	-51.1	-53.8	-52.7	69.6	9.6
BC	.364	.154	.146	.307	.471	.456	.792	.348	.03	.58
% Δ 92/03	32.5	67.7	276.8	90.6	-15.3	46.8	14.8	-34.1	251.1	34.4
MB	.368	.118	.17	.312	.419	.258	.436	.255	.028	.32
% Δ 92/03	28.6	19.1	105.5	29.5	-37.7	-34.2	-20.4	-36.7	76	10.2
NB	.505	.196	.148	.301	.422	.317	.54	.261	.054	.493
% Δ 92/03	38.7	29.1	61.8	-13.7	-28.2	20.4	21.3	-51.4	71.5	8.4
NL	.618	.178	.228	.319	.503	.362	.293	.428	.063	.481
% Δ 92/03	74.2	-23.1	-22.1	-51	-58.5	-46.7	-27.4	-65.2	4.9	-39
NS	.518	.11	.096	.171	.363	.198	.153	.215	.039	.34
% Δ 92/03	46.3	-10.9	29	-40	-44.6	-32.2	-23.6	-64.1	9	2.4
NT	.564	.294	.354	.383	.597	.54	.652	.612	.115	.537
% Δ 92/03	84.6	-33.4	-37.7	-49.2	-58.5	-23.9	-42.6	-49.5	-16.8	41.1
ON	.325	.133	.091	.299	.317	.257	.325	.19	.018	.244
% Δ 92/03	18.9	39.9	255.2	10.7	-4.9	18.8	-33.3	-54.2	290	10.8
PE	.584	.122	.152	.191	.4	.128	.107	.173	.054	.403
% Δ 92/03	33.6	-21.5	-28.2	-45.3	-59.5	-25.8	-8.2	-61.2	-32.7	-26.5
QC	.337	.14	.067	.266	.409	.238	.449	.167	.027	.278
% Δ 92/03	25.7	34.1	251.1	6	17	19.5	20.3	-58.2	207.1	27.8
ROW	.252	.127	.197	.196	.403	.16	.069	.089	.221	.253
% Δ 92/03	158.2	18.1	95.8	69.6	-9.2	112.9	-77.9	5.4	319.7	42.8
SK	.269	.08	.101	.197	.361	.169	.502	.266	.027	.415
% Δ 92/03	13.2	14.6	118.9	25.2	-50.7	-40.1	-10	-45.2	53.8	.4
USA	.171	.166	.148	.112	.319	.094	.376	.235	.066	.262
% Δ 92/03	26.9	-54.9	-78.3	-43.8	-43.6	-47.4	-31.2	-59.5	-60.6	-23.5
YT	.622	.245	.334	.432	.565	.535	.757	.624	.109	.548
% Δ 92/03	53.6	-16	-55.2	-28.3	-69.4	67	30.4	6.3	5.8	-9.2
All	.232	.145	.171	.163	.377	.132	.146	.14	.089	.257
% Δ 92/03	114.2	-28.7	-27.1	.1	-32.8	-14.4	-5.7	-22.1	-27.9	3.1
CAN	.326	.126	.088	.293	.354	.266	.419	.194	.021	.31
% Δ 92/03	20.5	39.7	237.1	12.5	1.4	15.5	-13.3	-54.6	250.4	16.7

Notes: This table reports Constructed Foreign Bias (CFB) indexes by region and commodity in 1996. It also lists the CFB percentage changes over the period 1992-2003. See text for description of the CFB index and discussion of results.

Table 8: Constructed Foreign Bias (CFB) against ROW

RGN	Year	TRNSP	CMNCN	WHLSL	FNCE	BUSNS	EDCTN	HELTH	ACMDN	OTHER
AB	2004	.043	.038	.005	.055	.066	.074	.001	.15	.049
	% Δ 04/07	-9.2	-4.9	4.5	-8	-12.8	-9.7	7.8	-18.9	-28.3
BC	2004	.046	.036	.004	.051	.071	.071	.001	.13	.041
	% Δ 04/07	-10.3	-11.8	11	-11.8	-1.2	-8.2	39	-6.5	-23.4
MB	2004	.063	.064	.007	.1	.104	.111	.001	.172	.06
	% Δ 04/07	-12.4	-3.5	16.8	-10.7	-3.6	-9.4	15.1	-8.2	-24.6
NB	2004	.081	.086	.009	.161	.158	.174	.001	.252	.096
	% Δ 04/07	-10	-4.9	18.4	-2.8	-1	4.7	46.5	-6.6	-24
NL	2004	.11	.106	.011	.194	.181	.2	.001	.357	.11
	% Δ 04/07	-8.7	-5.5	17.8	-9.6	7.7	-8.8	34.4	-9.5	-22.1
NS	2004	.091	.081	.009	.151	.159	.121	.001	.289	.088
	% Δ 04/07	-11.1	-6.3	18.2	-5.4	4.6	2.3	42.2	-10.6	-25.6
NT	2004	.152	.148	.016	.363	.32	.47	.003	.572	.177
	% Δ 04/07	-10.2	-9.4	12.4	-8.8	-4.1	-9.8	33.8	-6.3	-17.5
ON	2004	.031	.029	.004	.053	.059	.052	0	.069	.037
	% Δ 04/07	-13	-8.1	21.3	3.3	3.3	22.9	31.5	-21.3	-23.9
PE	2004	.111	.13	.012	.217	.175	.206	.001	.331	.15
	% Δ 04/07	-11.3	-7.1	17.3	-5.2	1.3	3	38.5	-7.9	-25.5
QC	2004	.036	.034	.004	.048	.062	.056	0	.078	.036
	% Δ 04/07	-12.7	-3.9	20.8	-7.6	1	13.2	39.9	-9	-23.8
SK	2004	.069	.071	.008	.12	.122	.162	.001	.234	.075
	% Δ 04/07	-8	-6.9	11.1	-13	-8.3	-13.3	14.7	-7.8	-27.8
YT	2004	.162	.163	.019	.375	.297	.45	.002	.477	.223
	% Δ 04/07	-9.8	-7	12.5	-9.2	-4	-10.9	13.9	-2.1	-19.7

Notes: This table reports provincial Constructed Foreign Bias (CFB) indexes, and the corresponding percentage changes 2004-2007, against the rest of the world.

Table 9: Constructed Foreign Bias (CFB) against US

RGN	Year	TRNSP	CMNCN	WHLSL	FNCE	BUSNS	EDCTN	HELTH	ACMDN	OTHER
AB	2004	.257	.061	.012	.022	.225	.046	.01	.556	.233
	% Δ 04/07	-10.3	-3.8	22.1	-9.4	-12.1	4.3	1	-48.3	-19.8
BC	2004	.308	.062	.012	.023	.291	.053	.008	.574	.221
	% Δ 04/07	-11.3	-10.8	29.7	-13.1	-.4	6	30.2	-40.4	-14.4
MB	2004	.421	.109	.019	.046	.421	.084	.011	.756	.326
	% Δ 04/07	-13.4	-2.3	36.5	-12.1	-2.8	4.6	7.8	-41.5	-15.7
NB	2004	.501	.142	.023	.068	.581	.117	.016	1	.479
	% Δ 04/07	-11.1	-3.8	38.4	-4.3	.7	20.9	37.2	-40.5	-15
NL	2004	.164	.078	.014	.015	.145	.036	.004	.422	.107
	% Δ 04/07	-9.8	-4.3	37.7	-10.9	8.6	5.3	25.9	-42.4	-12.9
NS	2004	.155	.064	.013	.014	.157	.027	.005	.423	.101
	% Δ 04/07	-12.2	-5.1	38.2	-6.8	5.5	18.1	33.2	-43.1	-16.8
NT	2004	.216	.106	.019	.027	.239	.078	.009	.634	.163
	% Δ 04/07	-11.2	-8.3	31.4	-10.1	-3.3	4.1	25.3	-40.3	-7.7
ON	2004	.269	.056	.013	.032	.356	.059	.013	.447	.269
	% Δ 04/07	-14.1	-7	41.7	1.8	4.1	41.9	23.3	-49.9	-14.9
PE	2004	.206	.106	.018	.022	.195	.053	.005	.546	.188
	% Δ 04/07	-12.3	-6	37.1	-6.6	2.1	19	29.8	-41.3	-16.8
QC	2004	.279	.062	.012	.025	.314	.053	.006	.427	.234
	% Δ 04/07	-13.7	-2.8	41.2	-9	1.9	30.7	31	-42.1	-14.8
SK	2004	.427	.117	.02	.051	.448	.108	.016	.927	.375
	% Δ 04/07	-9.1	-5.8	29.9	-14.3	-7.5	.2	7.5	-41.3	-19.3
YT	2004	.693	.225	.036	.105	.622	.164	.01	1.084	.722
	% Δ 04/07	-10.8	-5.8	31.5	-10.6	-3.2	2.9	6.7	-37.7	-10.2

Notes: This table reports provincial Constructed Foreign Bias (CFB) indexes, and the corresponding percentage changes 2004-2007, against US.

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