SAVING HOUSEHOLD PRODUCTION-CUM-CONSUMPTION TIME: IMPLICATIONS FOR INTERNATIONAL TRADE IN TRASH

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Saving household production-cum-consumption time: implications for international trade in trash

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Abstract/Résumé

This paper revisits trade theory under the Gossenian theme that consumption takes time. We show how the substitutability between time-intensive household-produced consumption goods and time-saving commercially produced consumption goods (which save households' consumption and production time) together with capital accumulation can lead to an increase in trash and in international trade in trash. The applicability of the standard gains from trade theorems is shown to be compromised by the externalities associated with international trade in trash between North and South. Under some parameter values, South is better off under autarky than under free trade in trash and the gains from trade by North is not sufficient to compensate South's loss from trade.

Cet article étudie le commerce international des déchets, en tenant compte du thème gossenien selon lequel la consommation prend du temps. Nous montrons comment la substituabilité entre les biens de consommation produits par les ménages à forte intensité de temps et les biens de consommation produits commercialement qui font gagner du temps ainsi que l'accumulation de capital peuvent conduire à une augmentation des déchets et du commerce international des déchets. L'applicabilité des théorèmes de gains du commerce international est compromise par les externalités associées au commerce des déchets entre le Nord et le Sud. Sous certaines valeurs de paramètres, le bien-être du Sud en autarcie est supérieur à celui en libre-échange et les gains du Nord ne sont pas suffisants pour compenser la perte du Sud.

Keywords/Mots-clés: Trade in trash; gains from trade; household production; North South trade; the economics of time management. / Commerce des déchets; gains d'échange; production domestique; Commerce Nord Sud ; l'économie de la gestion du temps.

JEL Codes/Codes JEL: F18, F13, D1

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Abstract

This paper revisits trade theory under the Gossenian theme that consumption takes time. We show how the substitutability between time-intensive household-produced consumption goods and time-saving commercially produced consumption goods (which save households' consumption and production time) together with capital accumulation can lead to an increase in trash and in international trade in trash. The applicability of the standard gains from trade theorems is shown to be compromised by the externalities associated with international trade in trash between North and South. Under some parameter values, South is better off under autarky than under free trade in trash and the gains from trade by North is not sufficient to compensate South's loss from trade.

Keywords: Trade in trash; gains from trade; household production; externalities; North South trade; the economics of time management.

JEL codes: F18, F13, D13

1. Introduction

Everyone knows that consumption takes time and that different consumption goods take different amounts of time to consume. However, standard microeconomic analysis of households' demand typically ignores the fact that consumption is time-consuming. A major exception was the paper by Becker (1965), in which he argued that "the allocation and efficiency of non-working time may now be more important to economic welfare than that of working time." While Becker cited the earlier work of Mincer (1962, 1963) on this subject, he did not mention of the pioneering work of Gossen (1854, 1983) who not only pointed out that consumption takes time but also emphasized the importance of consumption time allocation across goods by individual consumers. Recently, in an interesting article published in the Economics Letters, Kemp (2008) argued that, even in models with just two consumption goods, if one takes account of the Gossenian time constraint in addition to the usual budget constraint, then propositions using the Lerner-Samuelson model of international trade (which assumes that neither good is inferior) must be treated with reserve. Specifically, Kemp (2008) showed that if both the financial budget constraint and the time budget constraint are binding, then local inferiority must be accommodated even when household preferences are homothetic. Kemp's idea was further elaborated in Kemp (2009, 2018) where the normative trade theory was re-examined under the Gossenian assumptions. These recent papers by Kemp have inspired some authors to further explore the implications of the time budget constraint for trade theory, see Tran-nam (2012, 2017), and for general equilibrium theory (Le-Van et al., 2018).

In this paper, combining the idea that consumption takes time with Becker's idea that household production takes time, I explore some implications of consumers' desire to save household's production-cum-consumption time on the generation of trash and on the exportation of trash from Northern economies to Southern economies, and pointing out that free trade in trash involves externalities, I cast doubt on the applicability of the standard proposition that free trade is mutually gainful. Using a simple model of North-South trade in trash, I show that there exist parameter values such that South's welfare under autarky is greater than under free trade in trash, and North's gains from trade in trash is insufficient to compensate for South's losses.

2. Some empirical motivation

For many goods, the act of consumption involves both preparation time and consumption time. To enjoy a freshly made cup of coffee at home, a consumer must carefully grind the coffee beans (purchased from a store), making sure that the desired level of coarseness is attained, brew the coffee at the right water temperature (not at 100 degrees Celcius), and finally savors it slowly. Similarly, to eat fish, a traditional household in Asia would buy from the market a fish that is still alive, take it home, get rid of its scales and internal organs, slowly fry it, adding condiments and spices in a systematic order, and finally consume it leisurely with family members. To consume a pineapple, the traditional consumer must carefully choose a good pineapple from the seller's basket, take it home to peel the skin and remove the pineapple eyes, and so on. A similar time-consuming process applies when the traditional consumers want to consume the fresh coconut juice from a freshly harvested coconut. The time involved in the household's joint act of food preparation and consumption may be called household production-cum-consumption time. It involves hard work, but also provides a sort of Epicurian and possibly artistic pleasure.

In modern societies, increasingly many households decide to forego this sort of Epicurian pleasure, because the opportunity cost of time is becoming too high. To save time, many modern consumers would now choose to buy a cup of coffee from a coffee shop, usually in a foam or disposable plastic container. Supermarkets offer frozen battered fish filets wrapped in plastic and inserted in disposable paper boxes. Ready-to-eat pieces of pineapple come in plastic containers. Similarly, other time-saving products such as disposable razors and baby diapers were invented to save household time. The modern consumers save time by switching from household-produced goods to commercially produced goods and sell the saved time in the labor market to generate additional income.

Unfortunately, this consumption switching leads to an increase in trash, and the disposable foam, plastic, paper, disposable razors are typically disposed of in an environmentally unfriendly way. A large quantity of this trash is destined to domestic recycling firms that outsource the so-called recycling activities to firms located in poorer countries, which I call Southern economies for short. The Southern trash-importing firms do not recycle the trash but dispose of them in irresponsible ways. Consequently, mountains of imported trash can be observed in these Southern economies, creating health hazards to residents as well as marine species. Today, there are shocking scenes of imported plastic refuse piled high in poor neighborhoods of South and Southeast Asia, especially in India, the Philippines, Malaysia, and Indonesia. Eastern European countries also suffer from the growing problem of illegal waste exported from Western European economies. There is also extensive documentation of large quantities of waste being exported or simply dumped into the ocean (Cassing and Kuhn, 2003a, b, c).

Recently, some governments of trash-importing Southern economies came under pressure from organizations such as Green Peace to send back shiploads of trash to Northern trash exporting economies.

Despite the adverse press coverage of the harmful effects of trade in trash on the residents of poor neighborhoods on trash-importing economies, some economists have argued that trade in trash is beneficial to both trash importing and trash exporting nations. For example, Larry Summer, when he was chief economist at the World Bank, issued a memorandum to his staff to praise the gains from trade in trash. As reported in the magazine The Economist (1992), Summer stated that '*I think the economic logic behind dumping a load of toxic waste in the lowest wage country is impeccable and we should face up to that (…). I've always thought that the under-polluted countries in Africa are vastly under-polluted.*' These economists base their conclusion on the theory of voluntary exchange. If two parties enter into a voluntary agreement to exchange, by definition, they gain from such trade. This theory, however, assumes that there is no third party that is affected by the externalities generated by such exchange. In practice, in the case of international trade in trash, hundreds of thousands of metric tons of imported plastic waste are regularly burned by illegal operators, releasing toxic fumes around poor villages in trash importing countries such as Malaysia, Vietnam, Thailand, Indonesia and India that have stepped in to replace China after Beijing announced in July 2017 that it would reduce its imports of global plastic and paper waste.

3. A simple model of waste generation in a closed economy

Consider a Northern economy in which consumers consider as imperfect substitutes a household-produced consumption good (which involves a lot of production-cum-consumption time) and a commercially produced consumption good (which involves less consumption time). These are denoted by good 1 and good 2 respectively. To consume one unit of good 1 (e.g., a household-produced cup of coffee), the consumer needs to buy one unit of intermediate input (e.g., coffee beans) from the market and to spend τ units of her own time for the associated production-cum-consumption activity. In contrast, if she buys a unit of the ready-to-consume good 2, it takes her only δ units of time to consume it, where $\delta \leq \tau$. Each unit of good 2, however, is accompanied by one unit of an environmentally unfriendly by-product (e.g., plastic waste). The consumer must discard this waste after consuming good 2.

Borrowing from the recent literature on trade policies (Grossman and Helpman, 1994; Melitz and Ottaviano, 2008), we assume the existence of a numeraire good, good 0, which is produced under constant returns to scale, using labor alone. One unit of labor time produces w units of good 0. We call w the wage rate. For simplicity, we assume that the consumption of good 0 involves only a negligible amount of time.

3.1 Technology, unit costs, and prices in the closed economy

The intermediate input that must be purchased by the consumer for the household production of the final good 1 is produced by perfectly competitive firms employing labor: one unit of labor time produces one unit of the intermediate input. Thus, to a consumer, the effective per unit cost of the final good 1 is $(1 + \tau)w$.

Good 2 is produced by the commercial sector using capital and labor. Let Y denote the output of good 2. The production function of this good is given by

$$Y = B(KL_2)^{1/2}$$

where L_2 is the employment level in sector 2 (measured in units of labor hours) and K is the stock of capital. The parameter $B > 0$ represents the index of the level of technical efficiency in the production of good 2.

Under perfect competition, sector 2 firms take as given the wage rate w and the rental rate r, and choose the level of capital and labor input to minimize the cost of producing a unit of good 2. As is well known, the unit cost corresponding to the above Cobb-Douglas production function is

$$C(w, r) = \frac{2}{B}(wr)^{1/2}$$

Since the production of good 2 involves a joint product (trash) that gives rise to a harmful externality, the government may impose a per unit production tax t.

It follows from our assumptions that under perfect competition, the price of a unit of the intermediate input that households buy to produce the final consumption good 1 is $p_1 = w$ and the price of a unit of good 2 is $p_2 = t + C(w, r)$.

3.2 Consumers

We assume that in this closed economy there are n identical consumers. Each consumer owns k units of capital and is endowed with T units of time. Each derives utility from consumption:

$$U(c_0, x, y) = c_0 + Ax + Ay - \frac{(1-\mu)(x^2 + y^2)}{2} - \frac{\mu(x+y)^2}{2}$$

where c_0 is her consumption of the numeraire good, x is the quantity of household-produced final good 1 that she consumes, and y is her consumption of the commercially produced final good 2. The parameter μ indicates the extent to which goods 1 and 2 are considered as substitutable. If $\mu = 1$, the consumer considers the two goods as perfect substitutes. We assume that $0 \leq \mu < 1$. The parameter A is a positive constant.

Consumers do not like to see trash in their country. Let Z denote the amount of trash in the economy. Then $Z = ny$. This externality inflicts on each consumer a damage cost $D(Z)$. For tractability, we assume that $D(Z) = \frac{\beta Z^2}{2}$. Each consumer's welfare is

$$W \equiv U(c_0, x, y) - D(Z)$$

We assume that since the number of consumers is large, individuals do not take this externality into account in their consumption decision.

Each period, the consumer has a fixed endowment of Tunits of labor time. Let T_c denote the amount of time she reserves for her household production-cum-consumption activities. Then $T - T_c$ is the amount of her working time outside the household, for which she earns the total wage income $(T - T_c\ )w$.

Then her time budget constraint is

$$\tau x + \delta y = T_c$$

Note that in our model T_c is to be optimally chosen by the consumer. (This feature of our model is a significant departure from Kemp (2008) and Tran-nam (2012, 2017) where the amount of time available for consumption was assumed to be exogenously fixed).

Let M denote the consumer's income. Taking account of the fact that she must buy the raw material at the price p_1 per unit for her production of the final good 1, her financial budget constraint is

$$p_1\, x + p_2\, y + c_0 = M$$

Her income, M, is the sum of her total wage income and her rental income, plus a lump sum transfer, g, from the government sector, i.e., $M = (T - T_c\ )w + rk + g$.

The consumer's optimization problem consists of choosing the variables (c_0, x, y, T_c) to maximize utility subject to two budget constraints:

$$\tau x + \delta y = T_c$$

$$p_1\, x + p_2 y + c_0 = (T - T_c)w + rk + g$$

There is also an inequality constraint, $T - T_c \geq 0$, which means that the consumer's time for household production-cum-consumption activities cannot exceed her fixed total endowment of time.

Re-write the second equality constraint as follows

$$p_1\, x + p_2\, y + c_0 + wT_c = wT + rk$$

Substituting for T_c we end up with a *combined equality constraint*

$$p_1\, x + p_2\, y + c_0 + w(\tau x + \delta y) = wT + rk + g$$

and an inequality constraint,

$$T - (\tau x + \delta y) \geq 0$$

Let λ be the Lagrange multiplier associated with the combined equality constraint, and $\theta \geq 0$ be the Kuhn-Tucker multiplier associated with the inequality constraint. To solve the consumer's problem, we form the Lagrangian function

$$\mathcal{L} = U(c_0, x, y) + \lambda\{wT + rk + g - p_1\, x - p_2\, y - c_0 - w(\tau x + \delta y)\} + \theta[T - (\tau x + \delta y)]$$

The necessary conditions are

$$\partial\mathcal{L}/\partial c_0 = 1 - \lambda \leq 0, (= 0\ if\ c_0 > 0)$$

$$\partial\mathcal{L}/\partial x = A - x - \mu y - \lambda(p_1 + w\tau) - \theta\tau \leq 0, (= 0\ if\ x > 0)$$

$$\partial\mathcal{L}/\partial y = A - y - \mu x - \lambda(p_2 + w\delta) - \theta\delta \leq 0, (= 0\ if\ y > 0)$$

$$\partial\mathcal{L}/\partial\lambda = wT + rk + g - p_1 x - p_2\, y - c_0 - w(\tau x + \delta y) = 0$$

$$\partial\mathcal{L}/\partial\theta = T - (\tau x + \delta y) \geq 0, \theta \geq 0, \theta[T - (\tau x + \delta y)] = 0$$

Assuming that T is sufficiently large so that $\theta = 0$, we obtain the following proposition.

Proposition 1: If wT and A are sufficiently large, then all the three goods will be consumed in strictly positive quantities, and the Marshallian demand functions are

$$x^* = (A(1-\mu) - (p_1 + w\tau) + \mu(p_2 + w\delta))/(1 - \mu^2\ )$$

$$y^* = (A(1-\mu) - (p_2 + w\delta) + \mu(p_1 + w\tau))/(1-\mu^2)$$

$$c_0^* = w(T - T_c^*) + rk + g - p_1 x^* - p_2 y^*$$

(where $T_c^* = \tau x^* + \delta y^*$).

3.3 Competitive equilibrium under laisser-faire in the closed economy

Suppose the government adopts a laisser-faire regime, and set the pollution tax rate at zero, so that the consumers prices are equal to production costs, and there is no lump sum transfer. Our task is then to determine the equilibrium rental rate as a function of the parameters such as the capital stock per person, the productivity of labor in the numeraire good sector, and so on. Since the wage rate is the productivity parameter in the production of the numeraire good, once the rental rate is determined, the consumers price for good 2 is determined by the unit cost function, and the consumers price of good 1 is equal to the wage rate.

To determine the rental rate, we use the condition that the demand for the numeraire good per person (which depends partly on rental income) equals the supply of the numeraire good per person. Since the tax rate is zero and there is no lump sum transfer, the former is given by

$$c_0^* = w(T - T_c^*) + rk - p_1 x^* - \frac{2}{B}(wr)^{1/2} y^*$$

The supply of the numeraire good per person is equal to the product of the labor productivity parameter w and the excess of the maximum amount of available labor time per person, T, over her time used in the consumption and production of goods 1 and 2. Using duality theory, the amount of time used in the production of a unit of good 2 is

$$\partial C(w,r)/\partial w = \frac{1}{B}\left(\frac{r}{w}\right)^{1/2}$$

Thus, the supply of the numeraire good per person is

$$c_0^S = w\left[T - (1+\tau)\,x^* - \left(\frac{1}{B}\left(\frac{r}{w}\right)^{1/2} + \delta\right)\,y^*\right]$$

Then equilibrium in the numeraire good market gives us the equation

$$rk = \left(\frac{1}{B}(wr)^{1/2}\right)\,y^*$$

That is, $rk(1-\mu^2) = \left(\frac{1}{B}(wr)^{1/2}\right)\left[A(1-\mu) - \left(\frac{2}{B}(wr)^{1/2}\right) - w\delta + \mu(w + w\tau)\right]$.

Then

$$r\left[k(1-\ \mu^2) + \frac{w}{B^2}\right] = \frac{1}{B}(wr)^{1/2}\ [A(1-\mu) + w(\mu(1+\tau) - \delta)]$$

That is,

$$\sqrt{r} = \left[\frac{A(1-\mu) + w(\mu(1+\tau) - \delta)}{Bk(1-\ \mu^2) + wB^{-1}}\right]\sqrt{w}$$

Thus, we obtain the following Proposition:

Proposition 1: *Assume that* $A(1-\mu) + w(\mu(1+\tau) - \delta) > 0.$ *Then, in the absence of taxation, the equilibrium rental rate in a laisser-faire economy is given by*

$$r^* = w\left[\frac{A(1-\mu) + w(\mu(1+\tau) - \delta)}{Bk(1-\ \mu^2) + wB^{-1}}\right]^2$$

It follows that the equilibrium rental is a decreasing function of the capital stock and of the per unit consumption time of good 2; in contrast, it is an increasing function of the per unit consumption time of good 1.

Note that the output of good 2 is positive if B is sufficiently large, for

$$y^* = \frac{n}{(1-\mu^2)}\left[A(1-\mu) - 2(wr^*)^{1/2}/B\ + w(\mu(1+\tau) - \delta)\right]$$

Corollary 1: *In a laisser-faire economy without taxes, the amount of trash is given by*

$$Z = ny^* = \frac{n}{(1-\mu^2)}\left[A(1-\mu) - 2(wr^*)^{1/2}/B \; + w(\mu(1+\tau) - \delta)\right]$$

An increase in the capital stock will increase the quantity of trash in the economy, and this rate of response is higher, the smaller is δ.

Let us now turn to the case where the tax rate on good 2 is positive and the government distribute the tax revenue to consumers in a lump-sum fashion.

3.4 Competitive equilibrium in the closed economy under a regime of positive tax on good 2 with lump-sum redistribution of tax revenue.

When there is a tax rate $t > 0$ per unit of good 2, the consumers price of good 2 is equal to the unit production cost of that good plus the tax rate. The demand of the numeraire good per person is then

$$c_0^* = w(T - T_c^*) + rk + g - p_1 x^* - p_2 y^*$$

$$= wT + rk + g - w(\tau x^* + \delta y^*) - wx^* - y^*\left[t + \frac{2}{B}\right]\left(t + \frac{2}{B}(wr)^{1/2}\right)$$

The supply of the numeraire good per person is

$$c_0^s = w[T - (1+\tau)x^* - y^*\left[\delta + \frac{1}{B}\left(\frac{r}{w}\right)^{1/2}\right]$$

When the government's budget is balanced, i.e., $g = ty^*$, the equilibrium in the market for the numeraire good gives

$$rk = \left(\frac{1}{B}(wr)^{1/2}\right) y^*$$

Solving for r, we get

$$r^* = w\left[\frac{A(1-\mu) + w(\mu(1+\tau) - \delta) - t}{Bk(1-\ \mu^2) + wB^{-1}}\right]^2$$

Thus, the tax reduces the equilibrium rental rate, if the tax revenue is redistributed to all consumers in equal lump-sum amounts. The tax also impacts negatively on the quantity of good 2:

$$y^* = \frac{n}{(1-\mu^2)}\left[A(1-\mu) - t - 2(wr^*)^{1/2}/B \ + w(\mu(1+\tau) - \delta)\right]$$

Note that the consumers price of good 2 is

$$p_2 = t + C(w, r) = t + 2(wr^*)^{1/2}/B$$

As for good 1, the consumption per person is

$$x^* = (A(1-\mu) + w(\mu\delta - (1+\tau)) + \mu p_2)/(1-\mu^2\ )$$

Thus, the tax t will increase the consumption of good 1.

Proposition 2: *Assume that $A(1-\mu) + w(\mu(1+\tau) - \delta) - t > 0$. Then the equilibrium rental rate in a laisser-faire economy is given by*

$$r^* = w\left[\frac{A(1-\mu^2) + w(\mu(1+\tau) - \delta) - t}{Bk(1-\ \mu^2) + wB^{-1}}\right]^2$$

Thus, an increase in the tax rate on good 2 will reduce the rental rate, increase the consumption of good 1 and decrease the consumption of good 2.

Corollary 2: *In an economy with a positive per unit tax on good 2, the amount of trash is given by*

$$Z = ny^* = \frac{n}{(1-\mu^2)}\left[A(1-\mu) - t - 2(wr^*)^{1/2}/B \ + w(\mu(1+\tau) - \delta)\right]$$

Thus, an increase in the tax rate leads to a fall in the equilibrium quantity of trash:

$$dZ/dt = -n/(1-\mu^2\ )$$

The absolute value of the fall in trash is larger, the higher is the substitutability parameter μ.

Let us now turn to the case of a central planner with full power of control and command.

3. 5 The social planner's optimization problem for the closed economy

Let us now turn to the problem of social welfare maximization for the closed economy, assuming that recycling is not feasible. First, we show how a social planner that has full power of control and command would allocate resources in this economy. Next, we show how the social optimum can be achieved in a decentralized fashion, by setting a consumption tax t per unit of trash, with the total tax revenue being redistributed to all consumers equally, independent of their individual level of consumption of good 2.

The planner, taking the productivity parameters w, B and the capital stock person as given, maximizes the welfare of the representative individual, by choosing the consumption quantities x, y and c_0 and the labor allocation vector (ℓ_0, ℓ_1, ℓ_2) subject to the production constraints that

$$y = Bk^{1/2}\ell_2^{1/2}$$

$$x = \ell_1$$

$$c_0 = w\ell_0$$

and the resource constraint that each person's total labor used in production and consumption equals her time endowment T:

$$\ell_0 + (1+\tau)\ell_1 + \ell_2 + \delta\, Bk^{1/2}\ell_2^{1/2} = T$$

The welfare of the representative individual, net of her discomfort from seeing trash lying around her country, is

$$V = U - \frac{\beta}{2}Z^2 = w\ell_0 + A\left(\ell_1 + Bk^{\frac{1}{2}}\ell_2^{\frac{1}{2}}\right) - \frac{1-\mu}{2}(\ell_1^2 + B^2k\ell_2) - \frac{\mu}{2}\left(\ell_1 + Bk^{\frac{1}{2}}\ell_2^{\frac{1}{2}}\right)^2$$

$$-\frac{\beta}{2}n^2B^2k\ell_2$$

Form the Lagrangian function, where π is the Lagrange multiplier associated with the resource constraint:

$$\mathcal{L} = U - \frac{\beta}{2} n^2 B^2 k \ell_2 + \pi\left[T - \ell_0 + (1+\tau)\ell_1 + \ell_2 + \delta\, B k^{1/2} \ell_2^{1/2}\right]$$

The first order conditions are, assuming an interior maximum,

$$\frac{\partial \mathcal{L}}{\partial \ell_0} = w - \pi = 0$$

$$\frac{\partial \mathcal{L}}{\partial \ell_1} = A - \ell_1 - \mu B k^{\frac{1}{2}} \ell_2^{\frac{1}{2}} - \pi(1+\tau) = 0$$

$$\frac{\partial \mathcal{L}}{\partial \ell_2} = \left[\frac{B}{2}\left(\frac{k}{\ell_2}\right)^{1/2}\right]\left\{A - B(k\ell_2)^{\frac{1}{2}} - \mu \ell_1 - \pi\delta - \frac{2\pi}{B}\left(\frac{\ell_2}{k}\right)^{\frac{1}{2}} - \beta n B (k\ell_2)^{\frac{1}{2}}\right\} = 0$$

Using $\pi = w$, $\ell_1 = x$ and $y = B(k\ell_2)^{1/2}$, the first order conditions can be written as

$$A - x - \mu y - w(1+\tau) = 0$$

$$A - y - \mu x - w\delta - \frac{2y}{kB^2} - \beta n y = 0$$

Using these two equations, we can solve for the socially optimal consumption of goods 1 and 2:

$$\begin{pmatrix} 1 & \mu \\ \mu & 1 + \left(\beta n + \dfrac{2}{kB^2}\right) \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} A - w(1+\tau) \\ A - w\delta \end{pmatrix}$$

The determinant of the matrix is positive and is equal to

$$J \equiv (1 - \mu^2) + \beta n + \frac{2}{kB^2}$$

The socially optimal consumption levels of goods 1 and 2 are

$$\hat{x} = \frac{1}{J}\left\{[A - w(1+\tau)]\left(1 + \beta n + \frac{2}{kB^2}\right) - \mu(A - w\delta)\right\}$$

$$\hat{y} = \frac{1}{J}\{A(1-\mu) + w(\mu(1+\tau) - \delta)\}$$

Proposition 3: *Assume that* $A(1-\mu) + w(\mu(1+\tau) - \delta) > 0$. *Then the socially optimal consumption of good 2 per person,* $\hat{y}$, *is decreasing in the pollution damage parameter* β *and in the population size n, and is increasing in the capital endowment per person, k, and in the technology level B. An increase in the labor productivity in the numeraire good industry will result in an increase in* $\hat{y}$.

Remark: We may also express $\hat{x}$ as follows

$$\hat{x} = \frac{1}{J}\left\{A(1-\mu) + w(\mu\delta - (1+\tau)) + \left[(A - w(1+\tau))\left(\beta n + \frac{2}{kB^2}\right)\right]\right\}$$

Assuming that $A > w(1+\tau)$, a sufficient condition for $\hat{x}$ to be positive is $A(1-\mu) + w(\mu\delta - (1+\tau))$. A higher β will lead to an increase in $\hat{x}$.

Let us now show how the control and command optimum can be achieved by a competitive market supplemented with a tax on trash.

Under the control and command scenario, we have at the social optimum

$$\hat{x} + \mu\hat{y} = A - w(1+\tau)$$

$$\hat{y} + \mu\hat{x} = A - w\delta - \frac{2}{kB^2}\hat{y} - \beta n\hat{y}$$

Suppose that a tax rate t can decentralize this outcome, then it must hold that, given the tax, $y^* = \hat{y}$ and $x^* = \hat{x}$, with

$$x^* + \mu y^* = A - w\tau - p_1$$

$$y^* + \mu x^* = A - w\delta - p_2 = A - w\delta - C(w,r) - t$$

Clearly, $p_1 = w$ because of the Ricardian technology in the production of good 1, and the optimal tax must equal the marginal social cost of pollution, that is $t = \beta n\hat{y}$.

It remains to verify that under this optimal tax, it holds that

$$C(w,r) = \frac{2}{kB^2}\hat{y}$$

The verification is completed by using the fact that $rk = \left(\frac{1}{B}(wr)^{1/2}\right) y^*$.

Proposition 4: *The social optimum can be achieved by a tax rate that is equal to the marginal social damage of pollution*

$$t = \frac{dD}{dZ} = \beta Z = \beta n\hat{y}$$

This tax results in the equilibrium rental rate r,

$$r^{1/2} = w^{1/2}\left[\frac{A(1-\mu) + w(\mu(1+\tau) - \delta) - \beta n\hat{y}}{Bk(1- \mu^2) + wB^{-1}}\right]$$

The unit cost of producing good 2 is then

$$C(w,r) = \frac{2}{B}(wr)^{1/2} = 2w\left[\frac{A(1-\mu) + w(\mu(1+\tau) - \delta) - \beta n\hat{y}}{k(1- \mu^2)B^2 + w}\right]$$

4. Waste generation and North's import demand for South's trash disposal services

Let us now suppose that the representative Northern economy that we considered above can access an international market in which it can buy trash disposal services from the Southern economies. For simplicity, we assume that goods 1 and 2 are non-tradeable. Then the Northern economy must pay for its importation of trash disposal services by exporting the numeraire good. Let p_s denote the price of trash disposal services in terms of the numeraire good. Clearly, if under autarky, the marginal damage of pollution in North is greater than p_s , then the representative Northern country will find it advantageous to involve in trade. Would the Northern economy produce more trash under trade than under autarky? The answer is obviously in the affirmative. The trash that remains in the country is $Z = ny - s$ where s is the trash disposal services that it imports from the South (i.e., it ships s units of trash to the Southern economies, and to pay for the South, it ships $p_s s$ units of the numeraire good to South.)

Under such trade, the welfare of the representative individual in North, net of her discomfort from seeing trash lying around her country, is

$$V_T = U - \frac{\beta}{2} Z^2$$

$$= w\ell_0 - p_s s + A\left(\ell_1 + Bk^{\frac{1}{2}}\ell_2^{\frac{1}{2}}\right) - \frac{1-\mu}{2}(\ell_1^2 + B^2 k\ell_2) - \frac{\mu}{2}\left(\ell_1 + Bk^{\frac{1}{2}}\ell_2^{\frac{1}{2}}\right)^2$$

$$-\frac{\beta}{2}\left[nBk^{\frac{1}{2}}\ell_2^{\frac{1}{2}} - s\right]^2$$

The social planner of the Northern economy chooses the vector $(s, \ell_0, \ell_1, \ell_2)$ to maximize V subject to the resource constraint that

$$\ell_0 + (1+\tau)\ell_1 + \ell_2 + \delta\, Bk^{1/2}\ell_2^{1/2} = T$$

Let π denote the Lagrange multiplier. The Lagrangian function is

$$\mathcal{L} = V_T + \pi\left[T - \ell_0 + (1+\tau)\ell_1 + \ell_2 + \delta\, Bk^{1/2}\ell_2^{1/2}\right]$$

Assuming an interior maximum, the first order conditions are

$$\frac{\partial \mathcal{L}}{\partial \ell_0} = w - \pi = 0$$

$$\frac{\partial \mathcal{L}}{\partial \ell_1} = A - \ell_1 - \mu Bk^{\frac{1}{2}}\ell_2^{\frac{1}{2}} - \pi(1+\tau) = 0$$

$$\frac{\partial \mathcal{L}}{\partial \ell_2} = \left[\frac{B}{2}\left(\frac{k}{\ell_2}\right)^{1/2}\right]\left\{A - B(k\ell_2)^{\frac{1}{2}} - \mu\ell_1 - \pi\delta - \frac{2\pi}{B}\left(\frac{\ell_2}{k}\right)^{\frac{1}{2}} - \beta\left[nB(k\ell_2)^{\frac{1}{2}} - s\right]\right\} = 0$$

$$\frac{\partial \mathcal{L}}{\partial s} = -p_s + \beta\left[nB(k\ell_2)^{\frac{1}{2}} - s\right] = 0$$

Thus, we end up with two equations to determine x and y:

$$A - x - \mu y - w(1+\tau) = 0$$

$$A - y - \mu x - w\delta - \frac{2w}{kB^2}y - p_s = 0$$

Assuming that p_s is low in the sense that

$$p_s < \beta n\hat{y} = \beta n\frac{1}{J}\{A(1-\mu) + w(\mu(1+\tau) - \delta)\}$$

It is easy to show that under trade, the Northern economy will produce more trash than under autarky. The trash generated under trade is denoted by y_T and the output of good 1 under trade is denoted by x_T. They are solutions of the following system of equations

$$x_T + \mu y_T = A - w(1+\tau)$$

$$A - y_T - \mu x_T - w\delta - \frac{2y_T}{kB^2} - p_s = 0$$

Under the assumption that p_s is low, we can easily show that $y_T > \hat{y}$, i.e., the output of trash per Northern resident under free trade is greater than that under autarky. Indeed,

$$y_T = \frac{\{A(1-\mu) + w(\mu(1+\tau) - \delta) - p_s\}}{(1-\mu^2) + \beta n + \frac{2}{kB^2}}$$

Therefore,

$$\hat{y} - y_T = \frac{[A(1-\mu) + w(\mu(1+\tau) - \delta)]\beta n - Jp_s}{\left[(1-\mu^2) + \beta n + \frac{2}{kB^2}\right]J} > 0$$

The Northern economy's trash exports (i.e., its imports of South's trash disposal services) is

$$s = ny_T - \frac{p_s}{\beta} = \frac{n[A(1-\mu) + w(\mu(1+\tau) - \delta)] - \left(\frac{p_s}{\beta}\right)\left[1 - \mu^2 + \frac{2}{kB^2}\right]}{(1-\mu^2) + \beta n + \frac{2}{kB^2}}$$

Proposition 5: *Under free trade, Northern economies produce more trash than under autarky. The free trade output of trash per Northern resident is decreasing in the price of South's trash disposal services,* p_s*. The amount of trash that remains in the Northern economy is*

$$Z_T = ny_T - s = \frac{p_s}{\beta}$$

The Northern economy's demand for South's trash disposal services is decreasing in p_s *and increasing in* β

$$s^d = \frac{n[A(1-\mu) + w(\mu(1+\tau) - \delta)] - \left(\frac{p_s}{\beta}\right)\left[1 - \mu^2 + \frac{2}{kB^2}\right]}{(1-\mu^2) + \beta n + \frac{2}{kB^2}}$$

5. South's supply of trash disposal services

In this section, we provide a simple model of South's export of trash disposal services. We show that this export supply function is distorted by externalities: each person's supply of trash disposal services inflicts harms on his neighbors.

We assume that each Southern economy consists of v identical villages. Each village consists of m identical villagers. Each villager is endowed with $\bar{\ell}$ units of labor time and a unit of land, with which a subsistence good is produced. The villager considers the subsistence good as a perfect substitute for the North's numeraire good. The output level of villager i is denoted by q_i, which depends on the quality of his land, denoted by E_i.

Assume that $q_i = \bar{\ell}E_i$. The quality level E_i depends on the aggregate pollution level in his village:

$$E_i = (N - T_i - T_{-i})^{1/2}$$

where N is a positive constant, T_i is the amount of trash that he imports for incineration, for which he receives an income $p_s T_i$, measured in terms of the Northern numeraire good, and T_{-i} is the sum of the quantities of trash that the other villagers incinerate. We assume that each villager faces a capacity constraint $\bar{T}$ for his incineration, and that $N > m\bar{T}$, so that E_i is strictly positive.

Each villager chooses his level of incineration of the imported Northern trash to maximize his utility, which is the sum of the subsistence output he produces and the payment $p_s T_i$ that he receives for supplying his incineration services. In doing so, he takes as given the level of incineration supplied by his neighbors. It is this Nash behavior that accounts for the externalities of individual supply of incineration services.

Let $\bar{\ell} = 1$ without loss of generality. The first order condition for the villager's optimal T_i is

$$-\frac{1}{2}\left[\frac{1}{(N - T_i - T_{-i})^{\frac{1}{2}}}\right] + p_s \begin{cases} \leq 0 \; if \; T_i = 0 \\ = 0 \; if \; 0 < T_i < \bar{T} \\ \geq 0 \; if \; T_i = \bar{T} \end{cases}$$

In a symmetric Nash equilibrium of this game among the m villagers, we have $T_i = T^*$ for all i, therefore the village's supply function of trash incineration services is

$$mT^*(p_s) = \begin{cases} 0 \; if \; p_s \leq 0.5N^{-1/2} \\ N - 0.25(p_s)^{-2} if \; 0.5N^{-1/2} \quad \leq p_s \leq 0.5(N - m\bar{T})^{-1/2} \\ m\bar{T} \; if \; p_s \geq 0.5(N - m\bar{T})^{-1/2} \end{cases}$$

Thus, each village has an upward sloping supply curve for incineration services. Summing over all villages, the Southern country's supply of trash disposal services is

$$Q = vmT^*(p_s)$$

6. South's loss from trade

The free trade equilibrium price of trash disposal services, denoted by p_s^T , is obtained by equating North's demand and South's supply.

$$s^d = \frac{n[A(1-\mu) + w(\mu(1+\tau) - \delta)] - \left(\frac{p_s}{\beta}\right)\left[1 - \mu^2 + \frac{2}{kB^2}\right]}{(1-\mu^2) + \beta n + \frac{2}{kB^2}} = vmT^*(p_s)$$

If $0.5N^{-1/2} \leq p_s^T \leq 0.5(N - m\bar{T})^{-1/2}$, then under free trade in trash, the welfare of the representative resident of South is

$$V_{South}^{trade} = [N - mT^*(p_s^T)]^{1/2} + p_s^T T^*(p_s^T)$$

If, instead, trade in trash is banned, then the welfare the representative resident of South under autarky is

$$V_{South}^{autarky} = N^{1/2}$$

Numerical examples can be constructed such that South's welfare under autarky is higher than under free trade. For example, suppose that free trade in trash results in a corner solution where each villager's privately optimal level of incineration is equal to the capacity level $\bar{T}$. This happens if $p_s^T = 0.5(N - m\bar{T})^{-1/2}$. The South's welfare under autarky is greater than under free trade if

$$N^{1/2} > (N - m\bar{T})^{1/2} + 0.5\bar{T}(N - m\bar{T})^{-1/2}$$

This inequality is satisfied if $m > 2$ and $N > 2m\bar{T}$.

Proposition 6: *There exist parameter values such that South's welfare under autarky is greater than under free trade in trash, and North's gains from trade in trash is insufficient to compensate for South's losses.*

7. Notes on related literature

Our model is related to three streams of literature. First, consumption takes time. Second, private incentives for trade in trash. Third, loss from trade due to externalities. The first stream of literature began with the work by the German economist, Gossen (1854) whose work (written in German) has recently been brought to international attention by economists such as Winston (1982), Georgescu-Rogen (1983), Niehans (1990), Steedman (2001), Kemp (2008,2009, 2019), Tran-nam (2012, 2017, 2018), and Le-van et al. (2018). The related papers by Becker (1965, and Mincer (1962, 1963) did not refer to Gossen's pioneering work.

The second stream of literature specifically deals with trade in trash. It includes, among others, the papers by Shogren and Crocker (1991), Rauscher (2001, 2015), Cassing and Kuhn (2003a, 2003b, 2003c), Baggs (2009), Kaza et al. (2018). Shogren and Crocker (1991) showed that if self-protection implies transferring the externalities to another country, this will lead to over-protection. Raucher (2001) considered a model of exporting toxic waste. He pointed out that in a first-best world, trade is beneficial to all parties even when the object of trade consists of dangerous substances. However, he also noted that when account is taken of imperfections such as regulatory and enforcement failures, international trade may be harmful. Using the political economy paradigm (see, e.g., Hillman, 2019), Cassing and Long (2021) provided a solid theoretical foundation for North's incentives to export trash, by extending the model of Grossman and Helpman

(1994) to the case of heterogeneous preferences for environmental quality, in which there are brown consumers as well as green consumers of the NIMBY (not in my backyard) variety. They did not consider the case in which there are Super-Greens, i.e., those who have global concerns about environmental quality. (See Hillman and Ursprung (1992, 1994) for a political economy model where there are both Greens (of the NIMBY type) as well as

Super-Greens.)

The third stream of literature deals with possible loss from trade when there are externalities in general. It includes the works of Chichilnisky (1994), Brander and Taylor (1996), Antweiler et al. (2001), Copeland and Taylor (2004), among others. Specifically, Chichilnisky (1994) pointed out that, due to South's lack of well-defined property rights, South's comparative advantage in resource goods is apparent rather than real, and therefore trade between North and South can be harmful to South. This theme was explored further by Brander and Taylor (1996) in a Ricardian trade model.

8. Concluding remarks

Using a simple model where consumption takes time, I have been able to show that capital accumulation and increased productivities in North give rise to a process of consumers' substitution of time-saving commercially produced goods for the traditional time-intensive household-produced goods, leading to the harmful consequence that the environmental quality in both North and South deteriorate. Trade in trash is increasing with North's capital accumulation, and such trade is harmful to South's welfare if in South there is a lack of well-defined property rights.

In our model, we suppose that in the representative Northern economy, its government imposes a pollution tax that is equal to the marginal damage that the pollution stock in that country inflicts on its residents. The government does not try to influence the terms of trade between North and South. This assumption may be justified if there are many similar Northern economies. The pollution is local rather than global. The government does not care about the pollution that the country exports to South. Thus, the Northern government is Green in the NIMBY (not in my backyard) sense.

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