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ABSTRACT

Compatibility Standards and Strategic Trade Policy

We analyse the compatibility decisions of two national firms producing horizontally differentiated variants of a good that exhibits network effects for the world market. One of the firms is able to endogenously establish an installed base in its domestic market. The firm's effort in that respect is reinforced by a production subsidy that covers the firm's domestic market. With the help of a three-country model we ask under which circumstances this local subsidy may be and actually is used as a strategic trade-policy device. We show that the installed-base effect plays a role only when the firms opt for incompatibility. In addition, we obtain the result that only for intermediate values of the network-effect parameter is incompatibility chosen. In all other cases, compatibility emerges and so the local subsidy can be shown to increase world welfare.

JEL Classification: F12, F13 and L13
Keywords: compatibility decisions, standards and strategic trade policy

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1 Introduction

Industries with network effects play an ever increasing role. In these industries choice of compatibility and standards is decisive. These industries are by no means restricted to domestic production, rather often they act on a global scale. Telecommunication industries, software and media are more prominent examples in this respect.

The analysis of these industries has attracted a lot of attention in the economics literature in recent years (see e.g. Shy [1999]). But most of the papers dealing and analyzing industries with network effects have been confined to a closed-economy setting. This is rather surprising given the very often global nature of competition. Concentrating on a closed economy neglects two major issues. On the one hand, firms in network industries that act in global markets can establish an installed base in their home markets which may be used as a strategic advantage when competing in the world market. On the other hand, with more than one country, national policies do not necessarily lead to world-welfare maximization.

Against this background we investigate how firms may establish an installed base in their home markets while taking into account the effects of the installed base on competition in the international market. Our main aim is to investigate the repercussion of such a scenario on the (in-)compatibility decisions of firms. In addition, we ask for the incentive of a national government to increase the domestic installed basis via a subsidy on national production. In doing so, we link our discussion to questions which have been discussed in the strategic trade policy literature (see e.g. Brander and Spencer [1985] and Eaton and Grossman [1986]). We ask whether a domestic production subsidy can indirectly act as a strategic trade-policy device thereby circumventing the prohibition of export subsidies stated in international trade-policy agreements. Domestic production subsidies lead to a larger installed base and, hence, may improve the strategic position of the national producer in the world market.

In order to address all these questions we develop a three-country framework with two national firms producing horizontally differentiated products for their domestic markets in an industry with network effects. The two firms try to sell their products in a third market, the world market. Furthermore, we model the possibility for one firm to establish an installed base in its national market and thus enhance its strategic position in the world market. The government in this country intervenes with a subsidy to domestic sales. With the help of this policy instrument it maximizes national welfare by taking into account the potential indirect effects on the national firm's strategic position in the world market. Firms decide on the compatibility of their products at the beginning.

Using this framework, which extends the basic set-up in Woeckener (1999) to an international setting, we show that only with incompatibility the domestic installed base has an impact on the strategic interaction of firms in the world market. That is, only if firms decide for incompatibility the local subsidy can act as a strategic trade-policy device. Our analysis reveals that incompatibility only emerges with intermediate network effects. In this case, local subsidies enhance the strategic position of the domestic firm in the world market. Profit-shifting takes place. The local subsidy leads to suboptimal incompatibility thus potentially harming world welfare. Despite not being banned by international trade-policy agreements, the national production subsidy acts in a very similar way as the illegal export subsidy.

With weak as well as strong network effects compatibility prevails. In this regime, the compatibility decision of the firms maximizes world welfare. The local subsidy has no effect on the competition in the world market (i.e., the installed base effect is absent), it only improves the allocation in the domestic market. Therefore, the local subsidy is a *second best* alternative for increasing world welfare.

Our paper basically combines two strands of the literature. Most importantly, we extend the literature on network industries (see e.g. for an overview Shy [1999]) to an international setting. In this respect, our paper is reminiscent of a few other contributions in the literature which have already undertaken first steps in this direction. The general line of research has initially been suggested by Matutes and Regibeau (1996). It began, in more detail, with Gandal and Shy [2001] as well as Barrett and Yang (2001). Gandal and Shy (2001) explore the possibility of standardization unions in a three-country setting. Any government instruments besides the setting of standard are absent. Barrett and Yang (2001) consider the decision on (in)compatibility in an economy facing import competition. Compatibility of the new national technology with the international standard implies its incompatibility with the preceding domestic technology. While in our paper, incompatibility is used as a strategic device to reallocate profits in the world markets in favor of the national producer, in Barrett and Yang (2001) the main impetus to the decision for incompatibility is derived from the wish to protect the outdated technology's domestic installed base.

Another paper which is closely related to the present one is our companion paper (Woeckener and Walz [2002]). It analyzes two national monopolists as they build up a home base and then compete in a third market. Government intervention by means of subsidization is completely absent. Governments can only interfere in the market solution via regional standardization bodies. Rather than allowing for the endogenous establishment of an installed base in both markets, we focus here on the strategic trade-policy issue. It is in this sense that the two papers complement each other.

In addition, we take up aspects of the strategic trade-policy literature. In contrast to e.g. Horstmann and Markusen (1986) we provide a new channel through which government instruments directed towards the national market can have spillover effects on the world market: the strategic impact of a national installed base. We thus point to a new and important link between national policy instruments and world-market competition.

The structure of the paper is as follows. In the next section we outline the basic structure of the model. Section 3 deals with competition in the world market and the pricing behavior of firms. The fourth section is devoted to the analysis of the establishment of an installed base by the actively modelled firm establishes in its home market. Anticipating all this, we ask for the optimal subsidy level in section 5. Section 6 presents the main issue: the compatibility decisions. Section 7 concludes.

2 The model

We consider a three-country world. Country 1 and country 2 host one national producer each. Both producers also sell in country 3 (the world market). The two firms (F1 and F2, respectively) produce two horizontally differentiated variants of a good which exhibits network effects. They face identical and constant marginal costs the latter being normalized to zero.

We model one crucial asymmetry between countries 1 and 2: Whereas the national producer in country 1 has the opportunity to sell its output in the domestic market and thereby establish an installed base before entering the world market, this possibility does not exist for F2. This assumption implies a strategic advantage for F1 which is potentially reinforced by subsidies to domestic production in country 1. Alternatively we could, without changing the main mechanisms underlying our model, allow for an exogenously given installed base in country 2. In order to facilitate the discussion we chose to set the level of country 2's installed base to zero.

In both of F1's markets, i.e. in markets 1 and 3, consumers' willingness to pay is uniformly distributed along the Hotelling line with a density of one. The size of the world market is normalized to unity, i.e. the length of the Hotelling line is just one. The variants of the two producers are located at the two ends of the line. F1 (F2) is located to the left (right) end of the line. The alienation terms are linear in distance (to the ideal variant) and the alienation coefficent is normalized to one. The basic willingness to pay is identical for all consumers in both markets and denoted by V. It is enhanced by the existence of network effects. Network effects are captured by the product of the network-effect parameter n $(0 < n < 1)$ and the size of the network.

In the case of incompatible products the network size of variant 1 (2) in the world market is $x_1^3 + x_1^1$ (x_2^3), with x_i^j ($i = 1, 2; j = 1, 3$) representing the sales of producer i in market j. In the case of compatibility total network size adds up to $1 + x_1^1$. Hence, the surplus of a consumer of F1's (F2's) variant in country 3 with address h ($0 \leq h \leq 1$) reads

$$S_{h1}^3 = V - |i - 1 - h| - p_i^3 + \begin{cases} n(1 + x_1^1) & \text{for} \quad \text{compatibility} \\ n(x_i^3 + x_i^i) & \text{for} \quad \text{incompatibility} \end{cases} \tag{1}$$

with p_i^3 denoting the price of producer i in the world market and x_2^2 being normalized to zero.

The structure of market 1 is similar to the world market, the only difference being that total market size T may differ from one. Consequently, the surplus of the consumer of the national variant with address $h (h \in [0, 1])$ can be expressed as

$$S_h^1 = V - h - p_i^1 + \begin{cases} n(1 + x_1^1) & \text{for} \quad \text{compatibility} \\ n(x_1^3 + x_1^1) & \text{for} \quad \text{incompatibility} \end{cases} \tag{2}$$

with p_i^1 denoting the price of producer Fi in its home market.

The interaction of firms, consumers and country 1's government is modelled as a four stage game. The sequence of moves is as follows. In the first stage of this game, the two producers decide on (in)compatibility of their products. The move to compatibility requires the consent of both producers. In stage 2, the government in country 1 decides on the subsidy to national sales, so as to maximize national welfare. Given the (in)compatibility decisions and the choice of the subsidy, F1 determines its optimal price for the domestic market in stage 4. In the fourth stage, both firms compete in prices in the world market. We solve recursively for a subgame-perfect equilibrium.

3 Price competition in the world market

In order to analyze the pricing behavior of the two firms in the third market it is necessary to distinguish between the cases of compatibility and incompatibility. In both cases we assume that V is sufficiently large to assure a covered world market.

3.1 The compatibility case

Using Eq. (1) we can derive the demand function in the world market with given compatibility as

$$x_i^3 = 0.5 + \frac{p_j^3 - p_i^3}{2} \tag{3}$$

leading us to the profit functions for F1 and F2 resulting from their activities in the third market

$$\Pi_i^3 = p_i^3 x_i^3 = p_i^3 \left(0.5 + \frac{p_j^3 - p_i^3}{2}\right). \tag{4}$$

Using the first-order condition

$$1 - 2p_i^3 + p_j^3 = 0 \tag{5}$$

the profit-maximizing prices in the third market are $p_1^3 = p_2^3 = 1$. This, in turn, leads us, with the help of Eq. (3), to the well known result

$$\Pi_1^3 = \Pi_2^3 = 0.5. \tag{6}$$

That is, the two firms split the market equally between themselves. In the case of compatibility, a potentially larger installed base of F1 is shared with the competitor and therefore has no impact on the resulting equilibrium in the world market.

3.2 The incompatibility case

With incompatible products, the symmetry between the two firms vanishes as a consequence of differences in the domestic base. With the help of Eq. (1) we can compute the demand function for given incompatibility:

$$x_i^3 = 0.5 + \frac{(p_j^3 - p_i^3) + n(x_i^i - x_j^j)}{2(1-n)} \tag{7}$$

with x_i^i (x_j^j) denoting the installed base of the $i-(j-)$th producer in its respective home market. Comparing (3) and (7) reveals a higher demand elasticity with incompatibility. This is due to the fact that with incompatibility a lower price does not only attract directly more consumers (away from the competitor) but also indirectly (through the larger network in the presence of network effects).

Deriving, with the help of $\Pi_i^3 = p_i^3 x_i^3$ and (7), the first-order conditions

$$1 - n + p_j^3 - 2p_i^3 + n(x_i^i - x_j^j) = 0 \tag{8}$$

we are able to calculate prices and quantities for the Nash-equilibrium in this (duopolistic) subgame as:

$$p_i^{d,3} = 1 - n + \frac{n(x_i^i - x_j^j)}{3} \tag{9}$$

and

$$x_i^{d,3} = 0.5 + \frac{n(x_i^i - x_j^j)}{6(1-n)}, \tag{10}$$

respectively.

As can be seen from the best-response functions (8), prices are strategic complements in the compatibility as well as in the incompatibility case. In the latter, the installed base of F1 has an immediate effect on F1's strategic position in the world market. A larger installed base in the home market shifts F1's response function outward thus improving its competitive position in the world market. The firm with the potentially larger installed base can exploit this advantage by charging a higher price while still capturing a larger market share (see Eq. [10]).

Equilibrium profits amount to

$$\Pi_i^{d,3} = \frac{\left(1 - n + \frac{n(x_i^i - x_j^j)}{3}\right)^2}{2(1-n)}. \tag{11}$$

The duopolistic situation, however, only prevails if network effects are, relative to the installed base advantage of F1, moderate. Technically speaking, $x_2^3 > 0$ must hold. This is the case (see Eq. [10]) if

$$x_1^1 < \frac{3(1-n)}{n} \tag{12}$$

holds.

In a duopolistic market with given incompatibility price competition is fiercer than with given compatibility which leads to generally lower prices. With incompatibility the duopolists compete for the larger networks making them more aggressive in their pricing behavior. This mimics the so-called bandwagon effect.

If the condition given in (12) is violated, firm 1 is able to pursue a limit-pricing strategy. F1's optimal price is chosen such that F2 is driven out of the third market. The market share of F2 becomes zero if $1 - n + (p_1^3 - p_2^3) - x_1^1 = 0$ (see Eq. [7]) holds, even for $p_2^3 = 0$. This limit-pricing strategy with

$$p_1^{L,3} = n + nx_1^1 - 1 \tag{13}$$

therefore represents a Nash equilibrium since F2 has no incentive to undercut F1.

The limit-price hence gives us for F1's profits ($x_1^3 = 1$):

$$\Pi_1^{L,3} = n + nx_1^1 - 1. \tag{14}$$

The main difference between the compatibility and the incompatibility case is that with compatibility an installed base established in the home market does not lead to an advantage for F1 with compatibility but is crucial with incompatibility. If network effects and/or the installed base are sufficiently large this may even lead to a monopolization of the world market. In this case, incompatibility leads to competition for the (world) market (but with F2 always being driven out by F1). With weak network effects and a small installed base in country 1 duopolistic competition prevails in the world market under both the incompatibility and the compatibility regime.

4 Building up the installed base in the national market

We can now turn to the third stage, namely the establishment of firm F1's installed base in its home market. Once again we need to distinguish between the compatibility and the incompatibility case. Throughout the following discussion we always assume that consumers in country 1 be rational, thus anticipating the size of the network not only in the own market but also in the rest of the world.

4.1 The compatibility case

Using Equation (2) and our rational expectation assumption, we are able to derive the demand function in market 1

$$x_1^1 = \frac{V - p_1^1 + n}{1 - n}. \tag{15}$$

With given compatibility pricing behavior in market 1 has no implication for the situation in the world market. Therefore, we are able to focus only on the maximization of F1's profits in market 1.[1]

Taking the production subsidy s in market 1 into account we obtain optimal prices and quantities as

$$p_1^1 = \frac{V + n - s}{2} \tag{16}$$

and

$$x_1^1 = \frac{V + n + s}{2(1 - n)}. \tag{17}$$

The size of the installed base in F1's home market is, however, limited by the size of the market, i.e. the length of the Hotelling line, T. The market in country 1 is not covered if

$$x_1^1 = \frac{V + n + s}{2(1 - n)} < T.$$

[1] Moreover, we abstract from F2's home market; there is no indirect competition between the two firms in their home markets via the world market (see on this Woeckener and Walz [2002]).

When the market is not covered, total profits of firm 1 amount to

$$\Pi_1 = \frac{(V+n+s)^2}{4(1-n)} + 0.5. \tag{18}$$

4.2 The incompatibility case

With incompatibility we have to distinguish two subcases concerning competition on the world market: a duopoly versus monopolization by F1.

4.2.1 Limit-pricing in the world market

With sufficiently strong network effects country 1's firm is able to capture the entire world market using a limit-pricing strategy, i.e. $x_1^3 = 1$. This, together with rational expectations of consumers, leads us to the following demand function in country 1's market:

$$x_1^1 = \frac{V - p_1^1 + n}{1-n}. \tag{19}$$

With an identical network size in the third market, we obtain the same demand function as in the compatibility case.

Taking the production subsidy as well as the demand function into account total profits amount to

$$\Pi_1 = (p_1^1 + s)\frac{V - p_1^1 + n}{1-n} + (n-1) + n\frac{V - p_1^1 + n}{1-n}^{\cdot} \tag{20}$$

The profit-maximizing price is[2] $p_1^1 = 0.5(V - s)$ implying

$$x_1^1 = \frac{V + s + 2n}{2(1-n)} \tag{21}$$

Comparing price and installed base in F1's home market with those in the compatibility case, we find that with incompatibility prices are lower whereas the installed base is larger. This simply reflects the incentive of F1 to invest, in the case of incompatibility, in the installed base established in its home market in order to improve

[2] The second-order condition of this maximization problem is always fulfilled.

its strategic position in the world market. In the limit-pricing case, investments in the domestic installed base enable F1 to charge a higher limit-price, thus increasing its profits in the world market. Maximized profits read as

$$\Pi_1 = \frac{(V+s+2n)^2}{4(1-n)} + n - 1. \tag{22}$$

This subcase will emerge if the network established in F1's home market is sufficiently large (see Equation [12]). Inserting the profit-maximizing price into the demand function, and using (21), this condition becomes

$$\frac{V+s+2n}{2(1-n)} > 3(1-n)/n. \tag{23}$$

An additional requirement is that the market is not covered or that

$$\frac{V+s+2n}{2(1-n)} < T.$$

4.2.2 Duopolistic competition in the world market

With duopolistic competition in the third market and with incompatibility, the demand function in country 1 becomes

$$x_1^1 = \frac{V - p_1^1 + 0.5n}{1 - n - \frac{n^2}{6(1-n)}}. \tag{24}$$

Maximization of total profits

$$\Pi_1^1 = (p_1^1 + s)x_1^1 + \frac{\left(1 - n + \frac{nx_1^1}{3}\right)^2}{2(1-n)}$$

gives

$$p_1^1 = \frac{(V-s-n/6)9A - 2n^2(2V+n)}{18A - 4n^2} = \frac{V-s+n}{2} - \frac{7.5A - 2n^2(V+s)}{18A-4n^2} \tag{25}$$

with $A = 1 - n - n^2/(6(1-n))$.[3]

[3] The second order condition is fulfilled for n<0,6356.

The installed base in the home market of F1 results in

$$x_1^1 = \frac{(9/2)(2V + 7n/3 + 2s)}{18A - 4n^2} \tag{26}$$

The comparison with pricing behavior under compatibility reveals, as in the limit-pricing case, the incentive for F1 to invest in the installed base in its home market. By pushing the own best-response function in the world-market game outwards, F1 gains an advantage which stems from the strategic opportunity to invest in the domestic market.[4]

5 Optimal choice of production subsidy

We can now turn to the determination of the optimal subsidy. Due to international trade agreements, an explicit export subsidy is not available. One of the crucial arguments in our paper is, however, that one does not necessarily need to impose an explicit export subsidy to foster exports. It may suffice to enhance the installation of a domestic base in order to indirectly promote exports of the national producer. The larger national base acts in a similar manner as a qualitative advantage of the national producer. Given this mechanism we now ask for the optimal production subsidy.

Country 1's government uses this subsidy to maximize national welfare consisting in our partial equilibrium framework of F1's total profits, consumer surplus in country 1 and the expenditures of country 1's government on the subsidy:

$$W_1 = G_1 + \int_{h=0}^{x_1^1} S_h dh - s x_1^1.$$

5.1 Choice of subsidy with given compatibility

With compatibility, the domestic subsidy has no effect on the structure of the game in the third market. F1 has no strategic advantage from a larger installed base in

[4] A comparison between the two subcase with incompatibility does not reveal a clear-cut result.

the home market. Profits in the world market amount to $G_1^3 = 0.5$ (see Equation [6]) independent of the size of the installed base in the home market. The subsidy only alters the level of sales of the domestic market leaving the competitive situations in the world market unchanged. The first-order condition for the welfare-optimal subsidy in the case of a non-covered market in country 1 is

$$\frac{\partial W}{\partial s} = \left(V - x_1^1 + n(1 + 2x_1^1)\right) \frac{\partial x_1^1}{\partial s} = 0. \tag{27}$$

If the second order condition ($n < 0.5$) is fulfilled, the optimal subsidy in our compatibility case (co) with a non-covered market (nc), after taking (17) into account, reads

$$s_{nc}^{co} = \frac{V + n}{1 - 2n}. \tag{28}$$

The only justification for a production subsidy with given compatibility is that it helps to overcome a distortion in the domestic market. When deciding on p_1^1, F1 takes into account only the effect on the marginal consumer. The domestic firm has, however, no reason to internalize the (positive) network externalities that stem from the lower prices (and hence a higher installed base) for intramarginal consumers.

If network effects are sufficiently strong ($n \geq 0.5$), the second order condition of the above maximization problem no longer holds. Then, the government in country 1 has an incentive to opt for a corner solution, i.e. to set the subsidy such that the national market will be covered. Using the above condition for a covered market, this subsidy level will be[5]

$$s_c^{co} = 2T(1 - n) - V - n.$$

[5] A larger subsidy would affect neither the market allocation nor the country's welfare but rather redistribute income between F1 and country 1's taxpayers. In this case, we assume that the government uses the minimal subsidy in order to avoid distorting effects of taxation for financing the subsidy.

5.2 Subsidies with given incompatibility

With incompatibility the subsidy has a strategic effect by altering the competitive situation of the domestic producer in the world market. As before we have to distinguish different cases according to the emerging market structure in the third country.

5.2.1 Monopoly in the third market

If it is feasible and profitable for F1 to limit-price its competitor in the world market, the subsidy in the home market has an indirect effect in the third market. With given incompatibility, increased production in the home market following subsidization enables F1 to charge a higher limit price, and thus to extract a larger share of the consumer surplus in the world market. Sales, however, are not affected as the world market is assumed to be covered.

This additional effect is reflected in the first-order condition for the optimal subsidy:

$$\frac{\partial W}{\partial s} = \left(V - x_1^1 + 2n(1 + x_1^1)\right) \frac{\partial x_1^1}{\partial s} = 0.$$

The marginal welfare gain is more pronounced than in the compatibility case where the indirect effect on the world market is absent. Once again, the second order condition only holds if network effects are moderate ($n < 0.5$).

Inserting the profit-maximizing price into the demand function, we obtain the optimal subsidy for the subcase of incompatibility (ic), a monopoly in the world market (m) and a **non-covered national market** of F1 (nc)

$$s_{nc}^{ic,m} = \frac{V + 2n}{1 - 2n}. \tag{29}$$

Comparing the optimal subsidy level in the present subcase with the one under compatibility, shows that the government has a stronger incentive to subsidize when the products are incompatible and the home market is not covered, so as to shift the domestic producer in an advantageous position. Besides improving the allocation in the home market, country 1's government employs the subsidy to enable its domestic producer to extract a higher rent from consumers in the world market. By subsidizing local production, the government enlarges the installed base in the domestic market. This, in turn, makes it possible for the domestic producer to charge a higher limit-price, thereby extracting higher rents.[6] Hence, it becomes obvious that the compatibility-incompatibility decision has an impact on the subsidy granted in the domestic market. We will refer to this impact in the following as the subsidy-level effect.

Plugging (29) into our critical condition for the emergence of a monopoly situation in the world market, we find that F1, when it faces $s_{nc}^{ic,m}$, can limit-price F2 if

$$\frac{V+2n}{1-2n} \geq \frac{3(1-n)}{n}. \tag{30}$$

With strong network effects ($n > 0.5$) it is once again optimal for country 1's government to subsidize F1 such that a corner solution emerges in which the **national market is covered.** With Equation (17), this implies

$$s_c^{ic,m} = 2T(1-n) - V - 2n.$$

Somehow surprisingly, with a covered market the ranking of the optimal subsidy level between the compatibility case and the incompatibility regime (with a world-market monopoly) is reversed. The intuition behind this result, however, is rather straightforward. If a corner solution is anticipated, the objective of the subsidy is not to increase the installed base (at least not at the margin) but rather to achieve a covered national market. With incompatibility, F1 itself has, compared to the compatibility case, a stronger incentive to push (for given subsidy levels) its domestic installed base to a higher level.[7] Therefore, in the present case a lower

[6]Obviously, this latter effect is a purely distributive one. Since the world market is covered anyway, a higher limit-price is a pure redistribution from international consumers to F1.

[7]With incompatibility the marginal effect on F1's profits of a price decrease is more pronounced with incompatibility due to the indirect effect on the world market leading to a higher installed base.

subsidy (than with given compatibility) is sufficient to achieve a covered domestic market.

If F1's home market is covered the critical condition for a monopolization of the world market is (see Equation [12])

$$T \geq 3(1-n)/n.$$

5.2.2 Duopoly in the third market

With a duopolistic structure in the world market, the production subsidy improves F1's strategic position, thus increasing F1's market share in the third market. It becomes an indirect strategic trade-policy device in the sense of Brander and Spencer (1985).

The government's first-order condition reads

$$\frac{\partial W}{\partial s} = \left(V - x_1^1 + 2n(\frac{5}{12} + x_1^1 + \frac{3 + nx_1^1}{18(1-n)}) \right) \frac{\partial x_1^1}{\partial s} = 0.$$

The second-order condition holds for $n < 0.383$. Solving this first-order condition and using Equation (26), we obtain for the optimal subsidy in the duopolistic case with a **non-covered market in country 1**:

$$s_{uc}^{ic,d} = \frac{\left(\frac{5n}{6} + V\right)(18A - 4n^2)}{9 - 18n - \frac{3n}{(1-n)} - \frac{n^2}{(1-n)}} - 2V - \frac{7}{3}n. \tag{31}$$

Comparing this optimal subsidy level with the two previous ones, the following picture emerges. With duopolistic competition in the world market, a national subsidy has an impact on firstly, F1's profits in the world market, and secondly the size of the network for domestic consumers. The subsidy clearly improves the strategic position of the national producer in the world market, enabling F1 to charge a higher price and to acquire a larger market share (see Eqs. (9) and (10)). Therefore, this profit-shifting effect clearly calls for a larger subsidy. The network effect of the subsidy is, however, less pronounced than in the monopoly case since the overall network size for F1's customers is smaller with duopolistic competition than with either compatibility or limit-pricing.

The government has to realize, that by setting the subsidy in the case of given incompatibility, it is very well able to influence the structure of the world market. This has to be taken into account when deciding on the optimal subsidy for a given parameter range. In order to clarify this, we have to address two basic questions. First, we have to ask which subsidy level is preferable given that the associated market structure is feasible. Secondly, we need to investigate whether the targeted market structure is indeed feasible.

We proceed step by step. We start by addressing the first question. For that purpose, we insert the previously derived subsidies into the welfare functions, under the working hypothesis that the anticipated market structure will actually emerge in later stages of the game.

The result of this exercise is displayed as line 1 in Figure 1. To the right of this border line and with a monopolistic world market structure the government would prefer $s_{nc}^{ic,m}$. To the left of line 1 and with a duopolistic market structure the optimal subsidy $s_{nc}^{ic,d}$ is preferable. But the decisive question is whether all this is indeed feasible.

To find out more, we have to investigate whether the subsidies, chosen in stage 2, lead to the respective market structure in stage 4 of our game. We do this by inserting the expression for the subsidies into the respective critical conditions for the emergence of the market structures. Inserting Equation (31) into (24) gives us the critical line for the duopoly case (line 2 in Figure 1). To the left of it a duopoly structure is feasible, whereas to the right a limit-pricing strategy represents the Nash equilibrium. The respective critical line for the monopoly case is derived from Equation (30) and represented as line 3 in Figure 1. Above (below) this line a limit-pricing strategy is (is not) feasible. A closer look at these three lines reveals that in the intermediate range, the government would prefer a monopolistic structure which is, however, not feasible for the first-best subsidy level.[8] If the government chose its first-best subsidies $s_{nc}^{ic,m}$ within this parameter range, a duopolistic rather than a monopolistic market structure would emerge.

Therefore, the second-best alternative, namely a higher subsidy which just enforces a monopolistic world market structure, has to be considered. With the help of (23) we obtain for this second-best subsidy level:[9]

$$\tilde{s} = \frac{6(1-n)^2}{n} - 2n - V. \tag{32}$$

By inserting this expression into the welfare function under the (rationally) expected monopolistic structure and comparing it with the duopoly result, we can derive line 4 in Figure 1. To the right of this line (and below the critical lines 2 and 3) the second-best subsidy level for the monopolistic case is preferred over the duopoly solution.

Insert Figure 1 about here

The different subsidy levels under given incompatibility are summarized in Figure 2.

Insert Figure 2 about here

[8] An even closer inspection reveals that there is a small parameter range between lines 2 and 3 where an equilibrium does not exist (in the lower east corner of Figure 1) or multiple equilibria exist (in the upper left part of the Figure). Given that this only affects a rather small parameter range and since with multiple equilibria the government opts for the preferred monopolistic structure and the associated subsidy, we choose to neglect this parameter range in the subsequent analysis.

[9] Obviously, this is the second-best alternative. A smaller subsidy would imply the failure to achieve the desired monopolistic structure. Since the first best subsidy is smaller than $\tilde{s}$, $s > \tilde{s}$, in contrast, implies an even lower welfare level.

We can summarize these results in

Lemma 1 *With given incompatibility, the weak network externalities regime can be divided into three subcases. With very small network effects,* $s_{nc}^{ic,d}$ *is chosen leading to a duopolistic structure in the world market. For network effects in the upper range of this case (n close to 0.368),* $s_{nc}^{ic,m}$ *is the optimal subsidy leading to a monopoly in the world market. In the intermediate range, the second-best subsidy,* $\tilde{s}$*, is the preferred choice of country 1's government and leads to a monopolized world market.*

If the second order condition of the government's maximization problem does not hold, a corner solution is optimal. The government's subsidy ensures a corner solution in F1's home market, thus improving its strategic position to the maximal extent.

With (26) we derive the corresponding subsidy for a **covered market in country 1** as

$$s_c^{ic,d} = (T/9)(18A - 4n^2) - \frac{(2V + \frac{7n}{3})}{2} \tag{33}$$

The critical condition for the emergence of a duopoly solution in the world market is

$$T < 3(1-n)/n$$

A comparison of the subsidy with duopolistic competition in the world market (and a covered domestic market) and the other optimal subsidies with a covered domestic and world market reveals the following. The subsidy with a duopolistic market and incompatibility is always smaller than with compatibility. This is due to the stronger incentive for F1 itself to build up a larger installed base domestically and the fact that the subsidy is not used to shift F1's reaction function outward, but rather to assure the existence of covered market. With incompatibility, we observe a more pronounced incentive for F1 to expand its own installed base since this improves the firm's profits in the world market. Therefore, a smaller subsidy suffices to cover the domestic market.

An indecisive picture emerges if we compare the subsidies in the two incompatibility regimes. For a high maximal willingness to pay (V) and strong network effects (large n), the marginal effect on F1's profits of a larger installed base is more pronounced with duopolistic competition in the world market than with limit-pricing. Therefore, for these parameter levels (see Figure 3)[10] $s_c^{ic,d} < s_c^{ic,m}$.

Insert Figure 3 about here

6 The (in-)compatibility decision

We can now turn to the basic decision: should firms opt for compatibility or for incompatibility? Since the compatibility decision requires unanimity, we have to take a closer look at the firm with the strongest incentive to opt for incompatibility. Apparently, it is not F2. With incompatibility F2's profits are either zero (in the monopoly case) or (in the duopoly case) are given by Equation (11). In the latter case, F2's profits are maximal for $x_1^1 = 0$. But even in this extreme case, due to the price-competition effect, $G_2^{d,3} = (1-n)/2 < 0.5$. That is, F2 is always better off with compatibility than with incompatibility.[11] Therefore, it suffices to focus on F1's behavior in this respect.

Before we approach the compatibility/incompatibility decision in the various regimes, it is quite helpful to discuss the various forces driving this decision. There are four effects which determine the level of profits under both compatibility and incompatibility.

[10] This figure is drawn for V=2, but the general picture is independent of the value of V.

[11] This result is due to the fact that F2 does – by assumption – not invest in its home market. Allowing for this possibility would not alter our results, as long as F1's installed base is larger than F2's.

The **price-competition effect** describes the fact that price competition is fiercer with incompatibility than with compatibility. Since in the incompatibility case firms compete for larger networks they act more aggressively by setting lower prices (see section (3.2)). The higher the network-effect parameter, the more pronounced is this price-competition effect. The price-competition effect leads to, *ceteris paribus*, lower profits with incompatibility than with compatibility. The second effect, the **network-size effect**, also leads to higher profits with compatibility. The network-size advantages of compatibility result in a higher willingness-to-pay among domestic consumers and hence in higher profits for F1. The third effect, the **installed-base effect**, clearly acts in favor of incompatibility. The installed-base advantage is only possible under incompatibility, allowing F1 to improve its strategic position and potentially increasing F1's profits. As with the other effects, the installed-base effect increases with the network effect parameter n. The fourth effect, the **subsidy effect**, stems from the government's intervention in the domestic market. It affects the relative profit levels under the two regimes. The direction of the subsidy effect is, however, not clear-cut, as our above discussion has revealed, and depends, among other things, on whether the covered or non-covered market regime prevails.

Against this background we are now able to analyze the compatibility decision for the different regimes. We distinguish between the weak network effects regime ($n < 0.368$, with a non-covered domestic market) and the strong network effects regime ($n > 0.5$, with a covered domestic market). We neglect the intermediate parameter regime in order to avoid a confusing number of cases.

6.1 The strong network regime; $n > 0.5$

With sufficiently strong network effects it is always in the interest of country 1's government to opt for a corner solution, i.e. to set the subsidy such that the domestic market is covered.

Inserting the optimal subsidy level s_c^{co}, Equation (16) and the covered market condition ($x_1^1 = T$), into the profit function gives us the profit levels in the compatibility case:

$$\Pi_c^{co} = T^2(1-n) + 0.5. \tag{34}$$

The same procedure yields for the limit-pricing case under incompatibility

$$\Pi_c^{ic,m} = T^2(1-n) + (n-1). \tag{35}$$

A brief glance at the two profit functions reveals that $\Pi_c^{co} > \Pi_c^{ic,m}$. The intuition behind this result is the following. Given that the network size in both cases is the same, $(1+T)$, the network-size effect does not play any role. The installed-base effect clearly favors the incompatibility solution since it implies higher profits in the world market. The price competition effect points in the opposite direction. The crucial role falls on the subsidy effect, however. Our above discussion has shown that $s_c^{co} > s_c^{ic,m}$, implying higher profit levels with compatibility. For $n > 0.5$ this effect always overcompensates the installed base effect leading to our above result.

Inserting the optimal subsidy $s_c^{ic,d}$ into the profit function and comparing the result with Π_c^{co}, we obtain after some tedious calculations:

$$\Pi_c^{co} - \Pi_c^{ic,d} = \frac{n}{18(1-n)}\Big(9(1-n) + 6T(1-n) + nT^2(10-8n^2)\Big) > 0, \tag{36}$$

where $\Pi_c^{ic,d}$ denotes the profit level with incompatibility and duopolistic competition in the world market. Here, as in the above subcase, the subsidy effect plays the decisive role. In addition, the network effect points against the compatibility decision.

We can summarize our findings in

Proposition 1 *With strong network effects ($n > 0.5$) country 1's government always opts for a corner solution with a subsidy leading to a covered domestic market. In this case, both F1 and F2 experience higher profits with compatibility than with incompatibility. The choice for compatibility is mainly due to the subsidy effect, i.e. it emerges as a consequence of government intervention.*

6.2 The weak network regime: $n < 0.368$

With weak network effects, the optimal subsidy leads to internal solutions, i.e. a non-covered domestic market.

Inserting the optimal subsidy (28) into the profit function (18), yields for the compatibility case

$$\Pi_{nc}^{co} = \frac{(V+n)^2(1-n)}{(1-2n)^2} + 0.5 \tag{37}$$

With given incompatibility, matters are much less straightforward. Three alternative subsidy levels (see Figure 2) leading to two different world-market structures have to be considered.

Using (29) into (20) yields for the incompatibility case with limit-pricing and $s_{nc}^{ic,m}$

$$\hat{\Pi}_{nc}^{ic,m} = \frac{(V+2n)^2(1-n)}{(1-2n)^2} + (n-1) \tag{38}$$

In the parameter range in which F1 expects the government to provide $\tilde{s}$ we find, by inserting $\tilde{s}$ into (20),

$$\tilde{\Pi}_{nc}^{ic,m}(\tilde{s}) = \frac{9(1-n)^3}{n^2} + n - 1 \tag{39}$$

Comparing the corresponding profit levels for the duopoly case under incompatibility with Π_{nc}^{co} we can draw line 1 in Figure 4. To the right (left) of this line F1 prefers (in-)compatibility. The comparison between $\hat{\Pi}_{nc}^{ic,m}$ and Π_{nc}^{co} gives us line 2 in Figure 4. To the right (left) of this line F1 prefers (in-)compatibility.

However, the (in-) compatibility decision of F1 is constrained by the fact that to the left of line 3 (derived as line 4 in Figure 1) a monopolistic world market structure is never feasible from the point of view of F1. To the left of this line the national government would never employ a subsidy leading to limit-pricing in the world market. As we shall show in a moment, above line 3 an incompatible monopoly is not only preferred by F1 but also feasible from F1's point of view. The following picture emerges: In the shaded area of Figure 4 F1 opts for incompatibility, whereas it chooses compatibility in the non-shaded parameter space. With the exception of the area in-between lines 1 and 3 an incompatible monopoly emerges in the world market. Only in this rather small area, an incompatible international duopoly emerges. Incompatibility with duopolistic competition is only preferable to compatibility if the installed-base effect is rather pronounced (i.e. n is sufficiently large), but the network effect is not (i.e. V is rather small).

With weak network effects F1 opts for compatibility. As shown in our earlier discussion, the optimal subsidy with limit-pricing exceeds the one with compatibility. In addition to the subsidy effect, the installed base effect calls for incompatibility resulting in limit-pricing. Since the installed base effect is absent in this situation, only the price-competition effect stands in favor of compatibility. With strong network effects this latter effect is, however, outweighed by the the former,inducing F1 to opt for compatibility.

Insert Figure 4 about here

It remains to be shown that above curve 3 an incompatible monopoly is indeed not only preferred but also feasible from F1's point of view. This is done with the help of Figure 5. In this figure, line B denotes $V-n$ combinations for which $\Pi_{nc}^{ic,m}(\tilde{s}) = \Pi_{nc}^{co}$. Below this line $\Pi_{nc}^{ic,m}(\tilde{s}) > \Pi_{nc}^{co}$ holds. Line A represents the critical line for the first-best monopoly case (see Equation (30)). Above this line A, a monopoly solution with incompatibility (see also our reasoning above, related to Figure 4) and the first best subsidy is feasible and preferred by F1 as well as by country 1's government. Between lines A and 3, where the critical cut-off level for a monopoly is reached, an incompatible monopoly with an anticipated $\tilde{s}$ emerges. In a nutshell, in the present subcase an incompatible monopoly will prevail for all $V-n$ combinations above line 3.

Insert Figure 5 about here

We summarize our findings in

Proposition 2 *With weak network effects ($n < 0.368$) country 1's government never chooses a subsidy which leads to a covered national market. In this regime ($n \in [0, 0.368]$) relatively large values of n induce F1 to opt for incompatibility. Only for an intermediate willingness to pay the national government employs the domestic subsidy as a strategic device for intervention in the world market. For small values of n as well as large ones ($n > 0.5$) non-strategic subsidization leads to compatibility.*

7 Concluding remarks

The main objective of this paper has been to investigate the interaction between the (in)compatibility decisions in an internationally operating network industry and local subsidies granted to national producers.

Our analysis has revealed that installed-base effects, and therefore the strategic impact of the local subsidy only exist with incompatibility. Only then export promotion via a local subsidy may work. With compatibility, local subsidies only lead to an improved allocation in the home market.

Since the world market is, by assumption, covered, compatibility is always preferable in terms of world welfare. This result is achieved under strong as well as weak network effects. In both cases, the subsidy effect plays an important role. The subsidy leads to an improved allocation in the domestic economy of country 1 and thus increases world welfare.

With intermediate network effects, incompatibility becomes the optimal choice and local subsidies act as strategic trade policy devices. It is under these circumstances that national policies counteract the interest of the world as a whole. Our analysis suggests that, in this situation, local policy instruments should be integrated into international trade policy agreements. Thus, local production subsidies act de facto as export subsidies but without being banned by international trade policy agreements

The main limitation of the paper is, without doubt, the restriction to only one country and firm being able to endogenously establish an installed base. But considering the insights provided by the strategic trade policy literature, we believe that allowing both firms and governments to endogenously determine their installed bases would not alter our main qualitative conclusions.

A straightforward extension of our approach would be the analysis of import competition. One could ask under which circumstances a restriction of import competition (via an import tariff) rather than export promotion would be in the interest of the domestic government and may lead to an incompatibility decision. We leave this issue for further research.

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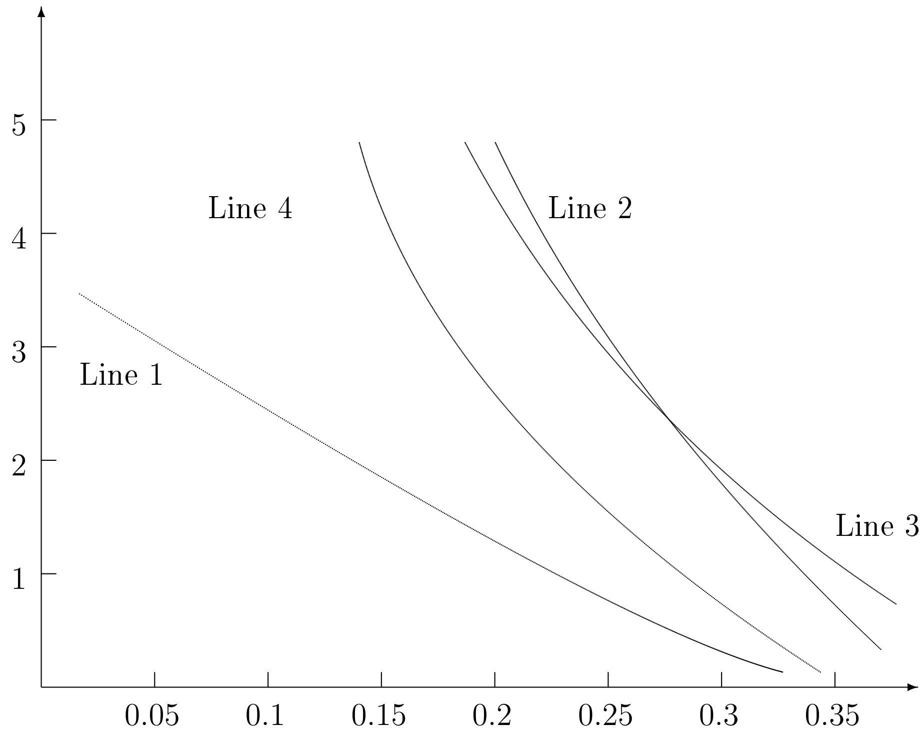

Figure 1: First- and second-best welfare levels for government 1 with a duopoly in market 3

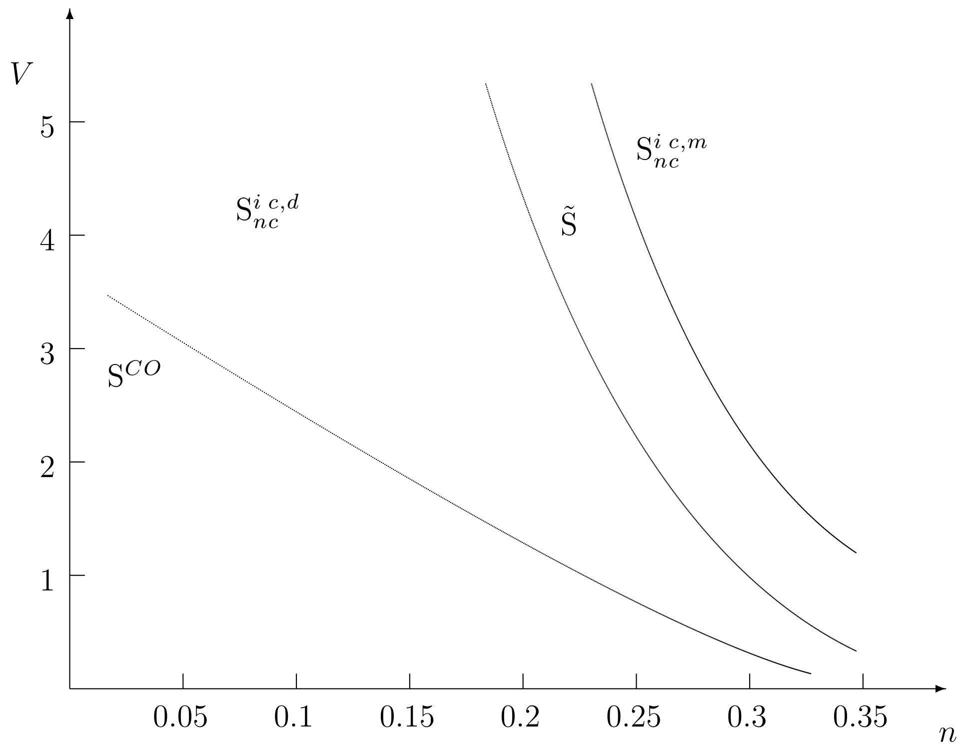

Figure 2: The optimal subsidies under incompatibility

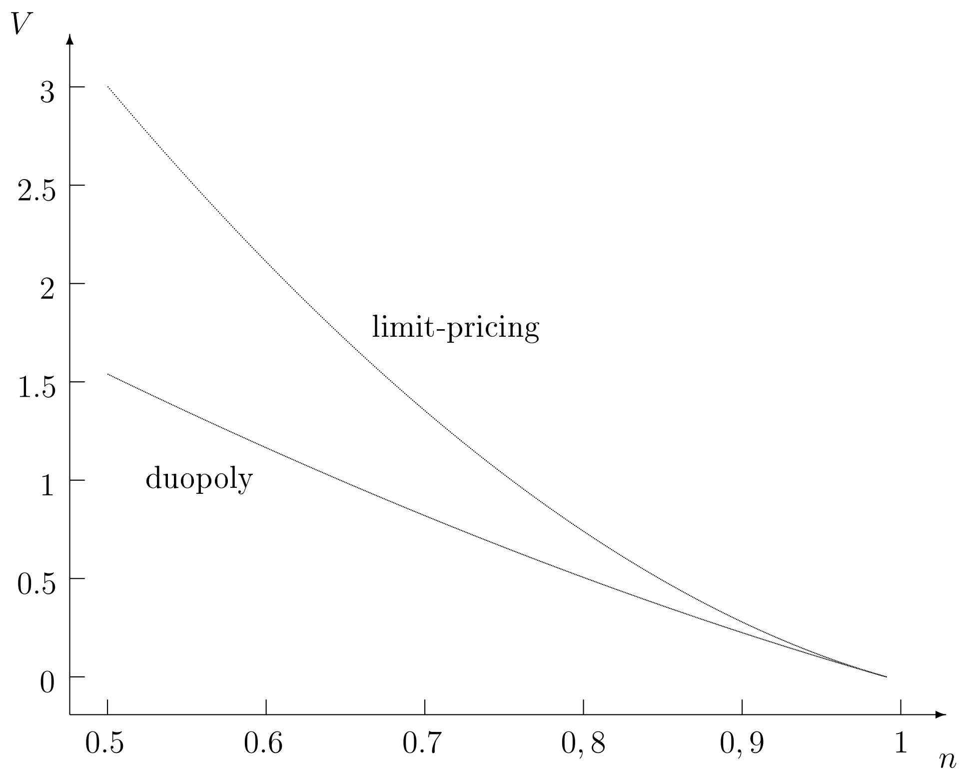

Figure 3: Subsidies in the covered market regime ($S_{nc}^{i\ c,m} > S_{nc}^{i\ c,d}$ holds for the entire range)

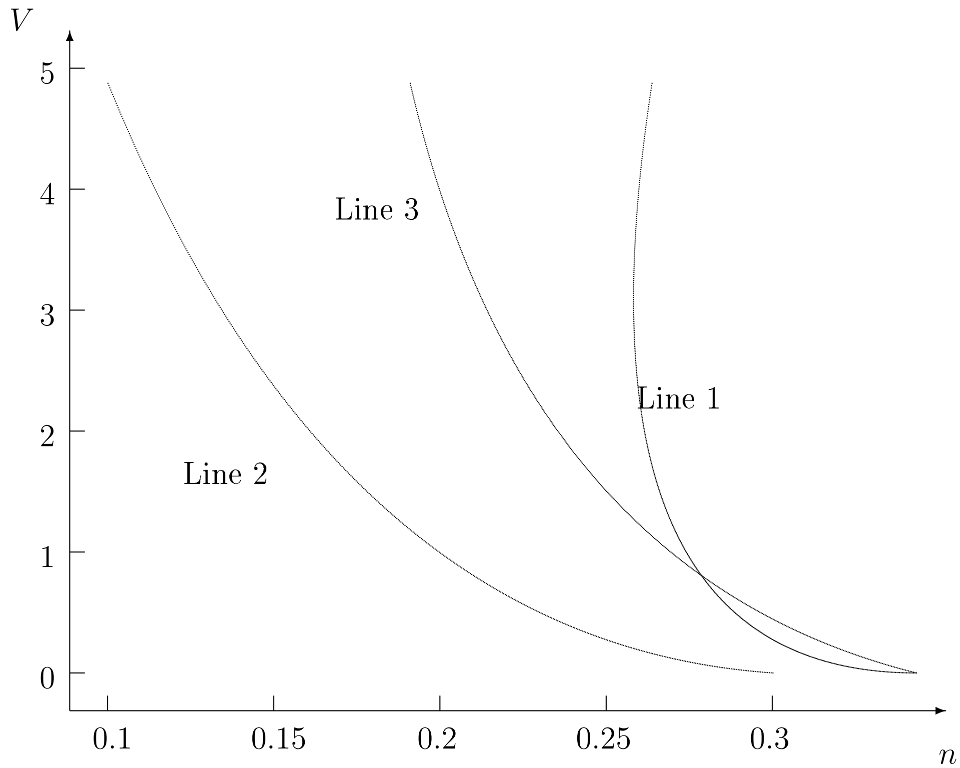

Figure 4: Profits and market structure in the weak network regime

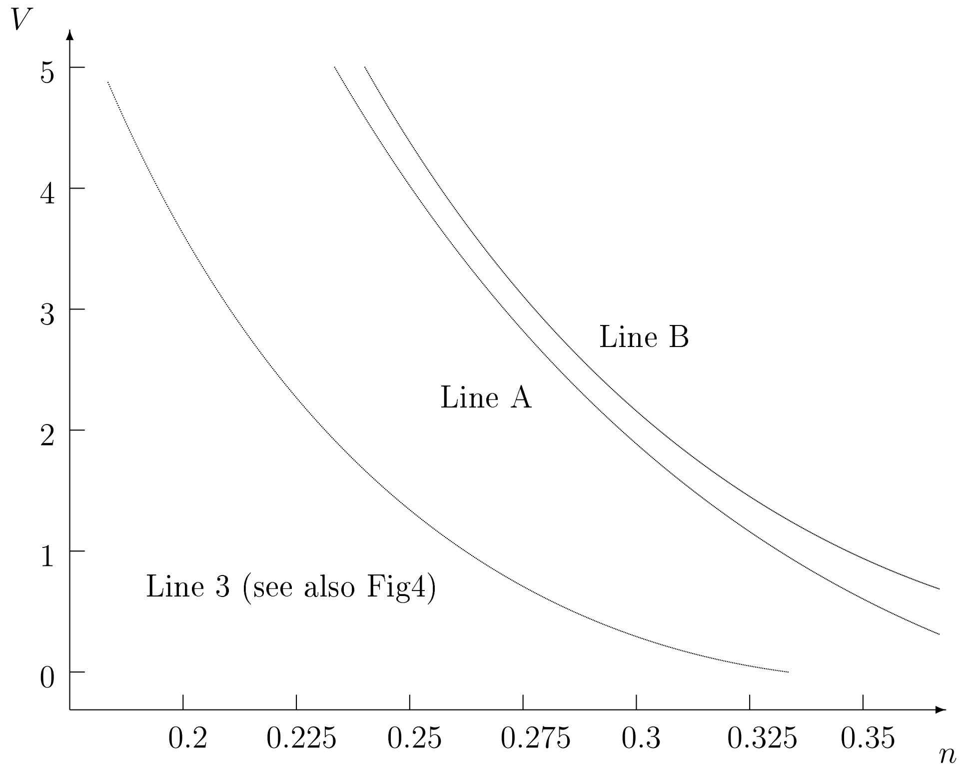

Figure 5: Profits level and the choice of (in-)compatibility