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ABSTRACT

A Model Of Market-Enhancing Infrastructure*

This Paper develops a framework for evaluating the social returns to infrastructure investments that intensify product market competition. We use a circular model with asymmetric production costs both for incumbent firms and potential entrants, where unit transport cost measures the intensity of competition (quality of infrastructure). The static and dynamic welfare effects of infrastructure investment that lowers unit transport cost are analysed, focusing on market selection among asymmetric firms, restructuring and entry. We show how these welfare effects depend on the initial level of market development, as measured by the distribution of costs in the economy, the number of incumbent firms, the degree of market competition, and restructuring and entry costs. The model generates an endogenous demand for infrastructure investment and the possibility of a low infrastructure trap that arises from cost heterogeneity rather than from any kind of non-convexities. We simulate the relative welfare effects of reducing transport, restructuring and entry costs, and we evaluate in each case the fraction of social returns which traditional cost–benefit analysis would fail to capture.

JEL Classification: L13, O12, P20
Keywords: infrastructure, heterogeneity, competition, market selection, restructuring, entry, cost–benefit analysis

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NON-TECHNICAL SUMMARY

This Paper develops a simple framework for analysing the social returns to infrastructure investments that foster market interactions and competition. Such investments include physical infrastructure that reduce search and transportation costs and thereby limit the scope for (local) monopoly power. But they also encompass institutional infrastructures that also have the effect of enhancing the competitive process in (emerging) market economies (e.g. competition agencies, regulatory frameworks for banking and securities markets, bankruptcy institutions, contract enforcement mechanisms etc.). We develop a model of monopolistic competition where infrastructure investment is modelled as an increase in 'market competition' and we analyse how such investment affects both incumbent firms' incentives to reduce production costs and the entry of new firms.

We develop an extension of the circular model of competition (Salop, 1979) in which there are *asymmetric production costs* both among incumbent firms and potential entrants. Product-market competition is measured by the unit transport cost and we first analyse the static and dynamic welfare effects of reducing that cost. The model allows us to capture three main contributions of infrastructure investment: (i) *market selection*: by lowering transportation costs, infrastructure investments reduces the equilibrium market share for higher-cost firms, which in turn reduces average production costs; (ii) *restructuring*: intensified competition changes the incentives of low- and high-cost firms to invest in lowering their production costs, but differently for the two types of firms; and (iii) *entry*: while increased Product-market competition dilutes the incentives for new high-cost firms to enter the market, in contrast to the symmetric cost case where a lower transport cost results in reduced entry – *ex post* competition drives out *ex ant*e competition (Dasgupta and Stiglitz, 1980) – here a lower transport cost can actually encourage entry by low-cost firms if there is sufficient cost asymmetry.

Second, we show how the effects of competition-enhancing infrastructure on market selection, restructuring and entry vary with the '*level of market development*,' as measured by the initial distribution of costs in the economy, the initial number of incumbent firms, the initial level of product market competition, restructuring costs and the cost of entry faced by new potential entrants (which in turn reflect characteristics such as the access to credit markets, the scarcity of physical and human capital, and the legal and regulatory environments).

Third, competition-enhancing infrastructure creates both *gainers* and *losers*. Intensifying product-market competition, infrastructure investments that lower communication, transportation and information costs help weed out existing *high-cost* firms while making it more attractive for *low-cost* potential competitors to enter the market because these low-cost firms anticipate that they will be able to compete more effectively after entry. This implies that firms with different cost structures will have different demands for infrastructure: low-cost firms will demand more infrastructure investment (if there is sufficient cost asymmetry), whereas high-cost firms will unambiguously oppose such investment. Our approach thus opens the way for a political analysis of the demand for (institutional and physical) infrastructure, and by doing so it points to the existence of a two-way causality between average productivity and infrastructure. Although we do not explicitly address political economy issues, the model generates an endogenous demand for infrastructure and points to the possibility that an economy with high initial transport costs get stuck in an inefficient low-level infrastructure trap because the infrastructure-induced loss of profits for high-cost firms more than counteracts the increase in profits for low-cost firms. Thus, in contrast to other models of infrastructure in which the possibility of low-infrastructure/low-development traps arises from the existence of increasing return and thick market externalities, here it arises from *cost heterogeneity among firms and the resulting potential conflict of interest*.

Finally, we simulate the model to compare the welfare effects of three *different* types of investments: those aimed at reducing unit transport costs, restructuring costs and entry costs. For each type, we evaluate the fraction of social returns that would be captured by traditional (static) *cost–benefit analysis*. The literature on cost–benefit analysis discusses the problem of measuring the 'indirect' social returns to infrastructure and other projects. But while this literature provides a coherent general equilibrium framework to evaluate static externalities in project appraisal, it has not produced a framework in which the (dynamic) relationships between infrastructure, restructuring and entry (or innovation) can be formally discussed. Our Paper can be viewed as a first attempt to produce such a framework.

1 Introduction

This paper develops a simple framework for analyzing the contribution of infrastructure investments that reduce transaction costs and thereby intensify market competition. Such investments include physical infrastructure that reduces search and transportation costs and therefore limits the scope for (local) monopoly power. But they also encompass institutional infrastructure which has the effect of enhancing the competitive process in (emerging) market economies (e.g, competition agencies, regulatory frameworks for banking and securities markets, bankruptcy institutions, and contract enforcement mechanisms).[1] In contrast, earlier theoretical work on infrastructure and development had emphasized the indivisibility and public good aspects of infrastructure and the coordination failures involved in building infrastructure ahead of demand (e.g, Hirschmann 1958; Murphy, Shleifer and Vishny, 1989). In those models, infrastructure changes production costs but does not directly affect the competitive interaction among firms.

Our focus on *competition-enhancing* infrastructure, is primarily motivated by three considerations. The first is the need for a better understanding of the relationship between *infrastructure and growth.* While a number of empirical studies have established an empirical link between infrastructure and (long-run) productivity growth[2](e.g., Aushauer 1989; Roeller and Waverman 2000; and Fernald 1999), to our knowledge there is no theoretical model of the underlying mechanisms at work. In particular, the traditional AK models of infrastructure and growth do not distinguish between capital accumulation and technical change, and are unable to distinguish between the growth impact of infrastructure and that of any other kind of physical investments. While the Schumpeterian growth literature (Aghion and Howitt, 1998) explicitly models technological innovation as a primary source of long-run productivity growth, it does not deal with the role of infrastructure. Our paper tries to fill this theoretical gap by developing a model of monopolistic competition where infrastructure investment is modelled as an increase in 'market competition'.[3] A main focus of our analysis is on how infrastructure

[1]For example, Johnson, McMillan and Woodruff (1999) show that, when contract enforcement is difficult, enterprises find other ways to discipline customers and suppliers for non-compliance including localising their market transactions. But restricting the scope of market interactions in turn softens competition among incumbent firms.

[2]Most of these studies focus on physical infrastructure, primarily telecommunications and transport. That institutional infrastructure might also be empirically related to growth is suggested by the cross-country growth regressions in Barro and Sala-i-Martin(1995), but overall the effects of institutional infrasturucture remain less explored. In all these studies, there is an issue about which way causality between infrastructure and productivity growth runs. Using a simultaneous equations framework, Roeller and Waverman (2000) show that the empirical impact of infrastructure on growth is not simply due to demand-induced infrastructure development.

[3]While our primary focus is on infrastructure investments that increase the degree of product market competition, we also consider the effects of "infrastructure" investments aimed at reducing entry costs or restructuring costs (See Section 6 below).

investment can affect both incumbent firms' incentives to reduce production costs and the entry of new firms (i.e., the innovation process).

The second motivation is the need to develop a framework in which to think about the *political economy aspects of infrastructure investment.* Unlike infrastructure investments aimed only at reducing production costs or facilitating consumption, infrastructure that lowers communication, transportation and information costs creates both *gainers* and *losers.* By intensifying product market competition, such infrastructure helps weed out existing *high-cost* firms, while making it more attractive for *low-cost* potential competitors to enter the market because these low cost firms anticipate that they will be able to compete more effectively after entry. This implies that firms with different cost structures will have different demands for infrastructure. In our model, low-cost firms may demand more infrastructure investment, if there is sufficient cost asymmetry, but high-cost firms unambiguously oppose such investment. While we do not explicitly analyze the political economy of infrastructure investments, our model generates an endogenous aggregate demand for infrastructure and identifies the possibility that an economy with high initial transport costs can be stuck in an inefficient, low-level infrastructure trap because the infrastructure-induced loss of profits for high-cost firms may exceed the increase in profits for low-cost firms.

Third, there is a need to improve upon traditional *cost-benefit analysis (CBA)* when evaluating infrastructure investments. The literature on CBA discusses the problem of measuring the 'indirect' social returns to infrastructure and other projects (Little and Mirrlees, 1974; for a review, Dreze and Stern, 1987). But while this literature provides a coherent general equilibrium framework to evaluate static externalities in project appraisal, it has not produced a framework in which the dynamic interplay between infrastructure investment, competition, enterprise restructuring and entry (or innovation), can be formally discussed. Our paper can be viewed as an attempt to provide such a framework.

We consider an extension of the circular model of competition (Salop 1979) in which there are *asymmetric* production costs, both among incumbent firms and potential entrants. Product market competition is measured by the unit transport cost, and we first investigate the static and dynamic welfare effects of infrastructure investments which result in reducing that cost. Our model allows us to capture three main contributions of infrastructure investment: (i) *direct market selection*: by lowering transportation costs, infrastructure investments generate a smaller equilibrium market share for higher-cost firms, which in turn reduces average production costs - in other words, infrastructure investment and the resulting increase in product market competition improve market selection among heterogeneous firms; (ii) *restructuring:* competition-enhancing infrastructure also affects the incentives for firms to engage in cost-reducing activities, and it does so in different ways for high and low-cost firms; (iii) *entry*: increased product market competition dilutes the incentives for new high-cost firms to enter the market but, in contrast to the symmetric cost case where a lower transport cost results in reduced entry (Dasgupta and Stiglitz,1980), here a lower transport cost can actually encourage entry by low-cost potential entrants for whom post-entry competition consequently becomes more favorable. The last two effects are themselves the dynamic by-products of the direct market selection effect in a two-stage framework where price competition is preceded by firms'decisions whether to reduce costs and/or enter the market.

We then analyse how the effect of competition-enhancing infrastructure on market selection, restructuring, and entry can vary with the 'level of market development', as measured for example by the initial distribution of costs in the economy, the initial number of incumbent firms, the initial level of product market competition (i.e., the quality of infrastructure), restructuring costs, and the cost of entry faced by new potential entrants.

Finally, our model can be used to compare the social returns to *different* types of investments. We simulate the model to compute the welfare effects of reducing unit transport cost, restructuring costs and entry costs, and we evaluate the fraction of the social returns that traditional cost-benefit analysis is likely to capture.

The analysis in this paper is related to four main strands of literature. The first is the recent empirical literature showing the pervasive micro-level heterogeneity (at both plant and firm levels) in terms of productivity growth, entry and exit both in industrialised and developing economies (e.g., Baily, Hulten and Cambell, 1992; Olley and Pakes, 1996; Roberts and Tybout, 1996). This literature suggests that the three selection effects identified in our paper – direct market selection, restructuring (within-plant improvement), and entry – have been important sources of growth in average productivity, but that the relative importance of these effects vary across sectors, countries and time.[4] The second strand is previous theoretical work on 'big push' and forward linkages (Hirschman 1958; and Murphy, Shleifer and Vishny, 1989). Whereas in this literature the possibility of a low-infrastructure/low-development trap arises from the existence of increasing returns and thick market externalities, in our model it arises from the *cost heterogeneity among firms and the resulting potential conflicts of interest.*

Third, our work relates to earlier research on the links between competition, entry and innovation incentives (Dasgupta and Stiglitz, 1980; Bolton and Farrell, 1990; Hart, 1983; Scharfstein, 1988; Schmidt,1997; Aghion, Dewatripont and Rey, 1999; Aghion and Howitt,1998). These papers emphasize the importance of competition in providing incentives, but none of them points to the role of competition in intensifying *market selection* among

[4]Moreover, as predicted by our model, there is typically both a lower *average* and greater *dispersion* of productivity growth in non-tradeables and other sectors protected from international competition. Also see Dutz (in Roberts and Tybout, 1996) who shows that trade liberalization in Morocco had a selection effect by shifting resources from small to large (presumably more efficient) firms.

incumbents and in the entry process. As we have argued above, market selection can dramatically affect the relationship between (ex post) product market competition and (ex ante) entry.

Finally, our emphasis on cost asymmetry and market selection is related to the literature on competition and market concentration in oligopolistic industries. In particular, our result that welfare is *positively* correlated with the equilibrium market concentration when there is sufficient degree of cost asymmetry among firms (see Section 2), is closely related to the analysis of the externality effects of horizontal mergers in Farrell and Shapiro (1990).[5]

The paper is organized as follows. Section 2 presents the basic model with asymmetric cost firms, exogenous cost levels and no entry, and examines the role of infrastructure in this context. In Section 3 we provide a preliminary attempt at endogenizing the aggregate demand for infrastructure. In Section 4 we endogenize production costs and investigate how infrastructure investment changes the incentives for high- and low-cost firms to reduce costs. Section 5 analyzes entry. In Section 6 we use simulation analysis to compare between the welfare impacts of different types of infrastructure investments, and to evaluate for each type the proportion of the welfare gains that traditional cost-benefit analysis is likely to capture. Section 7 concludes by suggesting some avenues for future research.

2 Basic model

We consider a horizontal product differentiation model (Salop 1977), where n firms evenly locate on a circle of length equal to one.[6] The demand side of the economy is standard: consumers are uniformly distributed on the circle, pay price p_j to purchase one unit of good from firm j, and incur a transport cost of t per unit of distance. We assume that consumers' willingness to pay for the differentiated product is sufficiently high that total demand remains equal to one for the range of prices considered.

Unlike the standard model, we introduce cost asymmetry: a fraction q of firms have high unit costs (c_H) and $1-q$ have low unit costs (c_L), and $\Delta c = c_H - c_L > 0$ denotes the degree of cost asymmetry. Firms do not know the cost characteristics of neighboring firms, and thus must base their pricing decisions on the "average" price of their neighbors, which reflects the mix between high and low cost firms in the economy. The parameters q, c_H and c_L are common knowledge. In this section we study price competition among the n firms. As price decisions are made simultaneously by firms, we can analyse the equilibrium without considering signalling of cost characteristics

[5] The idea that competition may be positively correlated with equilibrium market concentration goes back to Demsetz (1972), who emphasized the role of cost asymmetries in a perfectly competitive framework.

[6] Locational decisions are taken as exogenous.

through prices.

Let p_i , p_{i-1}, and p_{i+1} denote the prices charged by firm i and its two immediate neighbors. The marginal consumer between i and $i+1$, and i and $i-1$, lies at a distance x_L and x_R from firm i, where

$$x_L = \frac{p_{i-1} - p_i}{2t} + \frac{1}{2n}.$$

and

$$x_R = \frac{p_{i+1} - p_i}{2t} + \frac{1}{2n}.$$

When picking its price p_i, firm i does not observe prices p_{i-1} and p_{i+1} charged by its neighbors. Rather, anticipating that all low cost firms (resp. all high cost firms) will charge the same price p_L (resp. p_H) in equilibrium, firm i chooses price p_i to

$$\max_p \, (p_i - c_i) D_i(p_i \mid p_H, p_L)$$

where

$$\begin{aligned} D_i(p_i, p_H, p_L) &= E_{p_{i-1}} x_L + E_{p_{i+1}} x_R \\ &= \frac{q p_H + (1-q) p_L - p_i}{t} + \frac{1}{n} \end{aligned}$$

is the expected demand for good i conditional on all other high (resp. low) cost firms charging price p_H (resp. p_L).

Using the first order conditions, and the fact that in symmetric Nash equilibrium $p_i = p_H$ whenever $c_i = c_H$ and $p_i = p_L$ whenever $c_i = c_L$, we get the following equilibrium prices and market shares for high and low cost firms:

$$p_H = t/n + c_H - (1-q)\Delta c/2 \tag{1}$$

$$p_L = t/n + c_L + q\Delta c/2 \tag{2}$$

$$D_H = 1/n - (1-q)\Delta c/2t \tag{3}$$

$$D_L = 1/n + q\Delta c/2t \tag{4}$$

where the parameters $\{c_{L,} c_{H,} q, t, n\}$ must satisfy the constraints $p_j \geq 0$ and $1 \geq D_j \geq 0$ for $j = L, H$. Note that $D_L > D_H$ and that a reduction in t raises the market share of low cost firms.

Equilibrium profits are given by

$$\Pi_H = t(1/n - (1-q)(\Delta c/2t))^2 = t D_H^2 \tag{5}$$

$$\Pi_L = t(1/n + q\Delta c/2t)^2 = t D_L^2 \tag{6}$$

As these expressions show, a reduction in transport cost t has two effects on equilibrium profits. The first is a *competition effect:* a lower transport cost (greater product market competition) reduces the profit margins for both low and high cost firms, *for given (equilibrium) market shares.* The second is a *selection effect*: intensified product market competition increases the market share of a low cost firm and reduces it for a high cost firm. Thus a decline in t unambiguously reduces profits for high cost firms, but the effect on low cost firms depends on the relative strength of the competition and selection effects.

We next study the welfare effects of reducing transport cost t. Since total demand is fixed in this model, maximizing total surplus is equivalent to minimizing the sum of production costs incurred by firms and transport costs incurred by consumers. In the Appendix we show that this sum can be written as:

$$K = \underbrace{n\{(1-q)D_L c_L + qD_H c_H\}}_{\text{total production cost}} + \underbrace{\tfrac{t}{4n^2}\{1 + 2q(1-q)\left(\tfrac{\Delta c}{2t}\right)^2\}}_{\text{total transport cost}}. \quad (7)$$

Reducing transport cost t has three basic effects on welfare:

1. A *direct cost reduction* effect: a lower t reduces the expected transport costs incurred by consumers located between identical firms [term $\frac{t^2}{4n^2}$ on the RHS of (7)]. The direct effect is smaller in markets with many firms, since the average distance travelled is smaller.

2. A *selection* effect: a lower t increases the market share differential $D_L - D_H$ between low- and high-cost firms, which in turn reduces aggregate production costs in equilibrium.

3. A *reallocation* effect: a lower t increases the market share differential $D_L - D_H$, which raises the average distance travelled by a consumer located between high- and low-cost firms [term $\left(\frac{\Delta c}{2t}\right)^2$ in the RHS of (7)].[7]

Proposition 1 describes how these various effects add up in this circular model with linear transportation costs:

Proposition 1 *A reduction in transport cost increases aggregate welfare, and the welfare gain is increasing in the degree of cost asymmetry.*

Proof. From equation (7)

$$\frac{dK}{dt} = \underbrace{\frac{1}{4n^2}}_{\text{direct cost reduction effect}} + \underbrace{nq(1-q)(\frac{\Delta c}{2t})^2}_{\text{selection effect}} - \underbrace{\tfrac{q(1-q)}{8n^2}(\frac{\Delta c}{2t})^2}_{\text{reallocation effect}} > 0$$

[7] The selection and reallocation effects work in opposite directions on welfare.With linear transport costs the selection effect dominates. However, if transport costs were sufficiently convex with respect to the distance travelled, then total welfare could end up rising with t.

which established the first claim. The second claim follows from the fact that the sum of the selection and reallocation effects is positive and increasing in Δc. □

A reduction in t increases the asymmetry of market shares through the selection effect. This implies that an intensification of competition *increases* equilibrium concentration in the economy when there is cost asymmetry. At the same time, a reduction in t lowers the profit margin both for low and high cost firms. Since low cost firms have a higher profit margin (see (1) and (2)), the aggregate profit margin in the economy can rise when competition intensifies, if there is enough cost asymmetry. This is summarised in the following proposition.

Proposition 2 *When there is cost asymmetry, a reduction in t (i) increases equilibrium concentration, (ii) reduces the profit margin of each firm, but (iii) increases aggregate profit if $\frac{\Delta c}{2t} > \frac{1}{q(1-q)n^2}$, or equivalently, $H_0 > \frac{2}{n}$, where H_0 is the Herfindahl index of concentration.*

Proof: See the Appendix.

A key implication of Propositions 1 and 2 is that welfare and the equilibrium level of concentration should be *positively* correlated when there is sufficient cost asymmetry in the economy. This important idea dates back to early critiques of antitrust policy, which stressed the importance of cost asymmetries in a perfect competition setting (Demsetz, 1972), and it also underlies the more recent work of Farrell and Shapiro (1990) on the welfare effects of horizontal mergers.

3 Endogenous demand for infrastructure

In this section, we show that the model outlined above generates an endogenous demand for infrastructure. As equations (5) and (6) show, a reduction in t lowers the profit of high cost firms but increases it for low cost firms when there is sufficient cost asymmetry (i.e., when the selection effect dominates the competition effect). At the margin, a low cost firm is willing to pay $-\partial\Pi_L/\partial t = (q\Delta c/2t)^2 - 1/n \gtreqless 0$ to reduce the unit transport cost at the margin. A high cost firm is willing to incur the monetary transfer $-\partial\Pi_H/\partial t = ((1-q)\Delta c/2t)^2 - 1/n^2$ in order to *raise* it, which in turn is negative whenever $D_H > 0$. In a pure rent-seeking economy where incumbent firms "vote" in proportion to these marginal gains or losses, the aggregate demand for infrastructure would be:

$$DI = -q\partial\Pi_H/\partial t - (1-q)\partial\Pi_L/\partial t = -1/n^2 + q(1-q)(\Delta c/2t)^2 \qquad (8)$$

This aggregate demand is positive if there is sufficient cost asymmetry, and it increases with the degree of cost asymmetry and the number of firms, and it declines with the initial level of t. When we extend the model to allow for restructuring and entry in the next two sections, these factors will also indirectly affect infrastructure demand through their effects on equilibrium cost asymmetry and the number of firms (see Sections 4 and 5). This pure rent-seeking representation of the private sector's demand for infrastructure is highly stylized. In a full-fledged political economy framework, infrastructure demand should also depend upon the design of institutions that determine how "voting" takes place – e.g., whether there are mechanisms for workers, consumers and potential entrants to "vote."

The above discussion also points to the possibility of the economy being stuck in a low-level infrastructure trap. If the initial degree of cost asymmetry is small enough or the initial transport costs high enough (so that $\Delta c/2t < \frac{1}{n}\sqrt{q(1-q)}$, and therefore $DI < 0$), there will be an aggregate demand to *raise* transport costs. This should further reduce $\Delta c/2t$, thereby reinforcing the endogenous deterioration of infrastructure. Thus, absent coordinated side-transfer mechanisms, the economy may converge to a low development trap equilibrium which, unlike in previous models of infrastructure investments, does not stem from non-convexities in the production technology.

4 Endogenous production costs

In this section, we allow incumbent firms to reduce their production costs by investing in "restructuring" activity.[8] Suppose that firm i can reduce its unit cost from c_i^0 to $c_i = c_i^0 - e$ by incurring a quadratic effort cost be^2. Thereafter, firms compete on the circle as in the basic model. We solve for a symmetric perfect equilibrium where all firms with initial cost parameter $c_i^0 \in \{c_H^0, c_L^0\}$ first choose the same restructuring effort $e_i \in \{e_H, e_L\}$ and then set the same price $p_i \in \{p_H, p_L\}$.

We proceed by backward induction, solving first for equilibrium prices, given e_H and e_L. A type-i firm chooses restructuring effort e_i to solve:

$$\max_e \{ \max_{p_i} [p_i - c_i(e)][(qp_H + (1-q)p_L)/t + 1/n] - be^2\} \tag{9}$$

The corresponding Nash-equilibrium efforts e_H and e_L respectively for high- and low-cost firms are respectively given by (see the Appendix):

$$e_H = \frac{1}{2bn} - \frac{(1-q)\Delta c^0}{4bt-1} \tag{10}$$

[8] This can be interpreted as any costly action or effort aimed at improving productivity, such as labor-shedding investment, process innovation, and organizational and management change.

$$\text{and} \qquad e_L = \frac{1}{2bn} + \frac{q\Delta c^0}{4bt-1}. \tag{11}$$

where $4bt > 1$ by second order conditions.

¿From equations (10) and (11), we have:

Proposition 3 *Low cost firms have stronger incentives to restructure: $e_L > e_H$. Moreover, reducing t promotes restructuring by low cost firms and discourages it for high cost firms, thereby magnifying the initial cost asymmetry: $\frac{\partial e_L}{\partial t} < 0, \frac{\partial e_H}{\partial t} > 0$.*

Incentives to restructure differ for low and high cost firms. Since the payoff to cost-reducing effort is proportional to market share, the initial cost difference tends to be magnified by restructuring. Knowing that they will capture a lower share of the market, high cost firms are less inclined to invest in cost reduction. Incentives of low cost firms to reduce costs are positively correlated with: (a) the proportion of high cost firms q (the higher q, the bigger the additional increase in low cost firms' market share from reducing costs); (b) the initial degree of cost asymmetry Δc^0 (the higher Δc^0, the more will high cost firms be deterred from investing in cost reduction and therefore the higher the marginal return to restructuring for low cost firms). The incentive for low cost firms is negatively correlated with the number of firms, since more firms mean a more competitive product market and thus a lower marginal monopoly rent from further reducing costs.

Remark 1 *The finding that reducing t discourages high cost firms from restructuring may appear somewhat surprising, since intensified competition hardens firms' budget constraint. However, quadratic restructuring cost functions are sufficiently convex that a lower t will discourage a high cost firm from competing more effectively with low cost firms by restructuring. Greater restructuring incentives for high cost firms could easily be generated in variants of this model, e.g., by reducing the convexity of effort costs or introducing some other costs associated with low market shares, such as bankruptcy costs or a non-monetary private benefit (say, managerial reputation) that increases with a firm's market share.*

In this model, restructuring activity reinforces the selection effect on aggregate production costs because it magnifies cost asymmetry. In this sense, infrastructure improvements and restructuring are *complementary*. Formally, if $K_P = qD_Hc_H + (1-q)D_Lc_L$ denotes the average production cost, we have:

$$\frac{dK_P}{dt} = \underbrace{q(1-q)\tfrac{(\Delta c)^2}{t^2}}_{\substack{\text{selection effect} \\ \text{(magnified since } \Delta c > \Delta c^0)}} - \underbrace{q(1-q)\Delta c^0(D_L - D_H)\tfrac{d}{dt}\left(\tfrac{1}{2bt-1}\right)}_{\text{restructuring effect}} > q(1-q)\frac{(\Delta c^0)^2}{t^2} \tag{12}$$

Remark 2 *We have assumed that a firm's restructuring cost depends only on its own effort level. Suppose instead that there exists a "catch-up" advantage, whereby restructuring costs for a high cost firm vary inversely with the initial degree of cost asymmetry:* $C(e_H) = be_H^2 - \beta\Delta c^0 e_H$*, where* $\beta > 0$*. In the Appendix we analyze this case and find that, in the Nash equilibrium, high (resp. low) cost firms do more (resp. less) restructuring than in the case where there is no catch-up advantage. However, the relative effort levels of high and low cost firms depends on the size of the catch-up parameter,* β*. If* $\beta > \frac{1}{2t}$*, the results in Proposition 2 are reversed: the high cost firm does more restructuring than the low cost firm, thus reducing cost asymmetry, and this effect is intensified by a reduction in* t *if restructuring costs are not too convex, namely if* $\beta > 2b$*.*

We now turn to the welfare analysis of restructuring. As a benchmark for comparison with the equilibrium Nash restructuring levels, we shall concentrate on the *constrained-efficient* effort levels that are generated when the government controls restructuring but not prices. These constrained-efficient levels are determined by minimising the sum of production, transport and restructuring costs, subject to the Nash-equilibrium prices being set by firms in the second stage, and given the cost levels implied by restructuring. In the Appendix we derive the following solutions:

$$e_H^* = \frac{1}{2bn} - \frac{\lambda(1-q)\Delta c^0}{2bt - \lambda} \tag{13}$$

$$e_L^* = \frac{1}{2bn} + \frac{\lambda q \Delta c^0}{2bt - \lambda} \tag{14}$$

where $\lambda = 1 - \frac{1}{4n^2}$ and $2bt > \lambda$ by second order conditions. We summarize the welfare results in the following proposition.

Proposition 4 *With linear transport costs, it is "constrained-efficient" to have the low cost firms restructure more than the high cost firms:* $e_L^* > e_H^*$ *. Moreover, reducing transport cost* t *intensifies the efficient amount of restructuring by low cost firms and it decreases it for high cost firms:* $\frac{\partial e_H^*}{\partial t} > 0, \frac{\partial e_K^*}{\partial t} < 0$*.*

The fact that the constrained-efficient amount of restructuring should be higher for low cost firms than for high cost firms, may appear somewhat surprising at first sight. There are two countervailing effects at work. The first is a market share effect, which makes the social (as well as private) payoff to restructuring by low cost firms larger, in terms of its contribution to the reduction in overall production costs. This in turn will induce a social planner to encourage restructuring by low cost firms and thus to increase market share asymmetry. The second effect is that social welfare (but not firms' profits) decreases with aggregate transport costs, and these are lowered by reducing cost asymmetry. This effect should instead induce a social planner to favor restructuring by high cost firms, even though this may be mitigated by the convexity of effort costs. In the present model, with linear transport and quadratic restructuring costs, the market share effect dominates, that is $e_H^* < e_H$ and $e_L^* > e_L$. Thus it is actually efficient to tilt restructuring efforts further towards low cost firms. This conclusion, however, is not robust to alternative modelling specifications. For example, when transport cost are strongly convex instead of being linear, then it becomes efficient to *reduce* cost asymmetry in order to save on the aggregate transportation (or "reallocation") costs borne by consumers. In that case we can have $e_H^* > e_H$ and $e_L^* < e_L$

.Hence, in general one cannot determine whether efficient restructuring should increase or reduce cost asymmetry, or equivalently, whether there is any inefficiency in the composition of restructuring by high and low cost firms that emerges under laissez-faire in the two-stage game with restructuring and then price competition. [9]

5 Entry

Does a reduction in transport cost - and more generally an increase in product market competition - encourage or deter the entry of new firms? The classical circular model without cost asymmetry provides an unambiguous answer to this question: lower transport costs intensify *ex post* competition, thereby reducing post-entry rents and thus discouraging entry (Tirole, 1988). The same result holds in Schumpeterian models of innovation with symmetric costs, where greater product market competition discourages R&D by reducing the rewards to successful innovation (Aghion and Howitt, 1992). In this

[9] In related work we use a horizontal product differentiation model based on Dixit and Stiglitz (1977) to analyze the effects of infrastructure investments aimed at increasing the elasticity of substitution between products (Aghion and Schankerman, 1999). The basic analysis is similar to that in this and the previous Sections, except that: (i) the reallocation term in the expression for aggregate welfare disappears under the Dixit-Stiglitz specification; (ii) an increase in product market competition, as measured by the elasticity of substitution, has an additional *expansion effect* on aggregate welfare. That is, an intensification of competition leads to an increase in aggregate output and thus in aggregate consumption, abstracting from any cost heterogeneity among firms. This expansion effect - which we do not capture in the circular model in which total demand is fixed by assumption - will induce a 'social planner' to *reduce* the cost asymmetry *even in the absence of reallocation costs,* simply to expand the market and thereby increase aggregate consumption. As a result, the comparison between efficient and Nash-equilibrium restructuring efforts for high- and low-cost firms in Aghion-Schankerman (1999) is different from the one we obtain here.

section we show that the effects of competition on entry are less clear-cut, and possibly reversed, when *cost asymmetry* and *selection* considerations are taken into account.

For simplicity, we assume that the number of potential entrants is sufficiently large that strategic considerations can be ignored when analyzing entry decisions. Before entry takes place, there are n incumbent firms in the product market, a fraction q of which are high-cost. There are N potential entrants, a fraction θ of which are high-cost. The parameters θ and q may differ. We model entry as an "innovative process," in the sense that by investing effort cost $E(P_i) = \frac{\gamma}{2}P_i^2$, a potential entrant succeeds in entering the market with probability P_i. The entrant cannot target in advance who her future neighbours will be, and after entry all firms can adjust their locations on the circle so as to preserve maximum differentiation. Then, following entry, firms compete in prices.[10]

Each potential entrant chooses its entry effort P_i so as to:

$$\max \ P_i\Pi_i - \gamma P_i^2$$

where Π_i denotes the *post-entry* profit flow of an entrant with unit cost c_i, $i \in \{H, L\}$. This profit flow depends both on the number and type of firms that enter. The post-entry proportion of high cost firms is:

$$q' = \frac{nq + \theta N P_H}{n + k} \tag{15}$$

where $k = (\theta P_H + (1-\theta)P_L)N$ is the expected number of entrants. Post-entry profits for a low cost entrant are equal to:

$$\Pi_L = t(1/n' + q'\frac{\Delta c}{2t})^2 \tag{16}$$

and for a high cost entrant:

$$\Pi_H = t(1/n' - (1-q')\frac{\Delta c}{2t})^2 \tag{17}$$

where $n' = n + k$ is the post-entry number of firms in the market. The profit-maximising entry probability for a firm of type $i = (L, H)$ is derived from the first-order condition:

$$P_i = \Pi_i / 2\gamma. \tag{18}$$

[10] We have also analyzed a model in which the entrant chooses to locate between two high cost incumbents to soften price competition, and the same qualitative results turn out to hold in this polar case.

We define an *entry equilibrium* as a pair of probabilities $\{P_H, P_L\}$ that satisfies equations (15) - (18). This system of equations determines P_L and P_H as functions of the primitives $\{n, q, \Delta c, t, \theta, N\}$.

Proposition 5 summarizes the comparative static results on the equilibrium entry probabilities as a function of the transport cost t.

Proposition 5 *In the entry equilibrium, if the condition:* $\frac{\partial \Pi_L}{\partial t} \leq 0$ *is satisfied, then* $\frac{dP_L}{dt} < 0$ *and* $\frac{dP_H}{dt} > 0$. *This condition in turn is equivalent, both to: (i)* $H_0 > \frac{1}{nq}$ *where* H_0 *denotes the Herfindahl index of concentration, and to: (ii)* $\frac{\triangle c}{2t} > \frac{1}{nq}$.[11]

Proof. See Appendix.

Recall from the analysis in Section 2 that $\Pi_L = tD_L^2$. The condition $\frac{\partial \Pi_L}{\partial t} \leq 0$ holds when the selection effect of a decline in t, dominates the competition effect. Proposition 5 establishes that a reduction in transport costs *encourages entry by low cost firms*, provided there is sufficient cost asymmetry (equivalently, sufficiently high concentration in equilibrium). This finding goes counter to the traditional "Schumpeterian effect" of product market competition that operates in the absence of asymmetry. However, for high cost firms, the selection and competition effects reinforce each other in discouraging entry.

On the other hand, one can show that the competition effect dominates when the cost asymmetry is sufficiently small *or* unit transport cost is sufficiently high. That is:

Proposition 6 *As* $\frac{\Delta c}{t} \to 0$, $\frac{\partial P_L}{\partial t} > 0$.

Proof: See Appendix.

Thus, when $\frac{\Delta c}{t}$ is small, a decline in t reduces monopoly rents for *all* firms on the circle, and thus discourages entry by both high and low cost firms. This is the traditional result that *ex post* competition drives out *ex ante* entry.

6 Social Returns and Cost-Benefit Analysis: Some Simulations

In this section we use the model to simulate the social returns from three different types of investment, respectively aimed at reducing unit transport costs, restructuring costs, and entry costs. Specifically, we analyse the welfare

[11] The Herfindahl index H_0 is defined by $H_0 = \Sigma D_x^2$ where D_x denotes the market share of firm x. Thus, in our model: $H_0 = n(1-q)D_L^2 + nqD_H^2$.

effects (in terms of minimizing the sum of production, transport, restructuring and entry costs) of perturbations in the parameters t, b and $\gamma-$ denoted by dt, db, and $d\gamma$. These parameter changes are normalised so that each generates a one percent *reduction* in aggregate profits. Since the welfare effects depend on the parameters of the economy, the following simulations illustrate how the comparative social returns to these different types of investment might vary across different stages of development. For simplicity we assume that the marginal subsidy to restructuring and entry (db and $d\gamma$) applies both to high and low cost firms because the government cannot distinguish between them.[12],. We also illustrate how much of the welfare effects from each type of investment is likely to be missed by traditional cost-benefit analysis which would probably not capture the market selection, restructuring and entry effects analyzed in the previous sections.

The simulated model consists of equations (1)-(4), (7), (10), (11) and (15)-(18).[13] The underlying parameters are $\{\Delta c, t, q, \theta, n, N, b, \gamma, t\}$. We normalise $c_L = 1$. Baseline parameter values are: $\Delta c = 0.5$, $q = 0.75$, $b = 0.5$, $\gamma = 0.35$, $n = 10$ and $N = 10$. We examine three values of t, corresponding to high product market competition ($t = 2$), low market competition ($t = 10$), and intermediate competition ($t = 5$). For the high-competition environment, the parameters imply an aggregate price-cost margin of 19 percent (7 and 55 for high and low cost firms, respectively) and a Herfindah index of $H = 0.15$. For the low-competition environment, the implied margin is 75 percent and $H = 0.10$. In terms of restructuring, the parameters imply that in Nash equilibrium with $t = 2$, the low and high cost firms reduce initial cost respectively by 45 and 1 percent; with $t = 10$, the figure is about 10 percent for both types. With $t = 2$ the parameters imply entry rates for low and high cost firms of 9.2 and 5.2 percent, respectively, and an aggregate entry rate of 6.3 percent. For $t = 10$ the entry rates are 13.9 and 10.4 percent, with an aggregate rate of 11.4 percent . These figures are consistent with available microeconomic evidence.[14] Finally, the proportion of high cost potential entrants (θ) is set lower than for incumbents (q),as is likely in developing countries

Table 1 summarises the changes in welfare associated with dt, db, *and* $d\gamma$ for different values of t and Δc. For example, for $t = 5$ and $\Delta c = .50$, a reduction in t associated with a 1 percent *decrease* in profits generates a 0.79 percent *increase* in social welfare, when induced restructuring and entry effects are taken into account. Importantly, for all parameter pairs, *the* **private** *and* **social** *returns to reducing* t *and* b *are of opposite signs.*

[12]With suitable modification, the model can be used to analyse cases where the the government can distinguish between high and low cost incumbent firms, or potential entrants, with any specified probability.

[13]The simulations incorporate the relevant boundary conditions on equilibrium prices, market shares and restructuring effort levels.

[14]Average entry rates (at the *plant* level) typically fall between 6 and 13 percent per annum in developing countries (Roberts and Tybout, 1997), and about 7 percent for the United States (Dunne, Roberts and Samuelson, 1988).

This reflects the selection effects triggered by both types of infrastructure investments. The marginal gains in social welfare are much larger when the initial t is low and Δc is high, since that is when selection effects are stronger. But welfare (like private returns) is reduced by the entry subsidy when initial t is high, unless there is very substantial cost asymmetry. The reason is that the induced entry reduces profits and the direct market selection effect is too weak to counteract this decline in welfare.

Next, we compute a social rate of return (net of the subsidy) to restructuring and entry subsidies by comparing the welfare gains to the equilibrium costs induced by these subsidies.[15] [16]For the investment subsidy to be justified, this rate of return must exceed the shadow price of public funds (which is greater than unity). Table 2 summarises the results for different initial values of t and Δc. Not surprisingly, the same pattern pointed out in Table 1 is again observed: social rates of return for both types of investment are higher when infrastructure is initially developed (low t) and there is greater cost asymmetry (high Δc), since that is when selection effects are stronger. Relative to the restructuring subsidy, the entry subsidy looks very unattractive: the net social rate of return from that subsidy is far below unity for the above choice of parameter values. An important reason for why entry support does not pay off is that we have implicitly assumed that entry subsidies cannot be targeted to low cost firms. Thus entry subsidies do not produce any significant selection effect, unless infrastructure is initially very developed (low t). If the financing agency could target entry subsidies effectively, entry support would be more effective. Finally, the relative effectiveness of restructuring and entry subsidies obviously depends on the parameters b and γ, which reflect characteristics of the economy such as access to credit markets, the scarcity of physical and human capital, and the legal and regulatory environments.

Table 3 examines how much of these welfare gains would be captured by "traditional" cost-benefit analysis (CBA) which typically would not incorporate the market selection effect, and the induced restructuring and entry effects. The first column captures the direct welfare effects of infrastructure investment, excluding selection effects.[17]. The first column shows that traditional CBA substantially understates the welfare gains from infrastructure investments, unless the initial level of t is high (i.e, selection effects are weak). Less than half of the welfare gains are captured in most cases. This implies that *marginal* infrastructure investments are socially more valuable

[15] The social rate of return to the restructuring subsidy is defined as $\rho = \frac{\Delta W}{\Delta b\{qe_H^2 + (1-q)e_L^2\}}$ where ΔW is the sum of transport, production, entry and restructuring costs (net of subsidy), Δb is the marginal subsidy, and the denominator is the full cost of the subsidy in equilibrium. The expression for the entry subsidy is defined similarly.

[16] We cannot perform this type of computation for dt because the associated cost would depend on the specific type of infrastructure to which t refers.

[17] This would be the case if *current* market shares and cost levels were used to conduct the cost-benefit analysis.

than the "typical" CBA would indicate in more advanced countries with good infrastructure. While traditional CBA does capture most of the social gains from *marginal* reductions in t in less advanced countries with high initial t, CBA is likely to miss much of the welfare gains from "large" infrastructure investment that substantially lowers t and thus increases the importance of selection effects. The same conclusions hold for restructuring subsidies (column 3): ignoring selection effects makes a big difference in terms of the welfare gains unless the initial t is sufficiently high.

Since the entry subsidy is calibrated to reduce profit, it can only increase welfare if it improves productive efficiency through the selection mechanism (both through the mix of entrants and the post-entry market shares). In cases where the entry subsidy also reduces welfare (low Δc or high t), neglecting selection effects magnifies the decline (denoted 'mag.decline'). When the entry subsidy generates a welfare gain, we find that ignoring the selection effects turns this into a decline in welfare.

Finally, the last column in Table 3 takes market selection into account, but ignores the changes in restructuring and entry that the infrastructure induces. This "error" appears to be less important in general, but it can be large when the initial t is low (so selection effects are strong).

7 Concluding remarks

This paper developed a simple framework for analyzing the social contribution of infrastructure investments aimed at fostering market interactions and competition. Such investments were shown: first, to reduce the market share of less efficient firms and thereby economize on aggregate production costs (the *market selection effect);* second, to increase the incentive of firms - particularly the low-cost firms- to engage in cost-reducing activities (the *restructuring effect*); and third, to stimulate entry by new low-cost firms (the *entry effect*). We also argued that the magnitude of each of these effects depends upon the level of market development, as measured by the fraction of high-cost firms among incumbent firms, the initial level of infrastructure, and the cost of restructuring and entry. Using simulations, we quantified the relative importance of each of these effects for economies at different levels of market development, and evaluated the fraction of social returns to three generic types of investments which are likely to be captured by traditional cost-benefit analysis.

The analysis in this paper is a first step in a more ambitious research program. In particular, we see at least three potentially interesting directions for extending the framework. The first is to develop our model into a full-fledged *endogenous growth model* where new entry corresponds to productivity-increasing innovations. Developing such a model would allow us to study some effects of growth on the private and social incentives for infrastructure building; and also to provide a framework for miroeconometric work on the relationship between infrastructure and productivity growth. An endogenous growth model with market-enhancing infrastructure might also be used to study the interplay between vested interests and growth in a political economy context.

Second, while this paper identifies some key determinants of the social returns to infrastructure, we have not been prescriptive about the choice between private and public financing or provision. Yet, the analysis in Section 3 suggested the existence of a potential conflict between public and private interests (e.g., in situations where infrastructure investments would yield high social returns and yet high-cost firms have strong incentives to lobby against such investments). This, in turn, points to a deeper political economy question: How do firms express or signal their differing demands for market-enhancing infrastructure (through voting or various forms of lobbying)? We believe that the *political economy of infrastructure* development is an important topic for future research, and can build upon the framework in this paper where infrastructure generates both gainers and losers.

Finally, a third extension is to study how market-enhancing infrastructure may affect the *learning process of firms.* Firms have imperfect information about demand and costs, and operate in noisy environments that impede learning about these characteristics. The question is whether - and how - increased market interaction and competition enhance the ability of firms to learn from their own outcomes (learning through experimentation) or from observing competitors' performance (learning by demonstration).

Appendix

Expected Transport Costs: To derive expected total transport cost in equilibrium, consider two neighboring firms at random and calculate the transport cost incurred by consumers on the market segment between them.

1. (a) With probability $P_1 = q \cdot \frac{nq-1}{n-1}$, both firms have high costs and share the market segment equally. Consumers incur total transport costs on the segment equal to:

$$K_T^a = t\left[\int_0^{\frac{1}{2n}} x dx + \int_{\frac{1}{2n}}^{\frac{1}{n}} (\frac{1}{n} - x) dx\right] = \frac{t}{4n^2}.$$

   (b) With probability $P_2 = (1-q)\frac{n(1-q)-1}{n-1}$, both firms have low costs and share the market segment equally. In this case, total transport costs on the segment, are equal to:

$$K_T^b = \frac{t}{4n^2}.$$

   (c) With probability $P_3 = 2q(1-q)\frac{n}{n-1}$, one firm is high cost and the other is low cost. Consumers incur transport costs on the market segment equal to:

$$K_T^c = t\left[\int_0^{\overline{x}} x dx + \int_{\overline{x}}^{\frac{1}{n}} (1-x) dx\right],$$

   where $\overline{x}$ satisfies the indifference condition:

$$p_H + t\overline{x} = p_L + t(1-\overline{x}).$$

   Substituting for the equilibrium values of p_H and p_L :

$$\overline{x} = \frac{1}{2} - \frac{\Delta c}{4t} \quad \text{and therefore}$$

$$K_T^c = t\left\{\left(\frac{1}{2}\right)^2 + \left(\frac{\Delta c}{4nt}\right)^2\right\}$$

Total expected transport costs on the circle are then equal to: $K_T = P_1 K_T^a + P_2 \cdot K_T^b + P_3 K_T$, which is equal to the second set of terms in (7) when n is large. □

Proof of Proposition 2: Let D_j denote the market share of firm j. The Herfindahl index is $H_0 = \sum_j D_j^2 = n\{qD_H^2 + (1-q)D_L^2\}$. Using the equilibrium market shares $D_H = 1/n - (1-q)\Delta c/2t$ and $D_L = 1/n + q\Delta c/2t$, we get

$$H_0 = \frac{n^2 q(1-q)\left(\frac{\Delta c}{2t}\right)^2 + 1}{n}. \quad \text{(A.1)}$$

This implies $\partial H_0/\partial t < 0$, which establishes part (i) of the proposition.

Let $m_j = \frac{P_j - c_j}{c_j}$ denote the profit margin for firm of type $j = H, L$. Using the expressions for the equilibrium p_H and p_L [(1) and (2) in the text] it follows directly that $\partial m_j/\partial t > 0$,which proves part (ii).

To prove part (iii), we use the fact that $\Pi_j = tD_j^2$ for $j = L, H$ to write the aggregate profit margin as

$$M = n\{q\Pi_H + (1-q)\Pi_l\} = tH_0.$$

Using the expression for H_0, we get $\partial M/\partial t = \frac{1}{n} - nq(1-q)(\frac{\Delta c}{2t})^2$. Therefore, $\partial M/\partial t < 0$ if and only if: $(\frac{\Delta c}{2t})^2 > 1/n^2 q(1-q)$. Using (A.1), this condition is equivalent to $H_0 > 2/n$. $\square$.

Nash Restructuring Effort: We derive the perfect equilibrium where each firm with initial cost parameter $c_i^0 \in \{c_H^0, c_L^0\}$ sets effort level $e_i \in \{e_H, e_L\}$ in the first stage, and then the Nash equilibrium prices $p_i \in \{p_H, p_L\}$ are being determined in the second stage. First, for given $p_i's$, the stage-1 Nash-equilibrium in efforts is determined by:

$$e_i = \underset{e}{\text{argmax}} \{ \max_{p_i} [p_i - c_i(e)][(p^* - p_i)/t + 1/n] - be^2\} \quad \text{(A.2)}$$

where $i \in \{H, L\}$, $c_i(e) = c_i^0 - e$, and $p^* = qp_H + (1-q)p_L$. The equilibrium prices are then given by:

$$p_i = \frac{1}{2}(\frac{t}{n} + p^* + c_i^0 + e). \quad \text{(A.3)}$$

which yields first stage profits

$$\Pi_i = (p^* + \frac{t}{n} - c_i^0 + e)^2 \;/4t - be^2. \quad \text{(A.4)}$$

Thus restructuring effort for firm i is equal to:

$$e_i = (p^* + \frac{t}{n} - c_i^0\;)/(4bt - 1) \quad \text{(A.5)}$$

Substituting for e_i in the expression for p^*, we get:

$$p^* = \frac{t}{n} + q(c_H^0 - e_H) + (1-q)(c_L^0 - e_{L)}. \quad \text{(A.6)}$$

Substituting the $e_i's$ from (A.5) into (A.6), solving for p^* and then substituting it into (A.5), we obtain the equilibrium efforts:

$$e_H = \frac{1}{2bn} - \frac{(1-q)\Delta c^0}{4bt-1} \quad (A.7)$$

and $$e_L = \frac{1}{2bn} + \frac{q\Delta c^0}{4bt-1}. \quad (A.8)$$

Nash Restructuring with "Catch-Up": We specify effort costs as be_L^2 for the low cost firm and $be_H^2 - \beta\Delta c^0 e_H$ $(\beta \geq 0)$ for the high cost firm. Otherwise, the derivation follows exactly the same steps as in the previous case (details are omitted). The equilibrium effort levels then become:

$$e_H^* = \frac{1}{2bn} - \frac{\{1 - q - \frac{\beta}{2b}(4bt - q)\}\Delta c^0}{4bt-1} \quad (A.9)$$

and $$e_L^* = \frac{1}{2bn} + \frac{q(1-\frac{\beta}{2b})\Delta c^0}{4bt-1} \quad (A.10)$$

provided that $e_j^* \in [0, c_j^0]$ for $j = L, H$. Since $4bt > 1 \geq q$, it follows that $e_H^* > e_H$ and $e_L^* < e_L$, as claimed in the first part of Remark 2. The equations above imply $e_H^* - e_L^* = \frac{(2\beta t-1)\Delta c^0}{4bt-1}$, from which the second and third claims follow immediately. □

Efficient Restructuring: The government sets restructuring levels in the first stage, and then firms compete in prices, given the implied cost levels. The government's decision problem is to minimize social costs, S, which equals the sum of production, transport and restructuring costs. Using equation (7) in the text, we can re-express this problem as:

$$\min_{e_H, e_L} \; S = \{nK_P + \frac{t}{4n}\{1 + 2q(1-q)(\frac{\Delta c}{2t})^2\}\} + b(qe_H^2 + (1-q)e_L^2) \quad (A.11)$$

where $K_P = (1-q)c_L D_L + qc_H D_H$ is the aggregate production cost and $c_i = c_i^0 - e_i$. Substituting for the equilibrium demands $D_L = (\frac{1}{n} + \frac{q\Delta c}{2t})$ and $D_H = (\frac{1}{n} - \frac{(1-q)\Delta c}{2t})$, we can write the first order conditions as:

$$-(1-q) - nq(1-q)\frac{\lambda}{t}(\Delta c^0 - e_H + e_L) + 2bn(1-q)e_L = 0 \quad (A.12)$$

$$-q + nq(1-q)\frac{\lambda}{t}(\Delta c^0 - e_H + e_L) + 2bnqe_L = 0 \quad (A.13)$$

where $\lambda = 1 - \frac{1}{4n^2}$. The second order conditions require $2bt > \max(q, 1-q)\lambda$. Since this must hold for arbitrary $q \in [0,1]$, we have $2bt > \lambda$. Solving (A.12) and (A.13) for the efficient effort levels, we get

$$e_L^* = \frac{1}{2bn} + \frac{\lambda q \Delta c^0}{2bt - \lambda} \tag{A.14}$$

$$e_L^* = \frac{1}{2bn} - \frac{\lambda(1-q)\Delta c^0}{2bt - \lambda} \qquad \square \tag{A.15}$$

Proof of Propositions 5 and 6: The entry equilibrium satisfies the first order conditions:

$$2\gamma P_L = \Pi_L(t, n(P_H, P_L), q(P_H, P_L)) \tag{A.16}$$

$$2\gamma P_H = \Pi_H(t, n(P_H, P_L), q(P_H, P_L)) \tag{A.17}$$

where

$$\Pi_L = t(1/n + q\Delta c/2t) \tag{A.18}$$

$$\Pi_H = t(1/n - (1-q)\Delta c/2t) \tag{A.19}$$

$$n = n_0 + N(\theta P_H + (1-\theta)P_L) \tag{A.20}$$

$$q = (q_0 n_0 + N\theta P_H)/(n_0 + N(\theta P_H + (1-\theta)P_L)) \tag{A.21}$$

Totally differentiating (A.16) and (A.17), we get:

$$\begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} dP_L \\ dP_H \end{bmatrix} = \begin{bmatrix} \Pi_{L,t}\ dt \\ \Pi_{H,t}\ dt \end{bmatrix} \tag{A.22}$$

where

$$\begin{aligned} A_{11} &= 2\gamma - \Pi_{L,n}\, n_L - \Pi_{L,q}\, q_L \\ A_{22} &= 2\gamma - \Pi_{H,n}\, n_H - \Pi_{H,q}\, q_H \\ A_{21} &= -(\Pi_{H,n}\, n_L + \Pi_{H,q}\, q_L) \\ A_{21} &= -(\Pi_{L,n}\, n_H + \Pi_{L,q}\, q_H) \end{aligned}$$

In these terms, the subscripts n and q refer to the derivatives of Π with respect to those variables, and the subscripts L and H in q and n refer to the derivatives of q and n with respect to P_L and P_H. Using (A.18)-(A.21) to evaluate these derivatives, we get:

$$
\begin{aligned}
A_{11} &= 2\gamma + 2tN(1-\theta)D_L^2\ /n > 0 \\
A_{22} &= 2\gamma + 2tN\theta D_L D_H\ /n > 0 \\
A_{21} &= 2tN(1-\theta)D_L D_H\ /n > 0 \\
A_{12} &= 2tN\theta D_L D_H\ /n > 0
\end{aligned}
$$

It can be verified that det $A > 0$. From (A.22), we get

$$
\frac{dP_L}{dt} = \frac{A_{22}\Pi_{L,t} - A_{12}\Pi_{H,t}}{\det\ A} \tag{A.23}
$$

$$
\frac{dP_H}{dt} = \frac{A_{11}\Pi_{H,t} - A_{21}\Pi_{L,t}}{\det\ A} \tag{A.24}
$$

We know that $\Pi_{H,t} > 0$. Therefore, if $\Pi_{L,t} < 0$, we have $\frac{dP_L}{dt} < 0$ and $\frac{dP_H}{dt} > 0$. This establishes the first part of Proposition 5. From equation (A.18), $\Pi_{L,t} < 0$ if and only if $\frac{\Delta c}{2t} > \frac{1}{qn}$. Using the expression for the Herfindahl index, $H_0 = \frac{1}{n} + nq(1-q)(\frac{\Delta c}{2t})^2$, this condition is equivalent to $H_0 > \frac{1}{qn}$. This proves the second part of the proposition.

To prove Proposition 6, observe that $\frac{\Delta c}{t} \to 0$ implies that $\Pi_{L,t} = \Pi_{H,t} = \frac{1}{n^2}$, $A_{22} = 2\gamma + 2tN\theta/n^2$ and $A_{22} = 2tN\theta/n^2$. It follows directly that $\frac{dP_L}{dt} > 0$. $\square$

Table 1. Welfare Effects of Infrastructure, Restructuring and Entry Subsidies

	% Welfare Change (associated with 1% *reduction* in aggregate profits)		
	Infrastructure ($dt < 0$)	Restructuring ($db < 0$)	Entry ($d\gamma < 0$)
Parameters			
$\Delta c = .25$			
$t = 2$	.11	.22	.024
$t = 5$	.12	.34	-.030
$t = 10$	.22	.57	-.054
$\Delta c = .50$			
$t = 2$	.83	.86	.23
$t = 5$	.16	.37	.044
$t = 10$	.22	.52	-.006
$\Delta c = .75$			
$t = 2$	n.c.	n.c.	n.c.
$t = 5$	.26	.46	.15
$t = 10$	.23	.51	.049

Notes: The 'n.c.' denotes that the new (perturbed) equilibrium cannot be computed with the given parameters because boundary or second order conditions are violated.

Table 2. Social Rates of Return to Restructuring and Entry Subsidies (%)

	Restructuring	Entry
$\Delta c = .25$		
$t = 2$	1.28	0.16
$t = 5$	0.95	-0.12
$t = 10$	0.85	-0.22
$\Delta c = .50$		
$t = 2$	1.88	0.73
$t = 5$	1.04	0.17
$t = 10$	0.87	-0.07
$\Delta c = .75$		
$t = 2$	n.c.	n.c.
$t = 5$	1.18	0.48
$t = 10$	0.90	0.11

Notes: The 'nc' denotes that the new (perturbed) equilibrium cannot be computed with the given parameters because boundary or second order conditions are violated.

Table 3. Proportion of Welfare Effects Captured by "Restricted" Cost-Benefit Analysis

	% Welfare Gains Captured			
	Infrastructure		Restructuring	Entry
	(1)	(2)	(3)	(4)
	NSE	NREE	NSE	NSE
$\Delta c = .25$				
$t = 2$	41.9	84.0	66.3	c.s.
$t = 5$	90.3	88.9	96.4	mag.decline.
$t = 10$	98.0	83.0	100.0	mag.decline.
$\Delta c = .50$				
$t = 2$	13.7	77.4	29.9	c.s.
$t = 5$	67.4	90.4	83.9	c.s.
$t = 10$	92.8	85.0	97.6	mag.decline
$\Delta c = .75$				
$t = 2$	n.c.	n.c.	n.c.	n.c.
$t = 5$	46.2	91.4	67.5	c.s.
$t = 10$	83.1	86.9	92.5	c.s.

Notes: NSE denotes 'no selection effect.' NRE designates 'no induced restructuring or entry effects.' 'n.c.' denotes that the new (perturbed) equilibrium can not be computed with the given parameters because boundary or second order conditions are violated.. 'c.s.' denotes that the sign of the welfare change is reversed when selection effects are ignored: it is positive with selection effects but negative without them. 'mag.decline' denotes that the welfare change is negative when selection effects are included, and this is magnified when selection is neglected.

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