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product quality**

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ABSTRACT

It is widely argued that international arbitrage, or parallel trade (PT), trades off static against dynamic efficiency so that, compared with a national exhaustion regime of intellectual property rights, worldwide consumer surplus rises at the expense of R&D investment. We show that this common wisdom is rather the exception than the rule. Indeed, quality investment often rises under international exhaustion, since it strengthens vertical differentiation between the original product and parallel imports. In this case, there is no trade-off at all, so that encouraging PT improves welfare, or the reverse trade-off occurs where investment increases and consumer surplus declines, while PT has ambiguous welfare effects. We find that, when allowed to use dual pricing, the R&D firm artificially restores national exhaustion. We also find that the expected trade-off never occurs under non-linear pricing and when the foreign country is regulated, although in such cases welfare rises when PT is banned.

JEL Classification: L12, L43, F15, O34

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1. Introduction

In a long-running antitrust case, the European Court of Justice (ECJ) recently confirmed that the GlaxoSmithKline's (GSK's) practice of agreeing differentiated prices with Spanish wholesalers for certain medicinal products, according to whether those products were resold in Spain or exported to other European Union (EU) Member States (the so-called dual pricing system), is anti-competitive.¹

In so doing, GSK aimed at restricting parallel trade (henceforth, PT) in its medicines, in which Spanish intermediaries were engaging on account of the price differentials between Spain and other EU countries. PT relates to arbitrage operations in international trade. It refers to the purchase of patented or trademarked goods in one country, and the subsequent export of those goods to another country, without the consent of the patent or trademark owner.² The ECJ definitely stated that agreements aimed at limiting the practice of PT have as their object the prevention of competition.³

Nonetheless, the ECJ also invited the European Commission to take account of the nature and specific features of the sector concerned, and reconsider whether GSK's sales conditions in Spain may be exempted from competition rules since they contribute to promoting technical progress.⁴

¹ *GSK Services Unlimited vs. European Commission and Others*, Joined Cases C-501/06P etc., October 2009. GSK's dual pricing system entered into force in 1998, while the European Commission's first decision dates back to 2001.

² In 2008, PT in pharmaceuticals in the EU was estimated to amount to € 4,400 million at ex-factory prices, and the share of PT in pharmacy market sales has reached 16.5% in Denmark, 15.5% in Sweden, and 11.7% in UK (EFPIA, 2010). For some prominent patented drugs, PT has reached market shares above 50% (Kanavos and Costa-Font, 2005). Evidence shows that PT has gained importance in the software industry, consumer electronics, and musical recordings.

³ The exercise of PT hinges on Article 6 of the World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which leaves each state free to establish its own regime for the exhaustion of intellectual property rights (IPR). In this setting, the EU has adopted a regional exhaustion regime in which IPR are ended upon first sale within Member States, thus allowing free circulation of goods among them, but are not exhausted outside the region. United States have chosen national exhaustion, where IPR hold if the good is imported from abroad. Conversely, most developing countries have opted for international exhaustion with complete trade liberalization.

⁴ In related antitrust cases, the ECJ ruled largely in favour of quantity restrictions unilaterally imposed by pharmaceutical firms such as GSK and Bayer on distributors in low-price countries (Greece, Spain, or France) to curtail re-imports of specific drugs in high-price countries (mostly the UK), the so-called quota schemes (*Lélos Kai Sia EE and Others vs. GSK AEVE*, Joined Cases C-468/06 to C-478/06, September 2008; *Bundesverband der Arzneimittel-Importeure and European Commission vs. Bayer AG*, Joined Cases C-2/01P and C-3/01P, January 2004). However, in taking its decisions, the ECJ avoided any assessment of the impact of PT on firms' R&D incentives.

Thus, the Commission is asked to assess whether GSK's sales conditions are such that dynamic efficiencies from innovation may offset static inefficiencies due to restricted competition.

According to the ECJ's decision, PT poses a policy dilemma. A critical issue is the adverse effect that PT may produce on R&D investment. Research-based firms are generally hostile towards PT, since it interferes with IPR protection granted by patents and third-degree price discrimination strategies. Firms' concern about revenue for R&D investment is even higher in a regulated setting, where PT stems from different price controls set by national governments (as in pharmaceuticals).

In this paper, we investigate whether these arguments find theoretical support. Our purpose is to shed light on the following issues: i) Does the choice of regime for exhaustion of IPR indeed create a trade-off between static and dynamic gains, namely, between aggregate consumer surplus and R&D investment in the relevant countries?; ii) Does this trade-off (if any) always materialize in the expected form, namely, PT raises aggregate consumer surplus while reducing R&D investment, or rather the unexpected reverse trade-off may arise? iii) How do the results depend on the vertical contract (linear pricing, dual pricing, or two-part tariff) between manufacturers and wholesalers, or on whether or not prices are regulated? iv) What are the main policy implications from the analysis?

For this purpose, we set up a simple model where a profit-maximizing manufacturer sells to a controlled retail subsidiary in the domestic market, and in the foreign market to an independent firm at a linear wholesale price. The manufacturer invests to improve input quality. We assume that each downstream entity has a firm-specific ability to use the improved input and obtain a value-added product matching local tastes and needs. This results in product differentiation by country. The independent firm may parallel export the product to the manufacturer's own market, where there is downstream Cournot competition. Domestic consumers perceive the re-imported product as a low-quality substitute since it is less suitable to consumption, or it comes without warranty.⁵

⁵ For example, pharmaceutical manufacturers often decide to sell the same chemical with different dosage forms and strengths in different countries. Thus, independent foreign distributors differ in their ability to provide product varieties, and only the integrated entity is able to offer the complete set of products at home.

We obtain some results that run contrary to the prevailing wisdom. Indeed, we find that quality investment may be higher in a regime of international exhaustion than national exhaustion of IPR. The rationale is that quality investment spurs vertical differentiation between the original and the re-imported product, and thus benefits the R&D firm by limiting the scope for profit-reducing PT.

First, we show that, if the re-imported product quality is high enough, then the manufacturer chooses a combination of R&D investment and wholesale price that allows PT. While a high quality makes the re-imported product more competitive, it also raises consumers' valuation in the foreign market, and the manufacturer's overall quantity sold. For a quadratic R&D investment cost, the manufacturer gains from an equilibrium with a positive amount of PT.

Then, we show that quality investment is higher in the presence of PT than under national exhaustion when the R&D firm can effectively manage the impact of PT, that is, when the arbitrage cost is high enough, or the re-imported product quality is not too high. In this parameter region, there are two alternative cases. The first is that there is no trade-off at all between static and dynamic efficiency, since PT raises both quality investment and aggregate consumer surplus in the two countries. Hence, international exhaustion of IPR is the optimal choice of regime in terms of global welfare. The second case is that the unexpected reverse trade-off occurs where PT increases investment, but at the expense of aggregate consumer surplus. This case arises for the highest feasible values of the arbitrage cost, or the lowest feasible values of the re-imported product quality. In such a case, welfare implications are ambiguous.⁶

We also extend the model to check the robustness of our results to some deviations from our basic assumptions. First, we assume that the manufacturer offers the distributor different wholesale prices for the product, depending on whether it is sold in the foreign country or parallel exported. We find that such a dual pricing system perfectly replicates the outcome of a regime of IPR national exhaustion, so that welfare effects are the same as those with a ban on PT.

⁶ When the re-imported product quality is sufficiently low, the manufacturer finds it optimal to deter PT. In such a case, if PT is a credible threat then the manufacturer always has to invest more than under national exhaustion. This ensures that the trade-off between R&D investment and aggregate consumer surplus (if any) never arises in the expected form.

Second, we assume that the manufacturer offers a two-part tariff instead of a uniform wholesale price. We find that PT, or the threat thereof, reduces both R&D investment and aggregate consumer surplus in the two countries. Indeed, under national exhaustion the manufacturer achieves vertical efficiency by setting the wholesale price at marginal cost (independent of R&D investment), and thus realizes the industry monopoly profit. Conversely, under international exhaustion a higher investment would call for a higher wholesale price, which in turn would reduce vertical efficiency and the industry profit.

Third, we assume that there is a regulator in the foreign market that controls both the wholesale and the retail price to maximize national welfare.⁷ Under national exhaustion, the regulator sets the wholesale price at marginal cost.⁸ We find that, while PT affects the regulated prices, it does not alter the R&D firm's investment incentives. Indeed, should the foreign market be served, the regulator has to raise the wholesale price so as to compensate for the R&D firm's opportunity cost of selling abroad, that is, the retail profit loss due to parallel imports in the domestic market. Hence, the R&D firm's profit under international exhaustion is the same as under national exhaustion.⁹ Due to the higher wholesale price, worldwide consumer surplus is lower than under national exhaustion.

Thus, both with non-linear pricing and price regulation, there is no room for the expected trade-off between investment and surplus. Different from the basic model (or the case of dual pricing), in these model variants policy implications are clear-cut, since PT should be banned to raise welfare.¹⁰

⁷ This is often the relevant case for pharmaceuticals in the EU. For instance, in Spain pharmaceutical companies cannot sell their products at prices above the mandatory maximum prices set by the government, which also sets the margins of wholesalers and pharmacists. Similar price controls are active in France and in Italy.

⁸ In this case the local regulator free-rides on the protection of R&D granted by the manufacturer's domestic country.

⁹ This finding depends on the assumption that the local regulator has limited commitment ability, in the sense that it sets prices when quality investment is already sunk, but cannot force the R&D firm to sell the improved input in the foreign market (in section 5.3, we discuss different assumptions about the regulator's commitment ability). Empirical evidence shows that R&D firms delay the launch of new drugs in low price EU countries to retain revenue in high price countries. Low price countries have raised prices closer to the EU average in response to the growth of PT (Kyle, 2007).

¹⁰ Matteucci and Reverberi (2005) show that if a public service obligation requires the distributor to meet local demand first, then the regulator can improve aggregate consumer surplus by setting a retail price lower than the wholesale price, provided that the distributor recoups national losses through revenue from PT. In such a case, PT might be allowed.

This paper is organized as follows. Section 2 reviews the literature. Section 3 presents the basic assumptions. Section 4 analyzes PT in vertically differentiated products. Section 5 introduces model extensions. Finally, Section 6 concludes. Formal proofs are relegated to the Appendix.

2. Relevant literature

The bulk of the existing literature on PT deals with static efficiency, and identifies the cases where PT raises welfare *ex post* (when R&D investment is sunk). There are two main literature strands, one that relates PT to third-degree retail price discrimination (as in Malueg and Schwartz, 1994), and the other to vertical control issues (as in Maskus and Chen, 2004). The richer setting of vertical relations is well suited to explain why the regime of regional exhaustion of IPR has not led to retail price convergence across EU countries, and why manufacturers may tolerate a certain amount of PT, which indeed is not feasible when PT is assumed to occur in retail markets.¹¹

A number of papers consider the impact of PT on firms' incentive to invest, and thus on welfare *ex ante* (prior to the investment stage). Consistent with more informal analysis (Chard and Mellor, 1989; Danzon and Towse, 2003), these papers argue that PT is harmful to innovation and support the view that trade liberalization achieves static efficiency to the detriment of dynamic efficiency.

Li and Maskus (2006) prove that PT discourages investment in process innovation. They show that, when arbitrage occurs at equilibrium, restricting PT has ambiguous welfare effects, while, when arbitrage is deterred at equilibrium, a ban on PT raises welfare. However, they do not deal with product innovation. Our model does not support their results. We find that quality investment may rise in the presence of PT, and that the simple threat of PT may be welfare enhancing.

Valletti and Szymanski (2006) show that, under international exhaustion, investment in product quality is diluted as much as social welfare is negatively affected. In their model, the threat of PT induces price uniformity between countries so as there cannot be an equilibrium with a positive

¹¹ Ganslandt and Maskus (2007) find that declining trade costs may integrate wholesale markets, where PT is prevalent, even as they push retail markets toward greater segmentation. Raff and Schmitt (2007) show that PT originating at the wholesale level may even raise producers' profits.

flow of parallel imports. Actually, they only consider PT in retail markets and rule out both trade costs and the presence of vertical contracts between manufacturers and distributors.

Rey (2003) argues that, in a regulated setting, PT limits the ability of governments to independently face the trade-off between price and R&D. As a consequence, PT reduces world investment in technology. However, in his model the budget-oriented government does not make different choices of price controls depending on the regime of IPR exhaustion.

There are a few notable exceptions to the prevailing view. Li and Robles (2007) show that PT raises product innovation when the new product is a close substitute for the old one, and the transport costs of the two products are largely different. They assume that R&D investment produces horizontal differentiation, rather than improving product quality. Moreover, their finding holds in an equilibrium with PT in both goods, while manufacturers frequently restrict the scope for PT to the low-quality variant. Finally, they do not analyze the impact of PT on consumer surplus.

Grossman and Lai (2008) claim that the threat of PT induces the foreign government to lighten price controls to persuade the R&D firm to supply the country. This may boost the pace of innovation and the domestic (rather than aggregate) consumer surplus. It is crucial to their finding that the government commits to price before the R&D firm invests. We argue that the government may lose commitment ability when tackling with the motives of multinational firms to influence its decisions (see Veugelers, 1993).¹² We thus reverse the timing of the game and find that, with price regulation, R&D investment is not affected by the exhaustion regime of IPR.

3. The model

An upstream firm M sells an intermediate good in country 1 to a controlled subsidiary at marginal cost, and in country 2 to an independent firm D at a unit wholesale price w .¹³ Firm M has a constant

¹² In our setting, the main leverage of the R&D firm derives from the low capital commitment. Since the firm has not made a sunk investment in the foreign country, then it can withdraw and serve other countries at a negligible exit cost. As far as the firm has a monopoly patent, the distributor has not any sourcing alternative to supply the market. Finally, the firm is less attracted if foreign sales are not a sizeable share of total sales, or if consumers' willingness to pay is low.

¹³ Henceforth, the upstream firm is referred to as "she", the independent firm as "he", and the regulator as "it".

marginal production cost that is normalized to zero without loss of generality. Firm D sells the retail good in country 2 and may parallel export the good to country 1 at a unit transport cost s . For simplicity, all retailing costs are normalized to zero.

Consumers in each country are heterogeneous in their willingness to pay (henceforth, wtp) z_j ($j=1,2$) for the basic product. We assume that z_j is uniformly distributed between $-\infty$ and $\alpha_j > 0$, so as to avoid corner solutions with full market participation. We assume that $\alpha_1 = a > \alpha_2 = 1$. Hence, the reservation price for the basic product is higher in country 1 (that is, the “rich” country) than in country 2 (that is, the “poor” country). We also assume that $a \leq 2$, so as to limit the cross-country difference in the reservation price.¹⁴

Firm M invests in improving the quality of the good at cost $C(x) = x^2/2$, where $x \geq 0$ is the level of investment. Consumers in each country are homogeneous in evaluating the quality improvement of the basic product. We assume that each downstream entity has a firm-specific ability to transform input into output and thus offer a value-added retail product. It follows that retail products are differentiated by country. Due to the upstream firm’s quality investment, the value of the product sold by the downstream firm h ($h=M,D$) rises with $\beta_h x$. Let $\beta_M = 1 > \beta_D = \beta > 0$. Hence, the demand side spillover from the upstream firm’s investment to her controlled subsidiary is higher than the one to the independent firm. It follows that consumers’ valuation of the enhanced product in country j is $z_j + \beta_h x$, depending on which downstream firm h they purchase from.¹⁵

Assume that PT is not banned. In country 1, a consumer of type z_1 buys the domestic product instead of the re-imported product from country 2 when $z_1 + x - p_1 > z_1 + \beta x - p_t$, where p_1, p_t are the retail prices respectively of the domestic and the traded product (when net utilities are both negative, the consumer will not buy at all). If firm M and firm D are active in market 1 then quality-adjusted prices are such that $p_1 - x = p_t - \beta x = P_1$, so that consumer types $z_1 \geq P_1$ enter the market.

¹⁴ For instance, this assumption is well suited to the “old” EU 15 Member States.

¹⁵ The demand structure follows Katz and Shapiro (1985) and Foros (2004).

Due to the uniform distribution of consumers, there are $a - P_1$ active consumers. Hence $Q_1 = a - P_1$ must hold, where $Q_1 = q_1 + q_t$ is the quantity sold in country 1 respectively by firm M 's subsidiary and firm D . It follows that the inverse demand curves faced by the two firms are respectively $p_1 = a_1 - Q_1 = a + x - q_1 - q_t$ and $p_t = a_t - Q_1 = a + \beta x - q_1 - q_t$.¹⁶ In country 2, where firm D is a monopoly, a consumer of type z_2 buys when $z_2 + \beta x - p_2 \geq 0$, where p_2 is the retail price. By the above reasoning, the inverse demand curve faced by firm D is $p_2 = a_2 - q_2 = 1 + \beta x - q_2$.

Firms' profit functions are $\pi_M^i = p_1 q_1 + w(q_2 + q_t) - x^2/2$ and $\pi_D^i = (p_t - w - s)q_t + (p_2 - w)q_2$, where in the latter we distinguish net revenue from PT and net revenue in market 2 (superscript i stands for international exhaustion). Finally, $S_1^i = (q_1 + q_t)^2/2$ and $S_2^i = q_2^2/2$ are the consumer surplus respectively in country 1 and in country 2, while $S^i = S_1^i + S_2^i$ is the worldwide consumer surplus.

When PT is banned, firms' profit functions simply reduce to $\pi_M^n = p_1 q_1 + w q_2 - x^2/2$ and $\pi_D^n = (p_2 - w)q_2$, while $S_j^n = q_j^2/2$ is the consumer surplus in country j ($j = 1, 2$) and $S^n = S_1^n + S_2^n$ is the worldwide consumer surplus (superscript n stands for national exhaustion).

In what follows, we rule out the naïve case where PT is not a credible threat. In such a case, PT would be blocked at equilibrium even if firm M does not behave strategically and chooses the same R&D investment and wholesale price as under national exhaustion. This would occur if the arbitrage cost is sufficiently high, or the re-imported product quality is very low. Thus, we require that $s < s^n = 3(a-1)/10$ and $\beta > \beta^n = \frac{1}{2} \left(\frac{7-14a}{10-3a+10s} + \sqrt{\frac{289+52a+100a^2+80(13+a)s+800s^2}{(3a-10(1+s))^2}} \right) > 1/2$. The latter condition also excludes that downstream firms' abilities to offer enhanced products are so different that the upstream firm's quality investment *per se* reduces the re-imported quantity.¹⁷ The above conditions

¹⁶ An increase in x implies parallel upward shifts in demand curves. When $x=0$, firms produce perfect substitutes.

¹⁷ As we will show in the following sections, this assumption does not rule out the possibility that firm M uses a suitable combination of quality investment and wholesale price to foreclose the retail market in country 1.

on cost and quality parameters are tailored to our basic model and are overly restrictive for model variants. However, for clarity, we maintain these parameter restrictions throughout the paper.

The timing of the game is as follows. At the first stage, firm M chooses the level of investment in input quality. At the second stage, firm M sets the wholesale price of the improved input in country 2. At the third stage, firm D sets the price of the retail product in country 2. In country 1, should PT take place firm M and firm D engage in quantity competition, otherwise firm M is a monopoly.¹⁸ The standard solution procedure with complete information is backward induction.

4. Parallel trade in vertically differentiated products

In this section, we analyze the upstream firm's attitude towards PT and the impact of trade liberalization on R&D investment and consumer surplus. For this purpose we derive quality investment and aggregate consumer surplus, first in a regime of national exhaustion of IPR (section 4.1), where markets are legally segmented, and then in a regime of international exhaustion of IPR (section 4.2), where PT may indeed occur. Finally, we compare the results obtained (section 4.3).

4.1 National exhaustion

In this benchmark case, firm M is a monopoly in country 1 and firm D is a monopoly in country 2. At the third stage of the game, the first order condition on each firm's profit with respect to quantity gives $q_1^n = (a+x)/2$, $q_2^n = (1+\beta x-w)/2$, which are the optimal retail quantities in the two countries. At the second stage, the first order condition on firm M 's profit with respect to w gives the optimal wholesale price $w^n = (1+\beta x)/2$. Inserting for w^n , the quantity sold in market 2 is $q_2^n = (1+\beta x)/4$. At the first stage, the first order condition on firm M 's profit with respect to x yields that the optimal quality investment is $x^n = (2a+\beta)/(2-\beta^2)$.¹⁹

¹⁸ An alternative timing where firm M decides simultaneously for x and w would not alter the equilibrium of the game. The proposed timing is however essential for the results when we introduce a local regulator in country 2 (section 5.3).

¹⁹ At each stage of the game, the second order conditions on firms' profits are always fulfilled.

4.2 International exhaustion

Consider now the case where there is a regime of international exhaustion of IPR.²⁰

4.2.1 Third stage: Retail competition

In the case whereby PT is allowed, at the third stage firm M and firm D compete *à la* Cournot in country 1, while firm D is a monopoly in country 2. Hence, the equilibrium quantities are:

$$\begin{cases} q_1^i = (a + s + w)/3 + (2 - \beta)x/3 \\ q_i = (a - 2(s + w))/3 + (2\beta - 1)x/3 \\ q_2^i = (1 - w)/2 + \beta x/2 \end{cases} \quad (1)$$

Thus, the wholesale price w has the expected effect on retail quantities. Since we have assumed that $\beta > \beta^n > 1/2$, that is, cross-country vertical product differentiation is limited, then, for any given w , all retail quantities (including parallel imports) rise with the investment level x .

4.2.2 Second stage: Wholesale price

At the second stage, the first order condition on firm M 's profit with respect to w gives:

$$w^* = w^n + w_i = (1 + \beta x)/2 + (5(a - 1) - 4s)/19 + (1 - \beta)x/19.$$

Note that $w^* = w^*(x)$ is the sum of two terms: the first term $w^n = w^n(x)$ is the optimal wholesale price under national exhaustion, while the second term $w_i = w_i(x) = (5(a - 1) - 4s)/19 + (1 - \beta)x/19$ is related to the effect of PT. Since $w_i \geq 0$ then $w^* \geq w^n$. Hence, for any given investment, firm M has to raise the wholesale price relative to national exhaustion to suitably control parallel imports.

Caution must be paid to the case when markets are artificially segmented. This occurs when, for a given investment x , firm M sets the wholesale price $w^f = w^f(x)$ that deters PT (i.e. such that $q_i(w^f) = 0$), that is, $w^f = (a - 2s)/2 + x(2\beta - 1)/2$.

Both w^* and w^f rise with x . This means that, to effectively control or even deter PT, a higher investment calls for a higher price of the improved input. We have $\partial w^*/\partial x > \partial w^f/\partial x > 0$. Imposing

²⁰ When countries 1 and 2 are in the same *region* (e.g., the EU), this is the same as a regime of regional exhaustion.

$w^* = w^f$ and solving for x , we obtain $x = x' = (3(a-1) - 10s) / 7(1-\beta)$. Hence, $w^* \geq w^f$ when $x \geq x'$.

Provided that markets are segmented, any price above w^f is not profitable to firm M . Therefore, if quality investment is high enough (i.e. $x \geq x'$), then firm M sets $w = w^f$ so as to deter PT, which is otherwise allowed. To sum up, the optimal wholesale price under international exhaustion w^i is:

$$w^i = \begin{cases} w^f = (a - 2s) / 2 + x(2\beta - 1) / 2 & x \geq x' \\ w^* = (1 + \beta x) / 2 + (5(a - 1) - 4s) / 19 + (1 - \beta) x / 19 & x < x' \end{cases} \quad (2)$$

Assume that there is an equilibrium with a positive flow of parallel imports. Inserting for w^* into the equilibrium quantities, we obtain that the optimal quantity sold by firm M in country 1 can be written as $q_1^i = q_1^n - q_t / 2$. Thus, for any given investment, due to the re-imported quantity firm M reduces the quantity sold in country 1 compared with national exhaustion. However, we find that $Q_1^i = q_1^i + q_t = q_1^n + q_t / 2 > q_1^n$, so that the total quantity sold in country 1 is higher with than without PT. We also find that $q_2^i = 2q_2^n - w^* / 2 < q_2^n$ since $q_2^n = w^n / 2$ and $w^* > w^n$, so that, for any given investment, parallel exports reduce the quantity sold in country 2. As expected, both q_1^i and q_2^i rise with x . Conversely, since $q_t = \frac{1}{19}(3(a-1) - 10s - 7(1-\beta)x)$ then quality investment reduces parallel imports in country 1. The motivation is that the higher the investment the higher the quality differential between the domestic product and the re-imported one.

When PT is deterred at equilibrium (i.e. for $w^i = w^f$), we trivially obtain the retail quantities in country 1 by setting $q_t = 0$, and in country 2 by replacing w^* with w^f in the above expressions. Therefore, the equilibrium in country 1 is the same as under national exhaustion, while, due to the higher wholesale price, the simple threat of parallel exports reduces the quantity sold in country 2.

4.2.3 First stage: Quality investment

At the first stage, firm M maximizes her profit with respect to quality investment while anticipating the outcome of the next stages.

Firm M 's profit function at stage one is $\pi_M^i = R_M^i(w^i, x) - C(x)$, where $R_M^i(w^i, x)$ is the revenue under international exhaustion. Since at this stage $C(x)$ is independent of the exhaustion regime, then we can easily obtain that $\pi_M^i = \pi_M^n - \Delta R_M$, where $\Delta R_M = R_M^n(w^n, x) - R_M^i(w^i, x)$ measures the revenue change due to (the threat of) PT relative to national exhaustion.

We know from section 4.2.2 that, if $x \geq x'$, then $w^i = w^f$ and PT is prevented. In such a case, firm M 's revenue change is a loss that derives from increasing the wholesale price over the monopoly price to deter PT, and thus reducing the quantity sold in country 2. Conversely, if $x < x'$, then $w^i = w^*$ and PT is allowed. Hence, firm M 's revenue change is the sum of three terms: (i) the wholesale loss in country 2 at price $w^* > w^n$; (ii) the retail loss in country 1, where parallel imports reduce firm M 's price and quantity sold; (iii) the wholesale gain from parallel exports to country 1.

Formally, we have that ΔR_M is a convex quadratic function in x that, consistent with the outcome of stage two, can be written as:

$$\Delta R_M = \begin{cases} w^n q_2^n - w^f q_2^i & x \geq x' \\ (w^n q_2^n - w^* q_2^i) + (p_1^n q_1^n - p_1^i q_1^i) - w^* q_t & x < x' \end{cases} \quad (3)$$

Inserting for (1) into (3) and rearranging, we have:

$$\Delta R_M = \begin{cases} 1/2 (w^f - w^n)^2 & x \geq x' \\ 1/2 (w^f - w^n)^2 - 19/8 q_t^2 & x < x' \end{cases} \quad (4)$$

so as firm M 's revenue change can be expressed in terms of the wholesale price increase that is necessary to deter PT, and possibly the amount of the re-imported quantity. We can easily show that $\Delta R_M > 0$, that is, firm M 's revenue is always higher under national than international exhaustion.

Let $\partial \pi_M^k / \partial x$ ($k=n, i$) be firm M 's marginal incentive to invest, that is, the increase in firm M 's profit due to a marginal increase in quality investment, respectively under national and international exhaustion. Since there is a unique marginal cost function in x for both regimes, then we can focus on firm M 's revenue. We have that $\Delta R_M > 0$ and $\partial R_M^k(w^k, x) / \partial x > 0$ ($k=n, i$). Hence, to prove that

R&D investment is higher under international than national exhaustion it suffices to check whether and when $\partial\Delta R_M/\partial x < 0$, that is, to find the range of values of x where the marginal incentive to invest is higher in the former than in the latter regime. Proposition 1 summarizes the results.

Proposition 1. When PT is allowed at equilibrium, a sufficient condition for quality investment to rise compared with national exhaustion is that $s > s' = (a-1)/16$. When PT is deterred at equilibrium, quality investment is always higher than under national exhaustion.

We are now able to solve for firm M 's optimal investment under international exhaustion x^i . Consistent with the second stage, we find two classes of equilibria of the game, one where there is a positive amount of parallel imports and the other where PT is only a threat.

If firm D has a sufficiently high ability to use the improved input, then firm M finds it optimal to select a combination of R&D investment and wholesale price that allows PT. This is the outcome of two counteracting forces. On the one hand, if the re-imported product is a close substitute then competition significantly erodes firm M 's retail profit in the domestic market. On the other hand, a higher firm D 's ability to transform input into output raises consumers' wtp in the foreign market and the overall quantity sold by firm M , which in turn increases her wholesale revenue. Since the latter effect offsets the former, then we find an equilibrium with a positive amount of PT. While parallel imports may reduce firm M 's ability to price discriminate between countries, they enable firm M to price discriminate within her country between products of different qualities.

Conversely, if firm D has a limited ability to use the improved input, then firm M raises quality investment and the wholesale price as much as PT is deterred. Indeed, to deter PT firm M slightly modifies her choices relative to the most favorable case of a monopoly under national exhaustion.

The following proposition summarizes the results obtained in the relevant situation where firm M has to behave strategically when she faces the credible threat of PT.

Proposition 2. Under international exhaustion, if the re-imported product quality is sufficiently low then firm M invests to deter PT, which is otherwise allowed. Formally, firm M's investment x^i is:

$$x^i = \begin{cases} x^f = \frac{(2a + \beta) + (a - 1 - 2s)(1 - \beta)}{(2 - \beta^2) + (1 - \beta)^2} \geq x' & \beta^n < \beta \leq \beta^f \\ x^* = \frac{(2a + \beta) + (2(1 - \beta)(16s + 1 - a)/19)}{(2 - \beta^2) - (30(1 - \beta)^2/19)} < x' & \beta^f < \beta < 1 \end{cases} \quad (5)$$

The sketch of the proof is as follows. The first order condition on firm M 's profit with respect to x gives $x = x^*$. Hence, firm M invests $x^i = x^*$ and allows PT provided that $x^* < x'$, that is, when the re-imported product quality is high enough (i.e. $\beta > \beta^f = \beta^f(s)$, where the critical value β^f is found in the Appendix). Alternatively, there is a binding constraint on firm M 's profit that derives from the second-stage wholesale price (i.e. $w^i = w^f$), so as firm M invests $x^i = x^f$ and deters PT.

Let us briefly analyze the expressions of x^* and x^f . As expected, we find that both x^* and x^f rise with the reservation price for the basic product in market 1 (i.e. both $\partial x^*/\partial a > 0$ and $\partial x^f/\partial a > 0$ hold). *Ceteris paribus*, a higher reservation price calls for a higher investment both when firm M decides to tolerate PT and when she finds it profitable to impede PT.

We also find that x^* and x^f react differently to changes in transport costs. Indeed, we have that x^* rises with s (i.e. $\partial x^*/\partial s > 0$) while x^f decreases with s (i.e. $\partial x^f/\partial s < 0$). The intuition is that when firm M allows PT a higher transport cost provides the firm with higher investment incentives, given that a higher s protects firm M from the profit loss due to parallel imports. Conversely, when firm M chooses to invest so as to deter PT, a higher transport cost makes preserving domestic monopoly a simpler task to accomplish, given that it suffices a lower quality investment.

Finally, we find that an increase in the demand side spillover causes an increase in both x^* and x^f (i.e. $\partial x^*/\partial \beta > 0$ and $\partial x^f/\partial \beta > 0$). The latter result is intuitive, since if firm M invests to deter PT then a higher demand side spillover requires a higher investment to foreclose country 1. Conversely,

the former result is less intuitive. If firm M invests and tolerates PT then, when the spillover rises, a higher investment enables firm M to boost revenue in country 2 while effectively controlling PT.

4.3 Welfare analysis

We can now compare quality investment and consumer surplus (in each country and worldwide) under the alternative regimes of IPR exhaustion. The main aim is to assess whether or not the common wisdom that PT trades off static against dynamic efficiency is theoretically grounded. In what follows, without loss of generality in terms of the results obtained, we focus on the case with a positive flow of parallel imports at equilibrium, since it is the most interesting to our analysis.

4.3.1 Quality investment

In contrast to most of the recent literature, we obtain that PT (or the threat thereof) *per se* does not reduce the upstream firm's quality investment.²¹

Consider an equilibrium with a positive flow of PT. Proposition 1 has shown that a sufficient condition for investment to rise compared with national exhaustion is that the arbitrage cost is high enough (i.e. $s > s'$). Now, assume that $s \leq s'$. We show that, when the re-imported product is not a close substitute (i.e. when $\beta < \beta' = \beta'(s)$, where the critical value β' is found in the Appendix), firm M still raises investment relative to national exhaustion.²² The rationale for this result is that

²¹ This result does not follow from having restricted firm M 's strategy set so that she is not able to supply multi-product lines of different qualities. It may be argued that firm M could find it profitable to price discriminate through quality in the domestic country by selling both a high- and a low-quality version. However, we can prove that firm M never introduces an own low-quality variant at home, either in the absence or in the presence of PT. First, let country 1 be a monopoly. Since returns to quality are increasing (quality only imposes fixed costs), then firm M chooses to supply only the highest feasible quality. Now, assume that firm M and firm D compete in quantities in country 1. Thus, they face the Cournot incentive to reduce output as the rival's output rises. Since total sales of the low-quality good adversely affect the price of firm M 's high-quality good, then firm M cedes the low-quality market segment to firm D to save margins on the high-quality good. When firms compete in prices rather than quantities, and price competition raises demand, firm M expands her output following firm D 's entry. In such a case, firm M may introduce a low-quality brand as a response to firm D 's entry. For brevity, we omit the proof of these results, which follow from Johnson and Myatt (2003).

²² The fact that research-based firms are not sympathetic towards PT is not inconsistent with the result obtained, since R&D firms would achieve higher profits under national exhaustion.

quality investment reinforces cross-country vertical product differentiation. Hence, the more firm M invests the less parallel imports reduce her profit. When the exogenous setting inherently limits the scope for PT (since arbitrage costs are high, or the demand side spillover is not too high), firm M invests more when PT is allowed than when is banned. Proposition 3 summarizes the results.²³

Proposition 3. Quality investment is higher with a positive flow of PT than under national exhaustion when the transport cost is sufficiently high, or the re-imported product quality is not too high. Formally, we find that $x^i = x^ > x^n$ holds if and only if $(s > s') \vee ((s \leq s') \wedge (\beta < \beta'))$ holds.*

4.3.2 Consumer surplus

At country level, our findings confirm the standard result that, relative to national exhaustion, PT, or the threat thereof, reduces consumer surplus in the originating country (since it reduces the quantity sold), but increases surplus in the destination country (since it increases the quantity sold). This is the net effect of two counteracting forces on retail quantities, that is, changes in quality investment and the wholesale price under the alternative exhaustion regimes of IPR.²⁴

At the world level, we find that consumer surplus may increase under international exhaustion. Intuitively, when there is an equilibrium with a positive flow of PT, worldwide surplus rises when PT is most effective in increasing the retail quantity in country 1, that is, when the arbitrage cost is sufficiently low and the re-imported product quality is high enough (i.e. when both $s < s''$ and $\beta > \beta'' = \beta''(s)$ hold, where the critical values of the parameters are found in the Appendix).

More formally, assume that firm M invests $x^i = x^*$, so as $q_t > 0$. Proposition 4 shows that aggregate consumer surplus may be higher when PT is allowed than when is banned.

²³ An alternative equilibrium is one where firm M actually impedes PT. From Proposition 1, if PT is a credible threat then, to artificially segment markets, firm M has to over-invest compared with national exhaustion.

²⁴ For a given investment, retail quantities decrease with the wholesale price, while, for a given wholesale price, retail quantities rise with investment. Moreover, the wholesale price positively depends on quality investment.

Proposition 4. Aggregate consumer surplus is higher with a positive flow of PT than under national exhaustion when the transport cost is sufficiently low and the re-imported product quality is high enough. Formally we find that, when both $s < s''$ and $\beta > \beta''$ hold, $S^i(x^) > S^n(x^n)$ holds.*

4.3.3 PT and the relevant trade-off

We are now able to investigate the potential trade-off, if any, which is related to choosing the exhaustion regime of IPR. Figure 1 illustrates the results, depending on cost and quality parameters (where $\beta > \beta^f$ ensures that there is a positive flow of PT at equilibrium), for a given reservation price in country 1, that is, $a = 3/2$ (qualitative results are not affected by the value of a). Note that, if the arbitrage cost is higher than s' , then quality investment rises with PT independent of β , while, if it is higher than s'' , then consumer surplus rises with a ban on PT independent of β .

We find moderate support to the common view that PT raises aggregate consumer surplus, but reduces quality investment in the relevant countries. Indeed, the expected trade-off does only occur provided that the re-imported product quality is very high, namely, when $\beta > \beta'$ (i.e. in the dark grey area in Figure 1). In such a case, the welfare effects of trade liberalization are ambiguous.

Conversely, we find counter-intuitive results for the largest portion of the feasible region. First, since $s' < s''$ and $\beta'' < \beta'$, then we derive from propositions 3 and 4 that there is scope for PT to raise both quality investment and aggregate consumer surplus. Figure 1 shows that, when either $s' < s < s''$ and $\beta > \beta''$, or $s \leq s'$ and $\beta'' < \beta < \beta'$ hold (i.e. in the grey area), both $x^* > x^n$ and $S^i(x^*) > S^n(x^n)$ hold. In such a case, PT creates no trade-off at all between static and dynamic efficiency, so that international exhaustion is the welfare-enhancing regime for IPR protection.

We also find out the unexpected case where PT raises investment, but reduces aggregate consumer surplus. This occurs for the highest feasible values of the arbitrage cost, or the lowest feasible values of the re-imported product quality. Figure 1 shows that, if either $s'' < s < s^n$ or

$\beta^f < \beta < \beta''$ (i.e. in the light grey area), then $x^* > x^n$ but $S^i(x^*) < S^n(x^n)$. Indeed, because x^* is close to x^f , the re-imported quantity in country 1 is too small to offset the surplus loss in country 2 due to PT. In such a case, welfare implications are ambiguous.

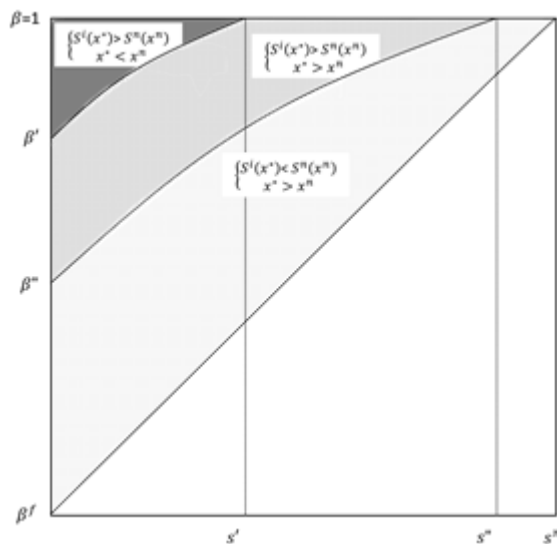


Figure 1. Quality investment and consumer surplus under alternative exhaustion regimes of IPR.

5. Model extensions

In this section, we extend our model to consider the cases where, at the second stage, first firm M employs a dual pricing system, then firm M offers a two-part tariff, and finally there is price regulation in the foreign market. To avoid notational ambiguity, where needed, we use superscript \sim under dual pricing, superscript $\hat{\cdot}$ in the two-part tariff setting and superscript $\tilde{\cdot}$ in the regulated case.

5.1 Dual pricing

Assume that under international exhaustion firm M introduces a dual pricing system in country 2, that is, sets different wholesale prices for the product depending on the country where it is sold. We show that dual pricing enables firm M to artificially reproduce a national exhaustion regime of IPR.

Let w_2 (respectively, w_1) be the wholesale price for the product when it is sold in country 2 (parallel exported to country 1). Thus, firms' profit functions are $\tilde{\pi}_M^i = p_1 q_1 + w_1 q_t + w_2 q_2 - x^2/2$ and $\tilde{\pi}_D^i = (p_1 - w_1 - s)q_t + (p_2 - w_2)q_2$. The third-stage quantities are easily calculated as follows:

$$\tilde{q}_1^i = (a + s + w_1)/3 + (2 - \beta)x/3; \quad \tilde{q}_t^i = (a - 2(s + w_1))/3 + (2\beta - 1)x/3; \quad \tilde{q}_2^i = (1 - w_2)/2 + \beta x/2.$$

At the second stage, the first order condition on firm M 's profit with respect to w_1 yields $w_1^* = (5a - 4s + x + 4x\beta)/10$, where $w_1^* > w^f$ for any investment level. Consequently, we have $w_1^i = w^f$, so that PT is deterred, and $w_2^i = w^n$. Finally, at the first stage, firm M can decide the investment level as if markets were legally segmented, so as $\tilde{x}^i = x^n = (2a + \beta)/(2 - \beta^2)$.

It follows from the analysis that dual pricing has the same welfare effects as a ban on PT.

5.2 Two-part tariff contract

Let us assume that firm M offers firm D a two-part tariff contract (w, T) , where w is the wholesale price and T is the franchise fee.

First, consider the national exhaustion regime. At the third stage of the game, given a contract (w, T) that is accepted by firm D , retail quantities are the same as with linear pricing (section 4.1). At stage two, firm M can extract firm D 's profit by setting $T^n = \pi_D^n$. It follows that firm M 's optimal choice of w is the one that maximizes the industry profit in the two countries, that is, $\Pi^n = \pi_M^n + \pi_D^n$. Since we have $\partial \Pi^n / \partial w = -w/2 < 0$, then the optimal wholesale price is $\hat{w}^n = 0$. As expected, firm M sets a cost-oriented wholesale price and thus achieves vertical efficiency. Finally, at stage one, firm M chooses the investment that maximizes the industry profit Π^n , that is, $\hat{x}^n = (a + \beta)/(1 - \beta^2)$.

Consider now the international exhaustion regime. Solving the third stage of the game gives the same retail quantities as in (1). At stage two, firm M can extract firm D 's profit by setting $T^i = \pi_D^i$. The first order condition on the industry profit $\Pi^i = \pi_M^i + \pi_D^i$ with respect to w gives the optimal wholesale price that allows PT, that is, $\hat{w}^* = 2((a + 2s) + (5 - 4\beta)x)/13 > \hat{w}^n = 0$, where \hat{w}^* rises with x .

Since retail quantities at the third stage are the same as with linear pricing, then the wholesale price w^f that deters PT is the same as in (2). We find that $\hat{w}^* \geq w^f$ when $x \geq \hat{x}' = (3a - 14s)/(11 - 14\beta)$, that is, when quality investment is high enough. It follows that, when $x \geq \hat{x}'$, firm M sets $\hat{w}^i = w^f$ and thus deters PT, while, when $x < \hat{x}'$, firm M sets $\hat{w}^i = \hat{w}^*$ and thus allows PT.

At the first stage, firm M maximizes the worldwide industry profit $\Pi^i = \hat{R}^i(\hat{w}^i, x) - C(x)$ with respect to x . We easily obtain that $\Pi^i = \Pi^n - \Delta\hat{R}$, where $\Delta\hat{R} = \hat{R}^n(\hat{w}^n, x) - \hat{R}^i(\hat{w}^i, x)$ is the industry revenue change due to (the threat of) PT relative to national exhaustion. We have that $\Delta\hat{R}$ is a convex quadratic function in x that, consistent with the outcome of stage two, can be written as:

$$\Delta\hat{R} = \begin{cases} \hat{w}^n \hat{q}_2^n - w^f \hat{q}_2^i & x \geq \hat{x}' \\ (\hat{w}^n \hat{q}_2^n - \hat{w}^* \hat{q}_2^i) + (\hat{p}_1^n \hat{q}_1^n - \hat{p}_1^i \hat{q}_1^i) - \hat{w}^* \hat{q}_t + (\hat{p}_t - \hat{w}^* - s) \hat{q}_t & x < \hat{x}' \end{cases} \quad (6)$$

Note that, as in section 4.2.3, the terms in $\Delta\hat{R}$ can be interpreted as firm M 's gains and losses from (the threat of) PT, where the last term in the case when $x < \hat{x}'$ coincides with firm D 's net revenue from parallel exports to country 1. Easy computation yields that:

$$\Delta\hat{R} = \begin{cases} 1/4(w^f)^2 & x \geq \hat{x}' \\ 1/4(w^f)^2 - 13/16\hat{q}_t^2 > 0 & x < \hat{x}' \end{cases}. \quad (7)$$

Proposition 5 shows that R&D investment is lower under international than national exhaustion. The rationale is that a higher investment would mean a higher wholesale price. This in turn would lead firm M further away from vertical efficiency that is achieved under national exhaustion with a cost-oriented price. Thus, if investment rises under international exhaustion then the industry profit loss also rises. It is worth noting that we find this result without using first-order conditions with respect to x . Proposition 5 also shows that, since R&D investment is lower and the wholesale price is higher, then the worldwide consumer surplus is lower under international exhaustion.

Proposition 5. If firm M offers a two-part tariff contract to firm D , then both quality investment and the worldwide consumer surplus are lower under international than under national exhaustion.

We have thus found that, when firm M offers a two-part tariff, under international exhaustion quality investment is not traded-off against worldwide consumer surplus. Indeed, they both decrease relative to national exhaustion. The obvious policy implication is that PT should be banned.

5.3 Price regulation

Let us assume that market 2 is regulated. Thus, there is a national regulatory authority (NRA) in country 2 that controls both the wholesale and the retail price to maximize welfare $W_2^k = S_2^k + \pi_D^k$ ($k=n, i$), which is given by the sum of consumer surplus in country 2 and firm D 's worldwide profit.

We assume the following timing of the game. At the first stage, firm M chooses quality investment. At the second stage, the NRA sets the wholesale price in country 2. Then, firm M decides whether or not to sell in country 2. At the third stage, the NRA sets the retail price in country 2, while in country 1 either there are parallel imports, so that firm M and firm D compete in quantities, or not, so that firm M is a monopoly. As usual, we solve the game backwards.²⁵

Consider first the benchmark case where there is a ban on PT. Thus, firm M is a monopoly in country 1 and firm D is a (regulated) monopoly in country 2. Since the welfare function in country 2 is convex both in the retail price (chosen at stage three) and in the wholesale price (at stage two) then the NRA sets both prices at marginal cost. This respectively means that, at stage three, $p_2 = \tilde{p}_2^n = w$ and, at stage two, $w = \tilde{w}^n = 0$. At stage one, the first order condition on firm M 's profit with respect to x gives the optimal quality investment under national exhaustion, that is, $\tilde{x}^n = a$.

Let us now consider the case where PT is legal. We prove that PT does not affect firm M 's R&D investment, though it influences government price controls. Compared with national exhaustion, the NRA has to raise the wholesale price so as to provide firm M with adequate incentives to sell the improved input in country 2. Indeed, firm M should be able to recoup the opportunity cost of exporting quality, which is equal to the domestic profit loss due to parallel imports.

²⁵ Solving this game is the same as solving the game where the NRA chooses both prices at stage two.

We show that under international exhaustion, for any x , the NRA selects exactly the wholesale price $w = \tilde{w}^i = \tilde{w}^i(x) > \tilde{w}^n$ that leaves firm M indifferent between exporting the improved input or not. Under national exhaustion, the NRA achieves first-best, since it obtains the improved input despite setting the wholesale price at marginal cost. Thus, firm M 's profit under international exhaustion is the same as under national exhaustion. Formally, we have $\Delta\tilde{R}_M = \tilde{R}_M(\tilde{w}^n, x) - \tilde{R}_M(\tilde{w}^i, x) = 0$, so that $\tilde{\pi}_M^i = \tilde{\pi}_M^n - \Delta\tilde{R}_M = \tilde{\pi}_M^n$. It follows that $\partial\Delta\tilde{R}_M/\partial x = 0$. Hence, in a regulated setting, R&D investment is not affected by the exhaustion regime of IPR. Consequently, PT does not create any trade-off between R&D investment and worldwide consumer surplus.²⁶

Let $\Delta\tilde{R}_{M0} = \tilde{R}_M(\tilde{w}^n, x) - \tilde{R}_M(\tilde{w}^i, x)$ be firm M 's (hypothetical) highest revenue loss from PT, that is, the one firm M would incur when under international exhaustion the NRA sets $w = \tilde{w}^n = 0$, and nonetheless firm M sells in country 2. Proposition 6 solves the game and summarizes the results.

Proposition 6. Assume that market 2 is regulated. Under international exhaustion, the NRA sets the

wholesale price $\tilde{w}^i = w^ - \frac{9}{28}w_t - \sqrt{\left(w^* - \frac{9}{28}w_t\right)^2 - \frac{9}{14}\Delta\tilde{R}_{M0}}$, where $\tilde{w}^n < \tilde{w}^i < w^f$, while firm M*

chooses to invest $\tilde{x}^i = \tilde{x}^n = a$ and tolerate PT.

The result obtained that under price regulation the exhaustion regime of IPR does not affect investment incentives depends crucially on the timing assumption, and particularly on the NRA's limited commitment ability²⁷. On the one hand, we assume that the NRA cannot commit to the wholesale price before firm M makes her investment decision. If the NRA has full commitment,

²⁶ We can show that, since a higher wholesale price is necessary to obtain the improved input, then aggregate consumer surplus is lower under international than under national exhaustion (for brevity, we omit the proof, which is available from the authors on request). Results may be different if the NRA is allowed to set a retail price lower than the wholesale price (as in Matteucci and Reverberi, 2005).

²⁷ In a related paper Avenali et al. 2010 show that, in the absence of regulatory commitment, to preserve quality investment, regulated wholesale prices should depend both on time and firms' entry period.

then R&D investment is higher under international than under national exhaustion when the NRA prefers to raise the regulated price so as to cover the cost of investment (that is not yet sunk), but is lower when the NRA prefers to diminish price despite sacrificing quality. On the other hand, we assume that the NRA commits not to impose a compulsory license on firm M 's improved input. Compulsory licensing occurs when a government allows national firms to produce the good without the IPR owner's consent²⁸. If there is complete regulatory discretion, so that the NRA can impose a compulsory license when firm M 's investment is already sunk, then investment incentives decrease under international exhaustion (although in our model they are not completely diluted).

Due to the nature of the traded good (e.g. pharmaceuticals), firm M might hardly withdraw from country 2. Thus, to avoid compulsory licensing on the improved input firm M may accept to license an old version at a low price. In this case, if the NRA aims at ensuring that country 2 is served with the improved input then it should loosen price controls relative to national exhaustion. Hence, the qualitative result that PT does not alter investment incentives carries over the case when firm M may decide to provide country 2 with an old product, but cannot refrain from serving the market.

6. Concluding remarks

It is widely argued that PT, legitimated by an international exhaustion regime of IPR, creates a trade-off between static and dynamic efficiency, such that aggregate consumer surplus in the relevant countries rises at the expense of R&D investment. Nonetheless, we have shown that this common wisdom is rather the exception than the rule.

We have found that, in an equilibrium with parallel imports, quality investment rises compared with national exhaustion provided that the arbitrage cost is high enough, or the re-imported product quality is not too high.²⁹ Indeed, quality investment reinforces vertical differentiation between the

²⁸ Under particular conditions, the TRIPS Agreement authorizes governments to make exceptions to IPR protection, so as there is no need to obtain a voluntary license on the basis of an adequate remuneration of the IPR holder.

²⁹ If PT is deterred at equilibrium (that is, when the re-imported product quality is sufficiently low), then quality investment is always higher under international than under national exhaustion of IPR.

original product and parallel imports, thus diluting the adverse effect of PT on the investing firm's profit. This effect is most evident when the exogenous setting inherently limits the scope for PT.

In principle, the opposite conditions on cost and quality parameters should be fulfilled for PT to effectively toughen competition in the destination country, and thus raise worldwide consumer surplus. However, there is enough room for both sets of conditions to simultaneously hold. In this case, PT does not trade-off static against dynamic efficiency. Alternatively, the unexpected reverse trade-off may arise where PT increases investment, but reduces aggregate consumer surplus.

In our basic model, a profit-maximizing manufacturer in country 1, which invests in improving product quality, sells the product at a linear wholesale price to an independent firm in country 2, which may parallel export to country 1. In the first model extension, the manufacturer employs dual pricing and thus sets different wholesale prices in country 2 depending on whether the product is sold in country 2 or parallel exported. We have shown that a dual pricing system perfectly restores a national exhaustion regime of IPR, so as welfare effects are the same as those with a ban on PT.

Then, we have developed two further versions of the model, one in which the manufacturer offers a two-part tariff to the distributor, and one in which there is price regulation in the foreign market³⁰. We have found that, both with non-linear pricing and price regulation, (the threat of) PT does not create the expected trade-off between R&D investment and worldwide consumer surplus.

Under non-linear pricing, an international exhaustion regime of IPR reduces both investment and surplus. Indeed, a higher investment would cause a higher wholesale price, which in turn would reduce vertical efficiency and thus industry profit. Consumers also benefit from national exhaustion, since the R&D firm sets the wholesale price at marginal cost independent of quality investment.

When there is price regulation, PT does not affect the manufacturer's incentives to invest in quality. Indeed, to obtain that the manufacturer sells in the foreign market, the regulator raises the wholesale price so as to incorporate the manufacturer's opportunity cost of selling abroad, that is,

³⁰ In our setting we assume that in country 1 the manufacturer is vertically integrated with the retail unit; a future development of the work could investigate how different vertical structures affect investment incentives and worldwide consumer surplus (i.e. see Avenali et al, 2008).

the domestic profit loss due to parallel imports. Because of the higher wholesale price, aggregate consumer surplus is always lower under international than under national exhaustion.

The results obtained shed some light on the welfare effects of trade liberalization, and underline that policy implications depend on the considered setting. In the basic model where the R&D firm uses linear pricing, quality investment and aggregate consumer surplus may simultaneously rise in the presence of PT. In such a case, choosing an international exhaustion regime of IPR definitely improves welfare. Alternatively, the welfare effects of PT are ambiguous. Different from the basic model, policy implications are clear-cut under non-linear pricing, since PT should be banned to raise welfare. This is also the case with price regulation in the foreign market (unless the NRA can effectively trim the retail price down the wholesale price). Quite surprisingly, this is not due to the adverse effect of PT on investment, but on aggregate consumer surplus.

It follows from the analysis that ruling out PT on the ground that it dilutes R&D investment is a controversial issue. A prominent case relates to pharmaceutical firms, which complain that allowing PT in a regulated setting limits their ability to invest in R&D. However, our theoretical model does not support this claim, while empirical evidence is not clear-cut. Kyle (2007) reports that the share of total pharmaceutical R&D done in the EU declined from 49% to 37% between 1990 and 2000, but a negligible share of sales is related to PT before 1998. In addition, in the same years pharmaceutical firms have spent huge financial resources on marketing and sales. In the years 2000-2008, R&D expenditure in the EU has been reducing relative to the pharmaceutical market value, while the value of PT has been fluctuating up and down (EFPIA, 2010). It is thus questionable that the R&D decline in the EU pharmaceutical industry derives primarily from the profit erosion due to PT. Actually, there are several economic factors underlying the loss of competitiveness of some EU firms that are independent of PT. It is up to future empirical work to further clarify this matter.

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Appendix

Proof of Proposition 1. First, assume that $x < x'$, so that PT is allowed. Computation yields that $0 < \partial w^f / \partial x < \partial w^n / \partial x$. Since $\partial q_t / \partial x < 0$ then, from (4), we have that $\partial \Delta R_M / \partial x$ has an ambiguous sign. We find that $\partial \Delta R_M / \partial x = 0$ when $x = x'' = (a - 1 - 16s) / 15(1 - \beta) < x'$. We also find that $\partial \Delta R_M / \partial x$ is linear and downward sloping in x . It follows that $\partial \Delta R_M / \partial x < 0$ when $x > x''$. If $s > s' = (a - 1) / 16$, then we have $x'' \leq 0$, so that $\partial \Delta R_M / \partial x < 0$ for any x , and investment always rises in the presence of PT. Now, assume that $x \geq x'$, so that PT is deterred. It follows from (4) that $\partial \Delta R_M / \partial x < 0$ holds. Hence, under the threat of PT firm M raises investment compared with national exhaustion. ■

Proof of Proposition 2. At the first stage of the game, the first order condition on firm M 's profit with respect to x gives $x = x^* = \frac{(2a + \beta) + (2(1 - \beta)(16s + 1 - a) / 19)}{(2 - \beta^2) - (30(1 - \beta)^2 / 19)}$, while the second order condition

is fulfilled. This is indeed firm M 's optimal investment provided that markets are not artificially segmented, that is, $x^* < x'$. Solving the equation $x^* - x' = 0$ with respect to β , we obtain two roots

$$\beta_{\pm}^f = \frac{11}{7} - \frac{1}{14} \left(\frac{29 + 36s \pm \sqrt{337 + 148a^2 + 96s(13 + 10s) - 4a(1 + 32s)}}{2 + 2s - a} \right).$$

With simple algebra we find that $\beta_-^f < 0$, so that β_-^f is not feasible, while $\beta^f < \beta_+^f < 1$. Let $\beta_+^f = \beta^f$. Note that $\lim_{\beta \rightarrow 1} x' = +\infty > \lim_{\beta \rightarrow 1} x^* = 1 + 2a$. Hence, x' may cross x^* only once from below in β^f within the interval $\beta^n < \beta < 1$. It follows that, when $\beta > \beta^f$, we have $x' > x^*$, so that $x^i = x^*$ and PT is allowed. Conversely, when $\beta \leq \beta^f$ we have $x^* \geq x'$, so that the second-stage wholesale price is the corner solution $w^i = w^f$. Inserting for w^f in firm M 's

profit function and imposing the first order condition with respect to x , we obtain

$$x^i = x^f = \frac{(2a + \beta) + (a - 1 - 2s)(1 - \beta)}{(2 - \beta^2) + (1 - \beta)^2}, \text{ so that PT is deterred at equilibrium. } \blacksquare$$

Proof of Proposition 3. Proposition 1 has shown that, when $s > s' = (a - 1)/16$, we have $x^i = x^* > x^n$.

Assume now that $s \leq s'$. The rest of the proof simply derives from comparing the values taken by

x^n and x^* when β converges to the extreme points of the feasible interval, and from analyzing the

sign of the first derivatives of x^n and x^* with respect to β . First, Proposition 2 implies that

$$x^n \Big|_{\beta=\beta^f} < x^* \Big|_{\beta=\beta^f} = \lim_{\beta \rightarrow \beta^{f+}} x^*. \text{ Then, we have that } \lim_{\beta \rightarrow 1} x^n = 1 + 2a = \lim_{\beta \rightarrow 1} x^*. \text{ Furthermore, computation}$$

yields that both $\partial x^n / \partial \beta > 0$ and $\partial x^* / \partial \beta > 0$ hold for any feasible a , s , and β . Solving the equation

$$x^* - x^n = 0 \text{ with respect to } \beta \text{ we find two roots } \beta'_\pm = \frac{15(2a-1)}{2(a-16-16s)} \pm \frac{1}{2} \sqrt{\frac{353+884a+788a^2+2176s+1664as+2048s^2}{(a-16-16s)^2}},$$

where only $\beta'_+ \in (\beta^f, 1)$. Let $\beta'_+ = \beta'$. It follows from the results obtained that x^n crosses x^* only

once from below in $\beta' \in (\beta^f, 1)$. Thus, if $s \leq s'$ then we have $x^* > x^n$ when $\beta \in (\beta^f, \beta')$. \blacksquare

Proof of Proposition 4. The proof follows from comparing the values taken by the aggregate

consumer surplus when β converges to the extreme points of the feasible interval, and from

analyzing the sign of the first derivatives of the aggregate consumer surplus with respect to β , both

under national and international exhaustion.

First, we have that, when $\beta \rightarrow \beta^{f+}$, $S^n(x^n) > S^i(x^*) \rightarrow S^i(x^f)$ holds. Then, computation yields

$$\text{that, when } \beta \rightarrow 1, S^n(x^n) < S^i(x^*) \text{ holds when } s < s'' = \frac{8(2+17a)}{29} - \frac{19\sqrt{36a+95a^2-3}}{29\sqrt{2}}, \text{ with } s'' < s^n.$$

Furthermore, we find that $\partial S_j^n(x^n) / \partial \beta > 0$, $j = 1, 2$, so that we have $\partial S^n(x^n) / \partial \beta > 0$. We also find

that $\partial S_j^i(x^*) / \partial \beta > 0$, $j = 1, 2$, so that we have $\partial S^i(x^*) / \partial \beta > 0$.

Let $s < s''$. Solving the equation $S^n(x^n) - S^i(x^*) = 0$ with respect to β , we find the feasible root

β'' (we omit the expression of β'' since it is too complicated). It follows from the results obtained

that $S^i(x^*)$ crosses $S^n(x^n)$ only once from below within the interval $\beta^f < \beta < 1$ in β'' . Therefore, when both $s < s''$ and $\beta > \beta''$ hold, $S^i(x^*) > S^n(x^n)$ also holds. ■

Proof of Proposition 5. We have that (the threat of) PT would spur investment when $\partial\Delta\hat{R}/\partial x < 0$.

However, we easily derive from (7) that $\partial\Delta\hat{R}/\partial x \geq 0$ always holds. It follows that quality investment is always lower under international exhaustion. To prove that worldwide consumer surplus is also lower, first we find firm M 's optimal investment under international exhaustion \hat{x}^i . As with linear pricing, if the re-imported product quality is low then firm M invests to deter PT, which is otherwise allowed (we omit the proof, since it follows the same logic as Proposition 2).³¹ Let

$\hat{\beta}^f = ((11+4s-20a)/14(2-a+2s)) + \left(\sqrt{(121+120a+120a^2+760s+64as+688s^2)/(2-a+2s)^2} \right) / 14$. We have:

$$\hat{x}^i = \begin{cases} \hat{x}^f = \frac{a(5-2\beta)}{(5-4\beta)} - \frac{2(2\beta(1+s)-s)}{(5-4\beta)} \geq \hat{x}' & \beta^n < \beta \leq \hat{\beta}^f \\ \hat{x}^* = \frac{13\beta+4a(2+\beta)-4s(9\beta-8)}{(64-49\beta)\beta-14} < \hat{x}' & \hat{\beta}^f < \beta < 1 \end{cases}.$$

First, let $\beta^n < \beta \leq \hat{\beta}^f$, so that $\hat{x}^i = \hat{x}^f$. We find that $\hat{S}^i(\hat{x}^f) - \hat{S}^n(\hat{x}^n) < 0$ holds when $s = 0$, and that $\partial(\hat{S}^i(\hat{x}^f) - \hat{S}^n(\hat{x}^n))/\partial s > 0$. Solving the equation $\hat{S}^i(\hat{x}^f) - \hat{S}^n(\hat{x}^n) = 0$ with respect to s we obtain that the only root \hat{s} is such that $\hat{s} > s^n$. It follows that $\hat{S}^i(\hat{x}^f) < \hat{S}^n(\hat{x}^n)$ for any feasible a , s and β . Now, let $\hat{\beta}^f < \beta < 1$, so that $\hat{x}^i = \hat{x}^*$. We find that $\hat{S}^i(\hat{x}^*) - \hat{S}^n(\hat{x}^n) < 0$ holds when $s = 0$, and that $\partial(\hat{S}^i(\hat{x}^*) - \hat{S}^n(\hat{x}^n))/\partial s < 0$. It follows that $\hat{S}^i(\hat{x}^*) < \hat{S}^n(\hat{x}^n)$ holds for any feasible a , s and β . ■

Proof of Proposition 6. At the third stage of the game, the equilibrium quantities in country 1 are those found in (1), that is, in the unregulated case. Let us now consider country 2. Since the welfare function is convex in p_2 then the NRA sets the retail price at firm D 's marginal cost, that is, $p_2 = \tilde{p}_2^i = w$. Hence, the quantity sold is $\tilde{q}_2^i = 1 + \beta x - w$, where $\tilde{q}_2^i = \tilde{q}_2^n = 2q_2^n$.

³¹ However, the proof is available from the authors on request.

At the second stage, the NRA sets the wholesale price $w = \tilde{w}^i = \tilde{w}^i(x)$. If w is such that firm M finds it profitable to export the improved input, then social welfare in country 2 is $W_2^i = W_2^i(w, x) = (\tilde{q}_2^i)^2/2 + (2w - 2w^f)^2/9$, where w^f is the wholesale price that deters PT found in (2). It follows that $W_2^i > 0$ provided that $\tilde{q}_2^i \geq 0$. Note that $\tilde{q}_2^i = 0$ for $w = \bar{w} = 1 + \beta x$, where $\bar{w} > w^f$. Hence, for any $w \in [0, w^f)$, we have that both $\tilde{q}_2^i > 0$ and $q_t > 0$ hold.

Conversely, if w is such that firm M 's wholesale profit from exporting is not enough to offset the retail profit loss due to parallel imports in country 1, then firm M decides not to sell abroad. In such a case, we simply have $W_2^i = 0$. It follows that the NRA always prefers to set the wholesale price in such a way that country 2 obtains the improved input. Let $\bar{\pi}_M = \bar{\pi}_M(x) = ((a+x)^2 - 2x^2)/4$ be firm M 's profit when she does not sell in country 2. Since $\tilde{w}^n = 0$, then we have $\bar{\pi}_M = \tilde{\pi}_M^n(\tilde{w}^n, x)$. Thus, the optimal wholesale price \tilde{w}^i solves the following optimization program: $\max_w W_2^i$ s.t. $\tilde{\pi}_M^i \geq \tilde{\pi}_M^n(\tilde{w}^n, x)$. Since W_2^i is a convex function in w then the incentive-compatible constraint on firm M 's profit is binding, and we find \tilde{w}^i by solving $\tilde{\pi}_M^i(w, x) = \tilde{\pi}_M^n(\tilde{w}^n, x)$ with respect to w :

$$\tilde{w}^i = w^* - \frac{9}{28}w_t - \sqrt{\left(w^* - \frac{9}{28}w_t\right)^2 - \frac{9}{14}\Delta\tilde{R}_{M0}},$$

where w^* and w_t are those found in (2), while $\Delta\tilde{R}_{M0} = \tilde{R}_M^n(\tilde{w}^n, x) - \tilde{R}_M^i(\tilde{w}^n, x)$. Calculation yields that the following conditions hold: i) $0 < \tilde{w}^i|_{x=0} < w^f|_{x=0}$; ii) both \tilde{w}^i and w^f rise with x ; iii) for any $x > 0$, \tilde{w}^i never crosses w^f . It follows that $0 < \tilde{w}^i < w^f$ holds for any $x > 0$. Thus, for any given quality investment, the NRA sets the wholesale price so as PT is allowed.

At the first stage, firm M anticipates that at stage two \tilde{w}^i is such that $\tilde{\pi}_M^i(\tilde{w}^i, x) = \tilde{\pi}_M^n(\tilde{w}^n, x)$ holds. Hence, firm M simply maximizes $\tilde{\pi}_M^n(\tilde{w}^n, x)$ with respect to x . We thus obtain $\tilde{x}^i = \tilde{x}^n = a$. ■

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