Commodity Taxation and Parallel Imports

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July 10, 2009

Abstract: We examine the interaction between commodity taxes and parallel imports in a two-country model with imperfect competition. While governments determine non-cooperatively their commodity tax rate, the volume of parallel imports is determined endogenously by the retailing sector. We compare the positive and normative implications of having commodity taxes based on destination or origin principle. We show that, as the volume of parallel imports increases, non-cooperative origin taxes converge, while destination taxes diverge. Moreover, origin taxes are more similar and lead to higher aggregate welfare levels than destination taxes.

JEL code: F12, F15, H21, H24.
Keywords: Parallel import, commodity taxation, tax harmonization

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Acknowledgments: We would like to thank Co-Editor Joel Slemrod and two anonymous referees for their detailed comments. The paper has also benefitted from comments from seminar participants at Aachen, Copenhagen, Grenoble, Leuven, Sydney, Tilburg, Tokyo, Århus, ETSG (Dublin), IIPF (Cyprus), and especially from discussions with Andreas Haufler, Christos Kotsogiannis, and Jota Ishikawa.
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1 Introduction

This paper examines the interaction between commodity taxes and parallel imports in a two-country model of imperfect competition. The main issue investigated is whether an increased volume of parallel imports — for many, a synonym of market integration — leads to a tax convergence or not. The paper shows that parallel imports do induce a tax convergence if taxes are based on the origin principle, and to a tax divergence if taxes are based on the destination principle. In our model, all this happens along with the fact that origin taxes lead to narrower rates and to unambiguously higher aggregate welfare than destination taxes.

Parallel imports are legal and highly encouraged within the European Union (EU).[1] To achieve this, the EU has adopted a *regional* exhaustion rule of intellectual property rights. This rule implies that if a EU producer chooses to export within the EU by using local retailers, these retailers can legally re-export the good. The European Court has repeatedly ruled in favour of parallel imports, arguing that they intensify competition and lead to deeper market integration.[2] Recent empirical analyses of the extent of parallel imports within the EU document the importance of these flows.[3]

The existence of parallel imports implies the existence of price differentials. These price differentials may exist for several reasons. Consumer's willingness to pay across countries for instance may differ whether due to tastes or income. This typically induces imperfectly competitive firms to engage in third-degree price discrimination and thus to charge different prices across countries (see Malueg and Schwartz, 1994). Prices may also differ, not because the markets are different but because the realization of demands is different across markets. Raff and Schmitt (2007) develop a model where producers and

[1] Parallel imports, also known as grey products, are genuine products sold in a country without the authorization of the intellectual property right owner. See Maskus (2000) for a general discussion.

[2] For example, see the European Commission's decision on the case of Glaxo Wellcome et al. (Official Journal, 2001), and on JCB (Official Journal, 2002) where a 39 million EUR penalty was imposed for attempting to stop parallel imports.

[3] For instance, NERA (1999) reports that for CDs, consumer electronics, auto spare parts, cosmetics, and soft drinks, 5-20% of trade within EU are parallel imports; Ganslandt and Maskus (2004) report that, for some brand names in the pharmaceutical sector, the share of parallel imports reach 50% in Sweden. Additional estimates can be found in OECD (2002), Ahmadi and Yang (2000), and Kanavos and Costa-Font (2005).

consumers may benefit from parallel imports when retailers must place orders before they learn about the intensity of the demand in their respective market. A third reason is government policies and regulations, such as price ceilings on pharmaceutical products (see Kanavos and Costa-Font, 2005; Grossman and Lai, 2008). The present paper fits within this last category of papers, where government policies affect parallel imports, but it turns its attention to *commodity taxes*.

Commodity taxes are important revenue-generating instruments in the EU countries. Different tax rates may naturally lead to different consumer prices giving arbitrage opportunities to parallel importers. In turn, parallel imports may affect the choice of these taxes. This simultaneous endogeneity of parallel imports and commodity taxes makes the analysis interesting.

Our reference point is the commodity-tax competition literature (see Lockwood, 2001 for a survey). In this literature, it is usually assumed that markets are fully integrated so that the law-of-one-price applies and parallel imports never arise. This literature then focuses on two issues: (i) whether the imposition of tax harmonization, i.e. forcing countries to adopt the same tax, leads to efficiency gains or not, and (ii) which tax regime is best — the destination or the origin tax regime.[4]

Our starting point, however, is somewhat different. We assume that markets are segmented and that the equilibrium is characterized by price differentials that parallel importers exploit given some transaction costs. The policy initiative is to reduce these transactions costs and thus to promote market integration.[5] Parallel imports then affect retail prices and the taxes set by the governments. In turn, these new prices and taxes affect parallel imports, and so on until a new equilibrium is reached.

Within this set-up we ask a novel question: *does promoting parallel imports bring tax convergence?* Our motive should be clear: while repeated calls for tax harmonization in the EU have had little success, we investigate whether a more 'market-oriented' initiative can bring about a tax convergence through the 'back-door'. Indeed, implementing mar-

[4] While most papers in this literature focus on one of the two issues, few papers analyse simultaneously the two of them, see Keen et al. (2002) and Behrens et al. (2007).

[5] One could interpret the consistent rulings of the European Court as steps needed to reduce transactions costs faced by parallel importers.

ket integration through parallel imports is arguably more 'market-oriented', and maybe simpler than asking member countries to harmonize their taxes. Needless to say, such a tax convergence is desirable only if it leads to Pareto efficiency gains, an issue that we also investigate in detail.

To analyze the interaction between commodity taxes and parallel imports, we adopt Maskus and Chen (2002, 2004)'s model of parallel imports.[6] This model has the advantage of providing an explicit level of parallel imports and of explaining parallel imports as a by-product of vertical control issues associated with retailing activities. In particular the model assumes a single good monopolist that sells in two countries. In the home country, the manufacturer sells directly to consumers and, in the foreign country, it sells through a retailer. This vertical separation in the foreign country creates a negative externality, viz. the so-called double-marginalization problem (see Tirole, 1988), where the existence of two successive mark-ups – one by the producer and one by the retailer – leads to a higher price and lower sales than in an integrated structure. A well-known solution to this problem is a two-part pricing strategy, viz. a wholesale price equal to the marginal cost of production and a fixed fee that captures the retailer's rent. However, faced with a low wholesale price, the foreign retailer may find profitable to engage in parallel imports and sell part of its order to the manufacturer's home country. Thus, in trying to avoid double-marginalization, the manufacturer may induce more competition in its home market (from monopoly to duopoly) and lowers its overall profit. The manufacturer chooses a two-part tariff contract that balances these two opposite forces.[7]

We augment this model with taxes that governments choose in a non-cooperative way. We then examine the implications of two different tax systems: *destination*-based taxes — where taxes are set and collected by the authorities of the country where the good is purchased and consumed (the current EU system) — and *origin*-based taxes — where taxes are set and collected by the authorities of the country where the good is produced

[6] In Maskus and Chen (2005), Li and Maskus (2006), and Ganslandt and Maskus (2007), the basic model is extended in several directions without altering its fundamental properties.

[7] In this model parallel imports are thus not necessarily a good thing — on the one hand they improve efficiency by creating competition, while on the other hand they reduce efficiency by creating double marginalization. Such a rich setup is ideal for addressing our central theme, viz. how parallel imports affect decentralised tax setting.

(a proposed EU system). We then investigate the effects of a reduction of the transaction cost specific to parallel imports on the equilibrium variables and we show three main results. First, the equilibrium tax rates in the two countries are more similar under origin taxation than under destination taxation. Second, given parallel trade, origin-based tax rates converge as the volume of parallel trade increases, whereas destination-based taxes diverge. Third, origin-based taxes lead in generally to higher welfare in both countries than destination-based taxes. Thus, market integration can indeed bring both tax convergence and higher welfare when taxes are origin-based.[8]

Three recent papers have looked at commodity taxation issues in segmented markets. Haufler et al. (2005) use a symmetric reciprocal-dumping trade model to examine how trade cost reductions affect the choice of commodity tax base. They show that, while origin taxes still outperform destination taxes when trade costs are low, the opposite is true when they are high. Haufler and Pflüger (2007) add government revenue requirements to the same reciprocal-dumping model and re-examine the comparison between destination and origin taxes. They show that ambiguity emerges in many of the earlier results. Finally, Behrens et al. (2007) examine how tax (origin- and destination-based) harmonization affects firm location. They use a general equilibrium model with monopolistic competition that allows for variable mark-ups and market segmentation. A main result of their analysis is that countries do not agree on a common tax regime — as firms agglomerate into the large country, this country prefers origin-based taxes while the smaller country prefers destination-based taxes. However, while their analysis introduces the interesting aspect of asymmetry in the location of production, it does not take into account the fact that commodity taxes also adjust to that asymmetry.

Our paper keeps firm location fixed as in Haufler et al. (2005) but allows for asymmetries in the location of production as in Behrens et al. (2007). Like Haufler et al.

[8] In this sense, we confirm the result that Keen and Lahiri (1993, 1998) derive, viz. that within models of imperfect competition, origin taxation is better than destination taxation. However, we do that in a model with vertical separation and market segmentation, while they analyze fully integrated horizontal markets. In addition, we show that the origin tax superiority does not conflict with a tax harmonization plan that a supranational authority may have. In our model, origin taxation and tax convergence go together (a result which is not true in the fully integrated horizontal markets model; see e.g. Keen et al.; 2002).

(2005), we look at how market integration affects the non-cooperative choice of origin and destination-based taxes, but we use a different trade model than theirs; one where vertical links and parallel imports play a key role. We perform our analysis around of what we think is a novel research question (‘*does market integration lead to tax convergence?*’) and we show some interesting new results (converging origin taxes are generally better than the diverging destination taxes). Thus, our simple model shows no ambiguity about which tax base is best (an ambiguity that exists in Haufler et al., 2005) and no conflict between countries on the choice of a common tax regime (a conflict that exists in Behrens et al., 2007).

We should emphasize that the structure of our model does not allow us to claim generality of our results. We work with linear demand and specific commodity taxes (as the rest of the literature on commodity taxes and imperfect competition) acknowledging that alternative assumptions may lead to different results. In that sense, the model examined here is an example. Nevertheless, our results are robust to a large range of parameters, and we identify mechanisms that are novel to the issues.

The paper is organized as follows. Section 2 develops the model and examines the case where taxes are set according to the destination principle. It derives the optimal taxes and whether they converge or diverge when parallel imports increase. Section 3 does the same for the case of origin taxes. Section 4 compares the two tax regimes and investigates the welfare consequences of having more parallel imports. Section 5 concludes.

2 The model and destination-based taxes

The structure of the model is based on Maskus and Chen (2002, 2004). A manufacturer sells a single product in two countries: its home country, called Country A, and a foreign country, called Country B. At home, the manufacturer sells q_A directly to the consumers, while abroad it sells to a single independent retailer. This retailer sells q_B units to the consumers in country B and, if it chooses to do so, m units as parallel imports to the consumers in country A.

Countries A and B are assumed to have the same size and preferences so that the (inverse) demand functions are respectively $p_A = a - bQ_A$ and $p_B = a - bQ_B$, where p_i $(i = A, B)$ is the consumer price in country i, Q_i is total sales in country i and $a > 0$ and $b \geq 1$.[9] For simplicity, production and retail costs (other than the cost of buying from the manufacturer) are constant and normalized to zero. In addition there is no trade cost associated with the exports of q_B, while there is a transaction cost g per unit of parallel imports that the retailer must pay.[10] It is assumed that parallel imports lead to Cournot competition in market A.[11] Finally, the manufacturer adopts a two-part pricing strategy; that is, it charges a wholesale price w and a fixed fee F for its shipment to country B.

We augment the Maskus and Chen (op.cit.) model with two elements. The first and the most important one is commodity taxes which provide a role for governments. The second one is a competitive fringe of producers/retailers in Country B. The role of the fringe is to make sure that, irrespective of the tax regime, there is always a tax base in Country B.[12] This fringe sells the same homogeneous product as the manufacturer from A but only to consumers in B. The fringe supply function is

$$p_B = t_B^j + d\tilde{q}, \tag{1}$$

where $d > 0$, t_B^j is either the destination $(j = D)$ or the origin $(j = O)$ tax per unit faced by the fringe, and $\widetilde{q}$ is the total volume sold by the fringe. Like with all competitive fringes, sellers take the price on this market as given. However, the retailer selling q_B units takes into account the existence of the competitive fringe to determine its own sales. In this sense it is a dominant seller.

Suppose now that countries set destination-based taxes, i.e. a tax collected in the country of consumption. Letting t_A^D (t_B^D) be the specific commodity tax in country A

[9] We assume $b \geq 1$ as it is a sufficient condition for most of our results. Thus, for $b < 1$, our results also hold, at least for b close enough to one but the proofs are less straightforward than those presented.

[10] Thus relative to international trade between the manufacturer in A and the retailer in B, parallel imports are costly. These costs are assumed to resource costs such as re-packaging and re-labeling of the goods – costs that parallel importers typically incur in the case of pharmaceutical products.

[11] Since products are assumed to be homogeneous, Bertrand competition in market A would never lead to parallel imports in equilibrium.

[12] Observe in particular that, without it, there would be no tax base in Country B in the origin tax regime.

(country B), the manufacturer and the retailer profits are respectively

$$\Pi^M = (p_A(Q_A) - t_A^D)q_A + w(q_B + m) + F; \quad (2)$$

$$\Pi^R = (p_B(Q_B) - t_B^D)q_B + (p_A(Q_A) - t_A^D - g)m - w(q_B + m) - F. \quad (3)$$

where $Q_A = q_A + m$ and $Q_B = q_B + \widetilde{q}$. The first term of the RHS of (2) is the manufacturer's revenue at home while the second and third terms are the revenues from selling to the retailer in country B. Similarly, the RHS of (3) captures respectively the retailer's revenue in its own market and from parallel trade, while the last two terms represent respectively the variable and the fixed retailer cost.

Since the government in each country imposes a (per unit) tax t_i^D ($i = A, B$) based on the destination principle, welfare is defined as

$$W_A^D = CS_A + \Pi^M + t_A^D(q_A + m); \quad (4)$$

$$W_B^D = CS_B + PS_B + t_B^D(q_B + \tilde{q}), \quad (5)$$

where CS_i represents the consumer surplus in country i, Π^M is the manufacturer's profit, PS_B is the producer surplus generated by the competitive fringe in country B, and the last term in both relationships represents the consumption-tax revenues collected in country i. Since the retailer in B earns zero profit in equilibrium, welfare in B does not include any retailer profit.

We investigate the following three-stage game. In the first stage, governments choose simultaneously their tax rates t_A^D, t_B^D. In the second stage, the manufacturer sets w and F. In the third and final stage, the retailer sets q_B and m taking as given the supply function of the competitive fringe, while the manufacturer sets q_A. The determination of $\tilde{q}$ follows from the choices made by the dominant retailer and by the manufacturer.

Starting with the last stage of the game, we maximize (2) with respect to q_A, (3) with respect to q_B and m taking into account the supply of the competitive fringe, and then solve for the Cournot outputs q_A and m. Knowing q_A, q_B and m and thus prices, $\tilde{q}$ can be determined. Outputs are:

$$
\begin{aligned}
q_A(w,t_A^D) &= \frac{a+g+w-t_A^D}{3b}; \qquad m(w,t_A^D) = \frac{a-2g-2w-t_A^D}{3b}; \\
q_B(w,t_B^D) &= \frac{ad-dt_B^D-w(d+b)}{2bd} \qquad \widetilde{q}(w,t_B^D) = \frac{ad+w(b+d)-dt_B^D}{2d(d+b)}.
\end{aligned} \tag{6}
$$

In the second stage of the game, the manufacturer chooses w and F. In the absence of parallel imports, the manufacturer's optimal pricing strategy is to set the wholesale price equal to the marginal cost of production, i.e. $w=0$, and a fixed fee equal to the retailer's profit. However, when parallel imports are allowed, a low wholesale price makes it easier to engage in parallel importing creating competition in country A. To mitigate this effect, the manufacturer sets its wholesale price higher than marginal cost. The optimal choice of w balances the double marginalization and the increased competition effects. Since the manufacturer sets F such as to extract the entire profit of the dominant retailer, then subsituting (6) and F such that $\Pi^R=0$ into (2), and maximizing with respect to w gives

$$
w(t_A^D) = \frac{2d(a+4g-t_A^D)}{13d+9b}. \tag{7}
$$

The equilibrium outputs for given tax rates and the international trade barrier for parallel imports are then found by substituting (7) into (6). We write them as implict functions of taxes and cost of parallel imports along with the sign of the partial derivatives with respect to g and t_i^D (see Appendix 1 for details):

$$
q_A(\underset{(+)}{g}, \underset{(-)}{t_A^D}); \qquad m(\underset{(-)}{g}, \underset{(-)}{t_A^D}); \qquad q_B(\underset{(-)}{g}, \underset{(+)}{t_A^D}, \underset{(-)}{t_B^D}); \qquad \tilde{q}(\underset{(+)}{g}, \underset{(-)}{t_A^D}, \underset{(-)}{t_B^D}). \tag{8}
$$

As expected, an increase in the cost of parallel imports g reduces parallel imports and increases the manufacturer's direct sales in A. Interestingly, it reduces the dominant retailer's sales in B and increases the sales of the competitive fringe. This is because an increase in g induces the manufacturer to increase its wholesale price and it does so because selling in A is more profitable than selling through the retailer in B. A tax increase has the expected effect on sales since a higher tax in a particular country reduces the sales in that country ($dq_i/dt_i^D < 0$). More importantly, a higher destination tax in country A directly discourages parallel imports (see (6)). Since a higher t_A^D also decreases the retailer's sales in A, the manufacturer focuses more on the double marginalization problem in country B by reducing its wholesale price ($dw/dt_A^D < 0$). This increases the retailer's sales in country B ($dq_B/dt_A^D > 0$), and reduces the sales of the competitive fringe ($d\tilde{q}/dt_A^D < 0$). Moreover, the direct effect of a higher t_A^D dominates its indirect effect through w so that parallel imports fall ($dm/dt_A^D < 0$). We underline the important effect of destination taxes on the manufacturer's choices in the following proposition.

Proposition 1 *Higher destination-based taxes have a direct negative effect on parallel imports, allowing the manufacturer to focus more on correcting the vertical control distortion with its retailer.*

Naturally, if the destination tax is negative, i.e. a consumption subsidy, the effects are exactly the opposite. That is, a consumption subsidy directly induces parallel imports and makes the manufacturer raise w and reduce sales in country B, worsening the double marginalization distortion.

In order to derive the optimal taxes, we now move to the first stage of the game where governments choose taxes by maximizing domestic welfare. Substituting (8) into (4)-(5) and solving for the optimal tax choices leads to the following implicit best-reply functions:

$$t_A^D = t_A^D(g) \qquad \text{and} \qquad t_B^D = t_B^D(\underset{(+)}{t_A^D}, g) \tag{9}$$

Thus, country A has a dominant tax rate strategy (i.e., its best reply does not depend on t_B^D) and taxes are strategic complements for country B ($dt_B^D/dt_A^D > 0$). The intuition is the following: we showed that, as t_A^D increases, the sales in country B rise. As a result, the manufacturer earns higher profits from country B (through the fixed fee). The government in country B has then an incentive to raise its consumption tax rate so as to extract additional rents from the manufacturer. However, country B's tax changes do not feed back to country A as the manufacturer's wholesale price, and thus the volume of parallel imports, do not depend on t_B^D.[13]

[13] This is due to the two-part pricing strategy. Introducing linear pricing removes this property and

Solving for the equilibrium tax rates $(\widehat{t}_A^D, \widehat{t}_B^D)$, we can write:

Proposition 2 *Under destination-based taxes, parallel imports take place in equilibrium if $g \leq g^D$. In this case, the equilibrium tax $\widehat{t}_A^D$ is always negative, while the equilibrium tax $\widehat{t}_B^D$ is always positive. Moreover, in the presence of parallel imports, the tax differential $(\widehat{t}_B^D - \widehat{t}_A^D)$ diverges as g falls.*
Proof. *See Appendix 1.* ■

If the consumption tax in country A is always negative, i.e. a consumption subsidy, it is to mitigate the monopoly distortion in that country both directly by lowering the consumer price, and indirectly by inducing a higher volume of parallel imports. Country B by importing from a foreign monopolist has an incentive to extract rent, and thus to impose a positive tax. However this incentive is mitigated by the presence of the domestic fringe.

Figure 1 illustrates the tax differential as a function of g.[14] It shows two regions: one where the tax difference is constant and the other where the tax difference increases monotonically as g falls. In between these two regions there is a discontinuity corresponding to g^D. Thus for $g > g^D$, there is no parallel imports, while for $g \leqslant g^D$, the retailer in B chooses to engage in parallel imports.

Figure 1: about here

To understand the reason for the discontinuity at g^D, consider the equilibrium without parallel imports. In this case, the manufacturer and the government in country A have clear-cut objectives. The manufacturer corrects the double marginalization problem that it faces in country B by setting its wholesale price equal to the marginal cost of production $(w = 0)$ and the government in country A focuses on the monopoly distortion by setting

allows for tax externalities in both directions. Note also that $dt_B^D/dg < 0$; this is because an increase in g decreases sales in country B and thus the incentive to tax the foreign manufacturer. A change in g has however an ambiguous impact on t_A^D depending on the value of b and d. When d is large with respect to b (specifically, $d > 1.54b$), $dt_A^D/dg < 0$ and when it is small, $dt_A^D/dg > 0$.

[14] We choose to illustrate this by setting $a = b = 1$ while letting $d = 1$ and $d = 10$ in order to emphasize the effect of the fringe competition in country B. Of course, similar figures can be drawn for other parameter values.

$\widehat{t}_A^D = -a$. This leads to marginal cost pricing and thus to a consumer price that is equal to zero. In country B, the main goal of the government is to extract rents from the foreign manufacturer taking into account the presence of the domestic fringe. As a result, the equilibrium tax rate is $\widehat{t}_B^D = a\frac{d}{4b+3d}$. Below g^D, positive volumes of parallel imports create a pro-competitive effect in country A. To limit the retailer's incentive to engage in parallel importing, the manufacturer raises w.[15] Country A takes this into account and reduces its subsidy since there is a smaller monopoly distortion. Similarly country B reduces its tax since there are less rents to extract from the manufacturer. This results in an unambiguous reduction of the tax differential with respect to the equilibrium without parallel imports.[16] However, as g continues to fall, the rent extraction tax in country B rises ($dt_B^D/dg < 0$) while the consumption subsidy in country A increases or decreases depending on the values of b and d ($dt_A^D/dg \lesseqgtr 0$). Hence the direct effect unambiguously increases t_B^D and it decreases (increases) the subsidy t_A^D when $d = 1$ ($d = 10$). In addition, there is an indirect effect on t_B^D through the strategic tax complementarity effect. As shown by Proposition 2, the net effect always results in a tax divergence as g falls towards zero.

3 The model with origin-based taxation

Suppose now that commodity taxes are imposed and collected in the country where production takes place. In this case, the profit and welfare equations become:

$$\Pi^M = (p_A(Q_A) - t_A^O)q_A + (w - t_A^O)(q_B + m) + F; \tag{10}$$

$$\Pi^R = p_B(Q_B)q_B + (p_A(Q_A) - g)m - w(q_B + m) - F, \tag{11}$$

[15] Indeed, at g^D, w jumps from zero to $\frac{8ad(3b+4d)}{27b^2+88bd+69d^2} > 0$.

[16] Note also that as d rises (i.e., essentially a smaller competitive fringe), parallel imports occur only at a lower value of g^D. This is because the production of the competitive fringe affects the retailer's incentive to engage in parallel imports: the larger the retailer's market in country B at any price (i.e. the higher d), the smaller the retailer's incentive to engage in parallel imports.

and

$$W_A^O = CS_A + \Pi^M + t_A^O(q_A + q_B + m) \tag{12}$$

$$W_B^O = CS_B + PS_B + t_B^O\tilde{q} \tag{13}$$

where t_i^O is the origin tax in country i. Now, the dominant retailer in country B does not directly face any tax, only the competitive fringe does.

Using the same game as in the previous section, the equilibrium quantities as functions of taxes, the wholesale price, and the parameters of the model are

$$\begin{aligned} q_A(w, t_A^O) &= \frac{a - 2t_A^O + g + w}{3b}; \;\; m(w, t_A^O) = \frac{a + t_A^O - 2g - 2w}{3b}; \\ q_B(w, t_B^O) &= \frac{ad + bt_B^O - w(b+d)}{2bd}; \;\; \tilde{q}(w, t_B^O) = \frac{ad - (b+2d)t_B^O + w(b+d)}{2d(b+d)}. \end{aligned} \tag{14}$$

From the second stage of the game, we get

$$w(t_A^O) = \frac{2da + 8dg + t_A^O(11d + 9b)}{13d + 9b}. \tag{15}$$

Substituting (15) into (14) gives the equilibrium values of outputs for given taxes and the international trade barrier for parallel imports. As in the previous Section, we write them as implict functions along with the sign of the partial derivatives (see Appendix 2 for details):

$$q_A(\underset{(+)}{g}, \underset{(-)}{t_A^O}); \qquad m(\underset{(-)}{g}, \underset{(-)}{t_A^O}); \qquad q_B(\underset{(-)}{g}, \underset{(-)}{t_A^O}, \underset{(+)}{t_B^O}); \qquad \tilde{q}(\underset{(+)}{g}, \underset{(+)}{t_A^O}, \underset{(-)}{t_B^O}) \tag{16}$$

Not surprisingly, a higher production tax in country A reduces sales in that country ($dq_A/dt_A^O < 0$). More interestingly and contrary to the destination case, an increase in t_A^O has a direct positive effect on both parallel imports (see (14)) and on the wholesale price ($dw/dt_A^O > 0$). Because a higher wholesale price has a strong negative effect on the volume of parallel imports, the net effect of an increase in t_A^O is to decrease parallel imports in country A ($dm/dt_A^O < 0$). To understand the difference with the destination case, note that the retailer does not face t_A^O when deciding how much to ship to country A. Thus the only tool with which the manufacturer is able to influence the retailer's choice is the wholesale price. By increasing it, it limits the volume of parallel imports (and thus protects market A) but it also reduces sales in country B ($dq_B/dt_A^O < 0$) and increases sales of the competitive fringe ($d\tilde{q}/dt_A^O > 0$). The other difference with the destination case is the effect of t_B^O on q_B. This effect is positive because a higher tax in B directly reduces the fringe production which helps the dominant retailer's sales. The qualitative impacts of a change in g on sales are the same as in the destination case. The following proposition summarizes how origin taxes influence the manufacturer's choices.

Proposition 3 *A higher origin-based tax has a direct positive effect on parallel imports forcing the manufacturer to focus less on the vertical control distortion and more on the competition induced by parallel imports.*

Again, if origin taxes are negative, i.e. production subsidies, they help the manufacturer coping with the vertical control distortion by reducing w and increasing sales in country B. This, however, also induces parallel imports and thus competition in the manufacturer's country.

Turning to the first stage of the game, the best tax-reply functions have similar properties as in the destination case:

$$t_A^O = t_A^O(g) \qquad \text{and} \qquad t_B^O = t_B^O(\underset{(+)}{t_A^O}, g)$$

As in the destination case, country A has a dominant tax rate strategy and taxes are strategic complements for country B ($dt_B^O/dt_A^O > 0$). However, the reason for the strategic complementarity is slightly different, since the origin tax in country B is exclusively based on the output of the competitive fringe. Thus the rent-extraction motive is no longer present. Still, q_B falls when the tax in country A increases, which increases the sales from the fringe. Because of this effect, country B has an incentive to raise its tax rate whenever country A raises its own tax rate.[17]

[17] Concerning g, it can be checked that, contrary to the destination case, $dt_B^O/dg > 0$. An increase in

Solving for the equilibrium tax rates $(\widehat{t}_A^O, \widehat{t}_B^O)$, we derive the following proposition:

Proposition 4 *Under origin-based taxation, parallel imports take place in equilibrium if $g \leq g^O$. In this case, the equilibrium tax $\widehat{t}_A^O$ and $\widehat{t}_B^O$ are always negative. Moreover, in the presence of parallel imports, the tax differential $(\widehat{t}_B^O - \widehat{t}_A^O)$ converges as g falls.*

Proof. *See Appendix 2.* ■

Like in the destination case, the purpose of the subsidy is to mitigate the monopoly distortion in country A by lowering the consumer price and by inducing a higher volume of parallel imports. Country B no longer has a direct incentive to extract rent from the manufacturer since its tax base corresponds to the production of the fringe, but still has an incentive to subsidize the production of its domestic fringe which competes with the dominant retailer. Thus, both countries set subsidies.

Figure 2 illustrates how the origin tax differential changes with g for the same set of parameters as in Figure 1. It is straightforward to show that in the absence of parallel imports ($g \geqslant g^O$), the government in country A still sets a subsidy. This subsidy is lower than in the destination case, as its impact increases not only the sales at home but also the output exported to country B. Country B has also an incentive to subsidize its competitive fringe, as it earns a producer surplus and it is in competition with the dominant retailer's sales. Indeed, without parallel imports, and assuming the same demands in the two countries, both countries have the same subsidy.[18]

Figure 2: about here

Just below g^O, the manufacturer discretely increases its wholesale price, which also happens to be country A's terms of trade. As its terms of trade improve, the government

g still decreases sales in country B but only because the manufacturer raises w, which in turn increases $\widetilde{q}$. A change in g has the opposite incentive on country A ($dt_A^O/dg < 0$). This is because an increase in g decreases total sales (Q_A) directly and indirectly through the wholesale price adjustment. Hence competition in A decreases inducing country A to reduce its tax rate.

[18] This result breaks down when we allow demands to be different between countries. However, when demands are the same across countries, and with no parallel imports, the two governments face exactly the same monopoly distortion – country A by its manufacturer and country B by its retailer, both facing the same marginal cost (viz. the tax rate t_A^O) and the same demands. Thus, they end up choosing the same subsidy.

in country A corrects the monopoly distortion by also discretely increasing its subsidy. Thus, $\widehat{t}_B^O - \widehat{t}_A^O$ discretely increases mainly because A increases its subsidy. As g falls further, the volume of parallel imports rises and the need for such a subsidy decreases ($d\widehat{t}_A^O/dg < 0$) as the pro-competitive effect of parallel imports operates. In country B, the decrease in g has a direct and an indirect effect. The first one increases the subsidy since $d\widehat{t}_B^O/dg > 0$ and the second one decreases it due to the strategic complementarity with t_A^O. As Proposition 4 shows, the net effect results in a higher subsidy in country B and thus to a tax rate *convergence* between the two countries.

4 Tax and welfare comparisons across tax regimes

We can now compare in detail the destination and the origin taxes and examine the welfare implications of the two tax regimes.

Starting with the tax levels, consider the case without parallel imports. In this case, the incentives in country A are quite different in the two tax systems. With origin taxation, the manufacturer's cost of selling abroad one unit of output is equal to the tax rate t_A^O, and thus the manufacturer charges $w = t_A^O$ to the foreign retailer. Hence, a change in t_A^O not only affects consumer surplus and production sold in country A but also the exports to country B. This induces country A's government to reduce the optimal subsidy to the manufacturer as compared to the destination case (since the destination tax does not influence the marginal cost of selling a unit abroad). As a consequence, country A's destination-based subsidy is higher than its origin-based subsidy, i.e. $\widehat{t}_A^D = -a < \widehat{t}_A^O = -\frac{ad}{2b+3d}$. For country B, the fact that it uses the destination-based tax mainly as a rent extraction instrument, while it does not have this incentive with the origin principle, makes the comparison obvious, i.e. $\widehat{t}_B^D = \frac{ad}{4b+3d} > \widehat{t}_B^O = -\frac{ad}{2b+3d}$. Thus, without parallel imports, $\widehat{t}_B^D > \widehat{t}_B^O = \widehat{t}_A^O > \widehat{t}_A^D$.

A similar ranking can be derived when parallel imports take place. In this case, A's destination-based subsidy is always higher than its origin-based subsidy, i.e. $\widehat{t}_A^D < \widehat{t}_A^O$. This is also true for country B, where the rent extraction tax incentive that existed under the destination principle is absent under the origin principle. Hence, independently of whether parallel imports take place or not, the following relation is true:

$$\widehat{t}_B^D > \widehat{t}_B^O \geq \widehat{t}_A^O > \widehat{t}_A^D. \tag{17}$$

It immediately follows that, regardless of g, the tax rate differential is systematically lower under origin taxation than it is under destination taxation, i.e. $\widehat{t}_B^O - \widehat{t}_A^O < \widehat{t}_B^D - \widehat{t}_A^D$. Proposition 5 summarizes this finding.

Proposition 5 *Whether parallel imports take place or not in both regimes, origin tax rates are more similar than the corresponding destination tax rates.*

Proof. *See Appendix 3.* ■

The comparison of the tax levels, however, says nothing about the desirability of a tax regime as compared to the other. Therefore, we now investigate the welfare properties of the two commodity tax regimes in the presence or not of parallel imports.

Country A and B's equilibrium welfare levels can be found by using (4) and (5) for the destination tax case, and (12) and (13) for the origin tax case once the equilibrium values of the endogenous variables are taken into account. Appendix 4 also derives the corresponding equilibrium welfare levels when there is no parallel imports. Proposition 6 summarizes the results based on the welfare comparisons.

Proposition 6 *In the presence of parallel imports in both regimes, each country generally prefers having an origin- to a destination-based tax. However, if each country could choose whether or not to have parallel imports, they would generally have no parallel import under destination taxes, and disagree about it under origin taxes. Finally, given parallel imports, a supranational authority always chooses origin-based taxes.*

Proof. *See Appendix 4.* ■

Figures 3 and 4 illustrate these results.

Figures 3 and 4: about here

The first statement comes from the fact that the welfare level in country B is always higher under origin taxes than under destination taxes, i.e., for any g, $W_B^O > W_B^D$. A similar ranking holds for country A, provided that the fringe producers cannot easily expand production (i.e, high d/b) or g is sufficiently high. This implies that, if the tax regime was a choice, the two countries would choose origin taxes provided the fringe producers remain small. The second statement comes from the fact that the introduction of parallel imports are beneficial to country A if taxes are origin based (i.e., $\widehat{W}_A^O(g \leq g^O) > \widehat{W}_A^O(g \geq g^O)$), but are generally detrimental if taxes are destination based (i.e., $\widehat{W}_A^D(g \leq g^D) < \widehat{W}_A^D(g \geq g^D)$). For country B, the introduction of parallel imports is detrimental regardless of the tax regime. Thus, if the level of transaction cost on parallel import was a choice, country B would always choose g high enough to avoid parallel imports under both tax regimes. Country A however would always choose g so as to have parallel imports ($g < g^D$) under the origin-based tax regime, while it would generally set a high g under destination taxes so as to avoid parallel imports.

Finally, the third statement comes from the fact that, given parallel imports, *total* welfare is always higher under origin taxes than under destination taxes. Thus, in the presence of parallel imports, a supranational authority (such as the EU) always prefers origin-based to destination-based taxation. Along with the second statement, this suggests that introducing both parallel imports and origin-based taxation by a supranational authority involves some redistribution to get a strict Pareto improvement.

5 Conclusions

Economic integration can take several forms. One of them is to encourage parallel imports as the EU has repeatedly done over the last decades. If this form of economic integration has been considered as important, it is because many markets are vertically related and thus not only manufacturers take decisions about given products, but wholesalers and retailers as well. Indeed, there is little point to liberalize standard barriers to trade if, at the same time, contractual arrangements contribute to segment markets and prevent or limit trade from taking place. Making parallel imports legal at the level of the European Union has made market segmentation more difficult and thus has made more effective the liberalization of barriers to trade.

This paper shows that the existence of parallel imports is not without consequences on the choice of commodity tax regime. In particular, we argue that, in a world in which free trade prevails for authorized products, the existence of parallel imports brings about a tax convergence between trading countries, a narrower range of tax levels, and a higher aggregate level of welfare when commodity taxation is origin based. This is in sharp contrast with the case of destination-based taxes where parallel imports are shown to bring a tax divergence. Thus, by including non-cooperative taxes into a model of parallel imports, we show that origin taxation is preferable to destination taxation in a setup where markets are not perfectly integrated. Moreover, we show that this superiority of origin taxes comes with extra windfalls: narrower tax levels and country tax rates convergence. Thus, the superiority of origin taxes does not conflict with the desire to bring tax rates closer to each other. To our knowledge, this is a novel result in the literature.

Whether it is the case that the flows of parallel imports are significant enough to influence the setting of tax policies is an open question. While there are ample evidence that parallel imports are important in several sectors — sectors that indeed are imperfectly competitive, e.g. pharmaceuticals — the larger bulk of trade is not of the parallel-import type. Still, our model indicates that if market integration initiatives seek to increase the volume of parallel imports, then taxes are affected. The main reason is the fact that more parallel imports modify manufacturers' and retailers' incentives and thus benevolent governments' incentives. Importantly, parallel imports affect incentives differently depending if the tax regime is destination- or origin-based. It is these differences that explain why the normative consequence of parallel imports make origin taxation superior to destination taxation. Such a result should be of interest to the general debate concerning the optimal commodity tax base. In this sense, our paper adds another argument in favour of origin taxation — a taxation principle that, as we know, performs quite well in imperfectly competitive markets (Keen and Lahiri; 1993, 1998).

The research agenda that we have proposed here points towards tax competition models that lead to a tax convergence/harmonization as an endogenous reaction to the countries' choices. Tax harmonization as a policy that the countries would happily implement, has not been very successful in practice. Countries protect their right to choose taxes, and perhaps we should try to find mechanisms that give them an incentive to choose similar taxes. Market integration through the encouragement of parallel imports is the mechanism that we have proposed in this paper. However, other mechanisms may also exist.

Appendix 1: Destination taxes

Solving stages 3 and 2, (8) takes the following form:

$$
\begin{aligned}
q_A(g, t_A^D) &= \frac{a(5d+3b)+g(7d+3b)-t_A^D(5d+3b)}{b(9b+13d)} \\
q_B(g, t_A^D, t_B^D) &= \frac{a(7b+11d)-8g(b+d)+2t_A^D(b+d)-t_B^D(9b+13d)}{2b(9b+13d)} \\
m(g, t_A^D) &= \frac{3a(b+d)-g(6b+14d)-3t_A^D(b+d)}{b(9b+13d)} \\
\tilde{q}(g, t_A^D, t_B^D) &= \frac{a(11b+15d)+8g(b+d)-2t_A^D(b+d)-t_B^D(9b+13d)}{2(b+d)(9b+13d)}
\end{aligned}
$$

Using these expressions, stage 1 tax equilibrium levels are:

$$
\begin{aligned}
\widehat{t}_A^D &= -\frac{2a(9b^2+19d^2+26bd)+g(9d^2-9b^2-8bd)}{2(18b^2+33d^2+49bd)} \\
\widehat{t}_B^D &= \frac{aX-3gY}{(18b^2+33d^2+49bd)Z}
\end{aligned}
$$

where

$$
\begin{aligned}
X &= 72b^4(b-1)+25d^4(2b-1)+bd^3(211b-151)+4b^3d(67b-64) \\
&\quad +b^2d^2(359b-312); \\
Y &= 7d^4(2b-1)+bd^3(45b-26)+b^2d^2(46b-29)+5b^3d(3b-2); \\
Z &= d^2(4b-1)+db(11b-4)+4b^2(2b-1).
\end{aligned}
$$

Note that for $b \geqslant 1$, X, Y and Z are unambiguously positive.

Proof of Proposition 2: Substituting $\widehat{t}_A^D$ into (8) gives

$$\widehat{m} = \frac{6a(3b^2 + 7bd + 4d^2) - g(27b^2 + 88bd + 69d^2)}{2b(18b^2 + 49bd + 33d^2)}$$

It follows that

$$\widehat{m} \geq 0 \qquad \text{if} \qquad g \leq g^D = \frac{6a(3b^2 + 7bd + 4d^2)}{27b^2 + 88bd + 69d^2}$$

To show that country A always imposes a subsidy and country B always imposes a tax, consider $g = 0$ and $g = g^D$. It is straightforward, though tedious, to show that whether $g = 0$ or $g = g^D$, $\widehat{t}_A^D < 0$ and $\widehat{t}_B^D > 0$. Since both $\widehat{t}_A^D$ and $\widehat{t}_B^D$ are linear in g, it follows that $\widehat{t}_A^D < 0$ and $\widehat{t}_B^D > 0$ over $0 \leq g \leq g^D$.

Finally, evaluating how the tax differential changes with g, we get:

$$\begin{aligned} \frac{d(\widehat{t}_B^D - \widehat{t}_A^D)}{dg} &= -\frac{1}{(18b^2 + 33d^2 + 49bd)Z}[36b^4(2b-1) + b^3d(253b - 128) \\ &\quad + b^2d^2(328b - 179) + bd^3(203b - 128) + d^4(48b - 33)], \end{aligned}$$

which is unambiguously negative for $b \geq 1$. That is, as g falls, the tax difference increases. *QED*

Appendix 2: Origin taxes

The corresponding quantities for the origin case are:

$$\begin{aligned} q_A &= \frac{a(5d + 3b) + g(7d + 3b) - t_A^O(5d + 3b)}{b(9b + 13d)} \\ q_B &= \frac{ad(7b + 11d) - 8gd(b + d) - t_A^O(9b^2 + 11d^2 + 20db) + bt_B^O(9b + 13d)}{2bd(9b + 13d)} \\ m &= \frac{3a(b + d) - g(6b + 14d) - 3t_A^O(b + d)}{b(9b + 13d)} \\ \tilde{q} &= \frac{ad(11b + 15d) + 8dg(b + d) + t_A^O(11d^2 + 20db + 9b^2) - t_B^O(26d^2 + 31db + 9b^2)}{2d(b + d)(9b + 13d)} \end{aligned}$$

Welfare maximization in each country leads to:

$$\begin{aligned}
\widehat{t}_A^O &= -2d\frac{a(27b^2+74bd+51d^2)+g(27b^2+80bd+61d^2)}{81b^3+351b^2d+511bd^2+249d^3} \\
\widehat{t}_B^O &= -d\frac{aK-2gL}{(81b^3+351b^2d+511bd^2+249d^3)(3b+4d)}.
\end{aligned} \tag{18}$$

where

$$\begin{aligned}
K &= 117b^3+471b^2d+643bd^2+297d^3; \\
L &= 9b^3+39b^2d+55bd^2+25d^3.
\end{aligned}$$

It is straightforward to see that for any $a, b, d > 0$, the equilibrium is characterised by production subsidies in both countries.

Proof of Proposition 4: Substituting $\widehat{t}_A^O$ into (14), we can show that

$$\widehat{m} \geq 0 \qquad \text{if} \qquad g \leq g^O = \frac{3a(9b^3+41b^2d+59bd^2+27d^3)}{54b^3+264b^2d+434bd^2+240d^3}.$$

To show that both countries always impose a subsidy, consider $g=0$ and $g=g_p^O$. It is straightforward to show that when $g=0$ and $g=g^O$, both $\widehat{t}_A^O$ and $\widehat{t}_B^O$ are negative. Since both $\widehat{t}_A^O$ and $\widehat{t}_B^O$ are linear in g, it follows that $\widehat{t}_A^O < 0$ and $\widehat{t}_B^O < 0$ over $0 \leq g \leq g^O$.

Finally, tax rates converge when g falls since

$$\frac{d(\widehat{t}_B^O - \widehat{t}_A^O)}{dg} = \frac{2d(90b^3+387b^2d+558bd^2+269d^3)}{(3b+4d)(81b^3+351b^2d+511bd^2+249d^3)} > 0$$

. *QED*

Appendix 3: Proof of Proposition 5

First notice that, irrespective of $a, b, d > 0$,

$$g^O - g^D = -\frac{3a(81b^5+441db^4+910b^3d^2+878b^2d^3+385d^4b+57d^5)}{2(27b^2+88bd+69d^2)(27b^3+132db^2+217bd^2+120d^3)} < 0.$$

Thus, $0 \leq g \leq g^O$ is the relevant range over which parallel imports exist regardless of the tax regime. Second, from Proposition 2, we know that $t_B^D > 0$, and from Proposition 4, $t_B^O < 0$, thus $t_B^D > t_B^O$. Third, we can then show that for $g = 0$,

$$\widehat{t}_B^O - \widehat{t}_A^O = \frac{3ad(15b^3 + 63db^2 + 85bd^2 + 37d^3)}{(511bd^2 + 351db^2 + 249d^3 + 81b^3)(4d + 3b)} > 0,$$

and for $g = g^O$,

$$\widehat{t}_B^O - \widehat{t}_A^O = \frac{3ad(15b^3 + 69db^2 + 101d^2b + 47d^3)}{(4d + 3b)(27b^3 + 132db^2 + 217d^2b + 120d^3)} > 0.$$

Since $\widehat{t}_B^O - \widehat{t}_A^O$ is linear in g, it follows that $\widehat{t}_B^O > \widehat{t}_A^O$ in the region with parallel imports.

Fourth, we can also show that for $g = 0$

$$\widehat{t}_A^O - \widehat{t}_A^D = \frac{a(6301bd^4 + 11326b^2d^3 + 9954b^3d^2 + 4293db^4 + 1365d^5 + 729b^5)}{(511bd^2 + 351db^2 + 249d^3 + 81b^3)(33d^2 + 49bd + 18b^2)} > 0,$$

and for $g = g^O$

$$\widehat{t}_A^O - \widehat{t}_A^D = \frac{a(741d^5 + 4777d^4b + 10102b^2d^3 + 9630b^3d^2 + 4293db^4 + 729b^5)}{4(27b^3 + 132db^2 + 217bd^2 + 120d^3)(33d^2 + 49bd + 18b^2)} > 0.$$

Since $\widehat{t}_A^O - \widehat{t}_A^D$ is linear in g, it follows that $\widehat{t}_A^O > \widehat{t}_A^D$ in the region with parallel imports.

Finally, in the region with no parallel imports, we know that

$$\widehat{t}_B^D = \frac{ad}{4b + 3d} > \widehat{t}_B^O = -\frac{ad}{2b + 3d} = \widehat{t}_A^O > \widehat{t}_A^D = -a$$

Hence, whether parallel imports take place or not in both regimes, we have $\widehat{t}_B^D > \widehat{t}_B^O \geq \widehat{t}_A^O > \widehat{t}_A^D$. *QED*

Appendix 4: Proof of Proposition 6

In the equilibrium with parallel imports, the welfare levels in the destination- and in the origin-based regimes are respectively

$$\widehat{W}_A^D(g \leq g^D) = \frac{1}{D^D}(a^2 A_A^D + agB_A^D + g^2 C_A^D);$$
$$\widehat{W}_B^D(g \leq g^D) = \frac{1}{D^D}(a^2 A_B^D + agB_B^D + g^2 C_B^D);$$

$$\widehat{W}_A^O(g \leq g^O) = \frac{1}{D^O}\left(a^2 A_A^O + agB_A^O + g^2 C_A^O\right);$$
$$\widehat{W}_B^O(g \leq g^O) = \frac{1}{D^O}\left(a^2 A_B^O + agB_B^O + g^2 C_B^O\right),$$

with $A_i^j > 0$, $B_i^J < 0$, $C_i^j > 0$ and $D^j > 0$ ($i = A, B$ and $j = D, O$) when $b \geq 1$. These are all highly non-linear polynomials in b and d that are not reported here (but are available upon request).

The first statement of the proposition requires that $\widehat{W}_A^O(g \leq g^O) > \widehat{W}_A^D(g \leq g^O)$ and $\widehat{W}_B^O(g \leq g^O) > \widehat{W}_B^D(g \leq g^O)$. The first inequality holds provided that d/b is sufficiently large or g is sufficiently close to g^O, while the second inequality holds for all feasible values of a, b, d and g consistent with parallel imports in both regimes.

The second statement also depends on the equilibrium level of welfare in the absence of parallel imports in the destination and in the origin cases. They are respectively:

$$\widehat{W}_A^D(g \geq g^D) = \frac{a^2(11d^3 + 41d^2b + 48db^2 + 16b^3)}{2b(d+b)(3d+4b)^2};$$
$$\widehat{W}_B^D(g \geq g^D) = \frac{a^2(d+2b)^2}{2b(d+b)(3d+4b)};$$
$$\widehat{W}_A^O(g \geq g^O) = \frac{a^2(b+2d)(7bd+3b^2+6d^2)}{2b(d+b)(3d+2b)^2};$$
$$\widehat{W}_B^O(g \geq g^O) = \frac{a^2(2d^2+7bd+4b^2)(b+2d)}{2b(b+d)(3d+2b)^2}.$$

Given these expressions it can be shown that:

1. $\widehat{W}_A^D(g \leq g^D) < \widehat{W}_A^D(g \geq g^D)$ unless d is sufficiently high and g is low, while $\widehat{W}_B^D(g \leq g^D) < \widehat{W}_B^D(g \geq g^D)$ for all feasible values of $a, b, d \geq 0$.

2. $\widehat{W}_A^O(g \leq g^O) > \widehat{W}_A^O(g \geq g^O)$ and $\widehat{W}_B^O(g \leq g^O) < \widehat{W}_B^O(g \geq g^O)$ irrespective of $a, b, d > 0$.

The third statement requires $\sum \widehat{W}_i^O(g \leq g^O) > \sum \widehat{W}_i^D(g \leq g^O)$ which holds irrespective of a, b, d and g. *QED*

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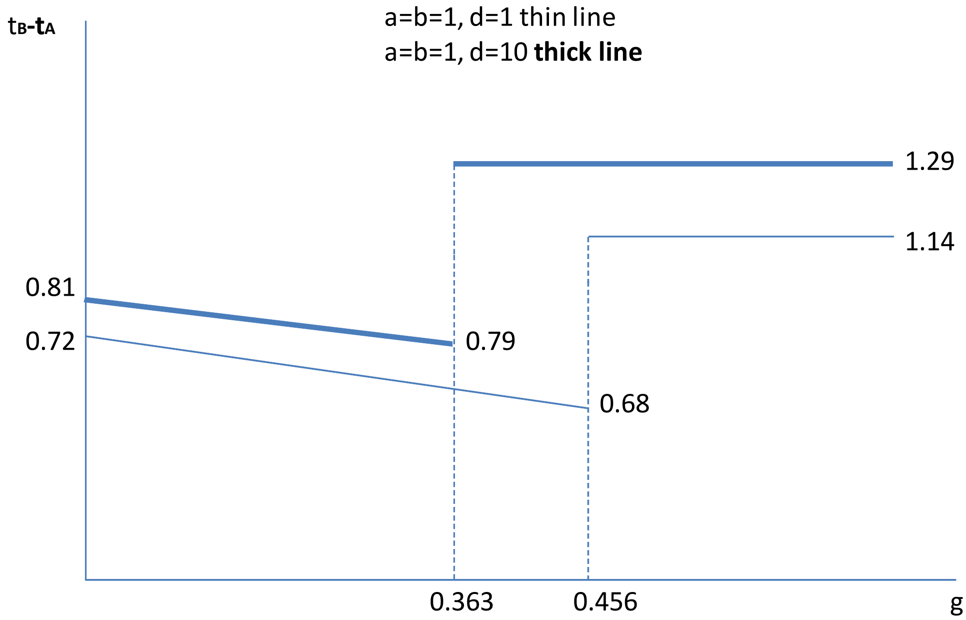

Figure 1: Destination-tax differential

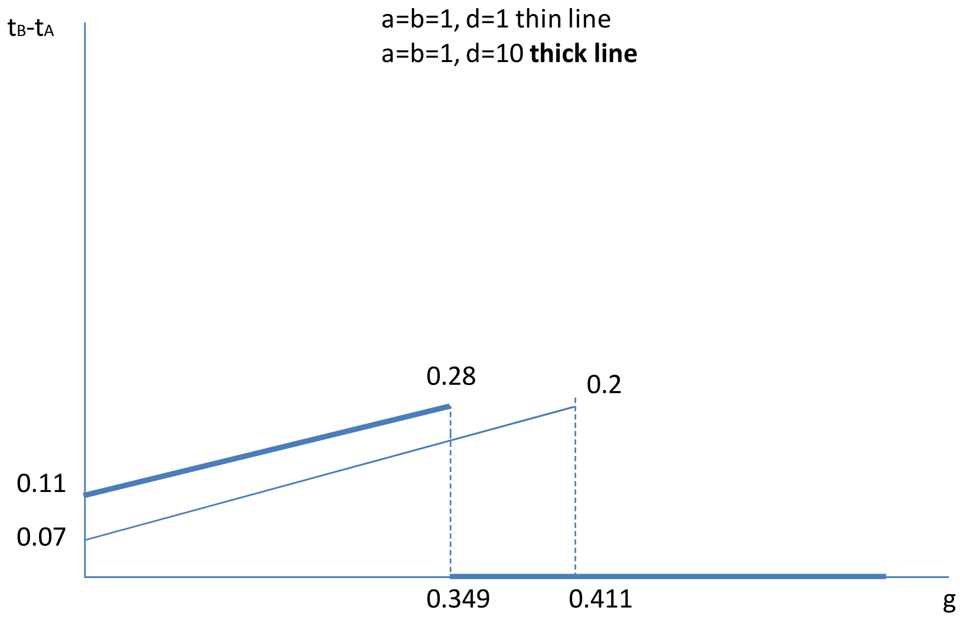

Figure 2: Origin-tax differential

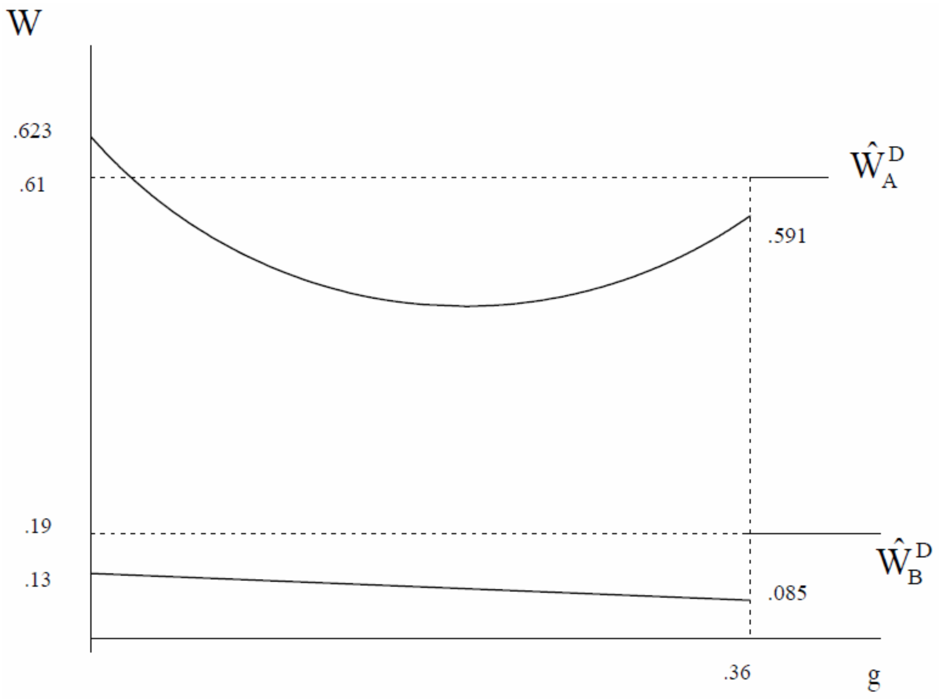

Figure 3: Welfare under destination taxes (a=b=1, d=10)

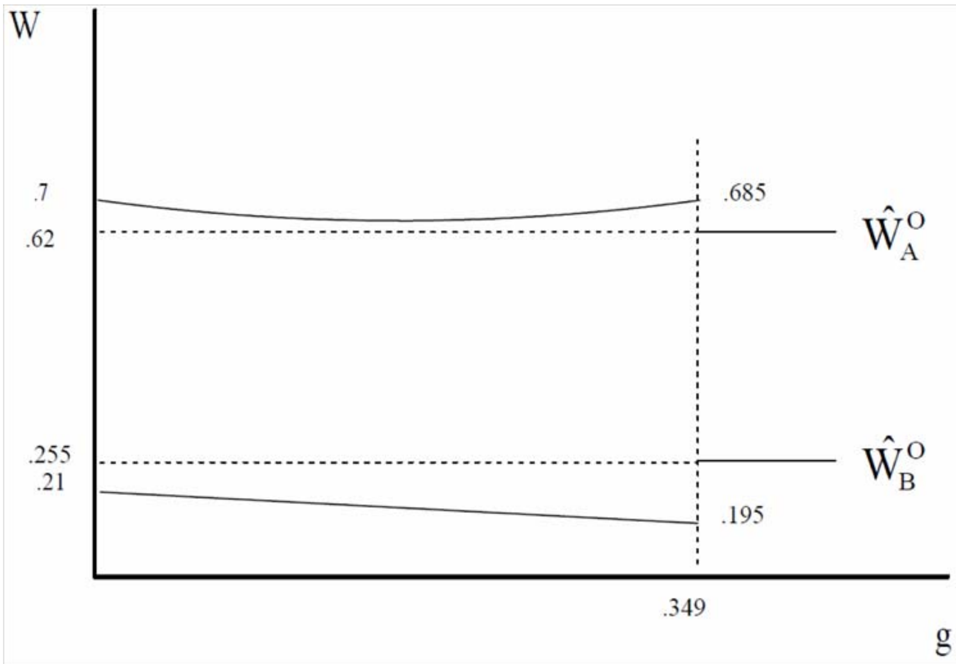

Figure 4: Welfare under origin taxes (a=b=1, d=10)

Supplementary note for the referees: (not for publication)

This note provides the polynomials A_i^j, B_i^j, C_i^j, and D^j ($i = A, B$ and $j = D, O$) used in Appendix 4. A sufficient (but not necessary) condition for their sign is $b \geq 1$.

$$\begin{aligned}
A_A^D &= 38304db^7 + 216916d^4b^4 + d^7b^2(168534b - 86828) + d^6b^3(606778b - 354768) \\
&+d^5b^4(1235130b - 811444) + d^8b(20258b - 9104) + d^3b^6(1241524b - 997472) \\
&+20736b^9(b-1) + db^8(171360b - 160992) + d^4b^5(1555544b - 1136408) \\
&+d^2b^7(613236b - 535728) + 5184b^8 + 11808d^7b + 54596d^6b^2 + 139964d^5b^3 \\
&+207704d^3b^5 + 120000d^2b^6 + 1088d^8 > 0
\end{aligned}$$

$$\begin{aligned}
B_A^D &= -d^6b^3(449952b - 289734) - d^4b^5(13484416b - 1060548) - d^8b(12396b - 5862) \\
&-20736b^9(b-1) - d^5b^4(996762b - 716406) - d^7b^2(113742b - 63906) \\
&-d^3b^6(1139328b - 965976) - d^2b^7(587100b - 530400) - 119424d^2b^6 \\
&-822d^8 - 168768b^9d + 160992b^8d - 9888d^7b - 49014d^6b^2 - 5184b^8 \\
&-131520d^5b^3 - 209820d^4b^4 - 38304b^7d - 204552d^3b^5 < 0
\end{aligned}$$

$$\begin{aligned}
C_A^D &= d^6b^3(874288b - 573902) + d^4b^5(2178713b - 1722544) + d^7b^2(246432b - 144366) \\
&+d^5b^4(1756093b - 1273422) + d^8b(30186b - 15534) + d^2b^7(821701b - 745156) \\
&+25920b^9(b-1) + d^3b^6(1705787b - 1452476) + db^8(222480b - 212760) \\
&+21099d^7b + 92815d^6b^2 + 306350d^3b^5 + 50760db^7 + 335829d^4b^4 \\
&+2052d^8 + 168064d^2b^6 + 6480b^8 + 227015d^5b^3 > 0
\end{aligned}$$

$$\begin{aligned}
A_B^D &= d^5(5706b - 64) + d^4b(17857b - 224) + d^3b^2(26660b - 292) + 625d^6 \\
&+d^2b^3(20800b - 168) + db^4(8208b - 36) + 1296b^6 > 0
\end{aligned}$$

$$\begin{aligned}
B_B^D &= -1050d^6 - 3984d^5b - 5880d^4b^2 - 4188d^3b^3 - 1422d^2b^4 - 180db^5 \\
&-1164d^4b - 1500d^3b^2 - 852d^2b^3 - 180db^4 - 336d^5 < 0
\end{aligned}$$

$$\begin{aligned}
C_B^D &= d^5(2394b - 441) + d^4b(4950b - 1512) + d^3b^2(4932b - 1926) \\
&+d^2b^3(2385b - 1080) + db^4(450b - 225) + 441d^6 > 0
\end{aligned}$$

$$\begin{aligned}
A_A^O &= 1452168d^9 + 52488b^9 + 38756762b^4d^5 + 26818752b^5d^4 + 37640256b^3d^6 \\
&+12469518b^6d^3 + 23689002b^2d^7 + 3754944b^7d^2 + 8764920bd^8 + 664038db^8 > 0
\end{aligned}$$

$$
\begin{aligned}
B_A^O &= -23990040b^3d^6 - 27154172b^4d^5 - 20494416b^5d^4 - 10309356b^6d^3 - 13635220b^2d^7 \\
&\quad -3331800b^7d^2 - 4526904bd^8 - 627588db^8 - 52488b^9 - 669312d^9 < 0
\end{aligned}
$$

$$
\begin{aligned}
C_A^O &= 1836624d^9 + 32735383d^7b^2 + 53529301d^6b^3 + 72171b^9 + 56137091d^5b^4 \\
&\quad +39162009d^4b^5 + 11647496d^8b + 18175941d^3b^6 + 5412447d^2b^7 + 938385db^8 > 0
\end{aligned}
$$

$$
\begin{aligned}
A_B^O &= 3951504b^4d^4 + 3875537b^3d^5 + 2503629b^5d^3 + 2279080b^2d^6 + 969300b^6d^2 \\
&\quad +718155bd^7 + 210519db^7 + 88209d^8 + 19683b^8 > 0
\end{aligned}
$$

$$
\begin{aligned}
B_B^O &= -461212b^3d^5 - 348684b^4d^4 - 157572b^5d^3 - 364532b^2d^6 - 39420b^6d^2 \\
&\quad -159340bd^7 - 4212db^7 - 29700d^8 < 0
\end{aligned}
$$

$$
\begin{aligned}
C_B^O &= 30900d^6b^2 + 38860d^5b^3 + 29004d^4b^4 + 13500d^7b + 12852d^3b^5 \\
&\quad +3132d^2b^6 + 324db^7 + 2500d^8 > 0
\end{aligned}
$$

$$
\begin{aligned}
D^D &= 2b(d^2(4b-1) + bd(11b-4) + 4b^2(2b-1))^2(33d^2 + 49bd + 18b^2)^2 > 0 \\
D^O &= 2b(d+b)(4d+3b)^2(511bd^2 + 351db^2 + 249d^3 + 81b^3)^2 > 0
\end{aligned}
$$