

POLITICAL ECONOMY OF INFRASTRUCTURE INVESTMENT

ARGHYA GHOSH AND KIERON MEAGHER

ABSTRACT. The importance of infrastructure for growth is well established in the macroeconomic literature. Previous research has treated public investment in infrastructure as exogenous. We remedy this shortcoming by providing a political economy analysis of infrastructure choice based upon consumer preferences derived from spatial competition models. In this setting, infrastructure investment has two possible effects: to directly lower transaction costs and indirectly to affect market power. We begin with a single marketplace model in which only the direct effect is present and then bring in the indirect effect by extending the analysis to competition on the circle. Analysis of market structure, consumer participation, entry and transport cost curvature give a rich variety of results. Socially optimal outcomes occur in some cases but infrastructure traps are common. Our results suggest that in less developed countries competition enhancing policies are a key prerequisite for public support of infrastructure investment.

1. INTRODUCTION

Whether it is the Internet or freeways, infrastructure improves the functioning of an economy. Road building and improvements in telecommunications infrastructure have both been found to have a significant impact on productivity and growth for a wide selection of OECD countries. At the same time, in both policy quarters and academic circles, lack of proper infrastructure is often blamed for the poor performance of the less developed countries (see Easterly and Rebelo, 1993; World Bank Development Report 1994). This traditional wisdom – of a positive relationship between infrastructure and productivity/growth – has found support in the empirical macroeconomic literature (see for example Aschauer (1989), Fernald (1999), Roller and Waverman (2001)).

These empirical models, though sophisticated in their treatment, are too macroscopic to show who benefits from infrastructure and how these individual benefits result in government investment decisions. Thus the macroeconomic literature leaves us with a clear indication of the importance of infrastructure, but no deep understanding of the economic role of infrastructure and the processes determining the level of infrastructure. The traditional theoretical response - infrastructure investment is chosen by a social

Key words and phrases. Spatial Competition, Infrastructure Investment, Political Economy, Voting, Referendum.

planner - is too unrealistic to be useful for prediction.¹ Though the social optimum is an important benchmark, choice of infrastructure investment, in any democracy, is a political process.

A key feature of infrastructure investment is that the gains and losses are not distributed equally across agents. To capture these differential benefits we incorporate consumer heterogeneity through a variety of spatial competition models.² The transport cost parameter in a spatial competition model has a natural interpretation as an index of infrastructure. We interpret infrastructure broadly to include physical (e.g. roads, telecommunications) as well as institutional (e.g. trade liberalization, banking sector reforms). Since consumers have different locations/types they utilize infrastructure differently. This in turn gives rise to preferences for the level of infrastructure that vary with location/type which feed into the political process.

We assume infrastructure is provided by the government “at cost” at a level determined by the existing political process. Two related political paradigms are analyzed — (i) the standard pairwise voting process in a representative democracy, which produces a Condorcet winner when individuals vote sincerely for their preferred level of infrastructure and (ii) what appears to be a new set based approach to represent a referendum in a representative democracy where individuals vote yes or no for a proposed increase from the status quo level of infrastructure provision.³

Infrastructure, such as roads, telephones and antitrust regulation, is important because it directly determines the net utility a consumer receives from a purchase. A second, indirect, effect of infrastructure is its influence on the competitive environment. Low levels of infrastructure give differentiated firms strong local monopoly power. Alternatively high levels of infrastructure make swapping between differentiated firms a low-cost activity for consumers leading to fierce local competition between firms. An effect which is true for both geographic and institutional interpretations of infrastructure.

We derive endogenously voter preferences over infrastructure from the dual role of voters as consumers in a spatial market. At an abstract level voter choices over infrastructure affect the “rules of the game” when they make their purchasing decisions. However the final impact of a change in infrastructure on voter/consumer utility depends in a subtle and rich way on the details of the spatial market. Rather than providing a taxonomy of every spatial model we instead focus on cases of practical and theoretical

¹Winer and Hettich (2004) provide an overview of how political economy is replacing the social planner as the organizing principle of public sector economics

²See for example Gabszewicz and Thisse (1992) or Chapters 4, 6 and 8 in Anderson et al (1992) for a survey of spatial competition models.

³Section 4 presents real world examples of referenda. In addition to capturing an aspect of real-world collective decision making, referenda are also a useful theoretical construct as it provides a politically viable set of investment proposals in the absence of *a priori* position selection mechanisms.

significance to illustrate the rich variety of outcomes possible under our approach.

While spatial models are used extensively in the industrial organization literature the underlying infrastructure provision as well as the institutional details determining the provision are treated as exogenous. On the other hand the public economics literature, despite its richness in tax and voting structures, typically assumes perfectly competitive markets. By embedding voting over infrastructure in spatial oligopoly models we provide an explicit link between market environment and infrastructure. In doing so, we hope to open up a new and important area of investigation on the interconnection between public economics and industrial organization.

2. A PREVIEW OF RESULTS

In a small or underdeveloped region or country agglomeration forces may have produced only a single commercial centre. We refer to this situation as a *single marketplace*.⁴

The single marketplace eliminates spatial competition making all firms homogeneous and thus allowing us to focus on the direct effect of infrastructure in facilitating trade. In less developed countries, with low levels of infrastructure, transport/transaction costs may prevent some consumers from accessing the single marketplace at all, referred to as *incomplete coverage*.

In this incomplete market coverage case the political analysis is complicated by the emergence of a group of voters who only pay tax and do not consume the good. As a result median voter theorems do not necessarily hold in this situation. However we show that an *infrastructure trap* (zero investment in infrastructure when the socially optimal level is positive) can occur. The possibility of an infrastructure trap depends on the initial level of infrastructure and market structure. Though traps can occur even with perfectly competitive prices, the traps are less likely to occur under competition compared to monopoly.

Large economies are characterized by greater firm differentiation which we analyze by extending our approach to a Salop circle model. This extension introduces a second effect for infrastructure investment, namely to increase spatial competition by lowering transport costs between firm locations. In the short run collusion or multiproduct monopoly still leads to an infrastructure trap. However short run competition on the circle leads to overprovision of infrastructure as opposed to the under provision in the single marketplace model. This overprovision occurs as consumers reap the indirect benefit of increased competition which was not present in the single marketplace. Aghion and Schankerman (2004) consider how differential

⁴Our single marketplace is related to the single place or monocentric city in regional science/urban economics (see Fujita and Thisse, 2002, for a survey). Unlike the regional science literature we do not focus on how land rents might form a single place but instead emphasize industrial organization by considering the consequences of a single place on product market competition.

producer interests, based on asymmetric production costs, impact on regulation and allocative production efficiency. Although their model uses a circular city it does not include voting or different market structures and is orthogonal to our analysis.

Free entry transforms our conclusions about the role of competition on the circle. Entry/exit means that an improvement in infrastructure causes not just a change in per unit transport costs but also a different configuration of firm locations. Forming expectations over possible firm locations causes consumers endogenously to exhibit an aversion to change for small investments. This aversion manifests itself as a reduced preference for investment leading to an infrastructure trap when the marginal cost of investment is large. Even though the pairwise voting outcome is the same as the socially optimal when the marginal cost of investment is small, the referendum set remains smaller than the welfare enhancing set of investments. In particular a proposed investment wins the referendum only if it is greater than a threshold while the welfare improving set of investments displays no such threshold feature. Fernandez and Rodrik (1991) illustrate how uncertainty can cause a status quo bias within a general equilibrium trade model. Besides the difference in context, infrastructure rather than trade, the threshold effects of our analysis are also new.

We conclude the preview by offering three remarks. First, as we show in the subsequent sections, in all scenarios, there exist strictly positive investment levels that increase aggregate surplus. This suggests that the traps and thresholds arise for political economy reasons rather than from the existence of fixed costs or increasing returns. Second, though it is well known in general that political outcomes can differ from the social optimum, to our knowledge, our work is the first to explore how the difference between the two depend on the subtleties of the market environment within a voting setup. Finally, despite the differences in the market environments and consequently the differences in the workings of the models across the sections, one common theme seems to emerge: competition enhancing policies are a key prerequisite for public support of infrastructure investment.

3. A MODEL OF INFRASTRUCTURE INVESTMENT

Assume that a unit mass of consumers are uniformly distributed in a region of some space Z . We will consider the two canonical spaces used in spatial competition: Hotelling's (1929) linear city and Salop's (1979) circular city. We assume that there are $n(\geq 1)$ firms producing a product with marginal cost $c \geq 0$ and fixed cost K (possibly zero). Firm i has location x_i in the space which can be interpreted either geographically or as a characteristic space. Each consumer buys either zero or one unit of the product which yields gross utility of A per unit of consumption. If a consumer living at address y purchases from firm i then he incurs a mill price of p_i and a transport cost or utility loss of $t|y - x_i|^\beta$ ($\beta \geq 1$). Consumer y 's

net utility from consumption of good i , denoted by $V_i(y)$ is given by

$$(3.1) \quad V_i(y) = A - p - t|y - x_i|^\beta.$$

The consumers have a generic outside option, whose utility we normalize to zero and choose whichever option yields the highest net utility. This implies that consumer y purchases product i as long as $V_i(y) \geq 0$ and $V_i(y) \geq V_j(y), j \neq i$.

We interpret the transport cost parameter t as an index of infrastructure. More specifically we consider a reduction in t as resulting from an investment in infrastructure. The interpretation is quite natural in the geographical context where improvements in roads or rail connections, or the construction of a freeway system naturally leads to lower physical transportation costs. More generally we might think of the consumers being located in a characteristic space. Aghion and Schankerman (2004) suggest that the transportation cost parameter in a characteristic space measures the level of competition between firms. As a result they claim t would be reduced by infrastructure investments which increase competition, for example law and order, or anti-trust regulation and enforcement.

We assume t is determined by consumers/voters through a political process which we describe below. Starting from an initial t_0 , an investment of $I \geq 0$ reduces transport cost to $t_0 - I$. An investment of amount I costs $\frac{\gamma I^2}{2}$ and is financed by a lumpsum tax of g per consumer. Since there is unit mass of consumers the total tax revenue is $g \cdot 1 = g$ as well. This implies that in equilibrium $g = \frac{\gamma I^2}{2}$.⁵ The tax g or equivalently the level of investment I is determined by political process.

The sequence of events is as follows. Given some status quo t_0 , the political process determines the level of infrastructure investment I which determines transport cost $t = t_0 - I$. Subsequently, firms set prices, then consumers make their purchasing decisions.

In order to focus on the voting behavior of consumers, we assume that profits, if any, accrue to a measure zero elite. This accords well with findings in developing countries where shareholding is extremely skewed.⁶ In the absence of shareholding by consumers, surplus of a consumer y , denoted by $S(y, I)$, is the indirect utility from consumption less tax, i.e.

$$(3.2) \quad S(y, I) = \max\{V_1(y), \dots, V_n(y), 0\} - \frac{\gamma I^2}{2}.$$

3.1. Aggregate Surplus Measures. Though the individual surplus measure determines the voting behavior of an individual the cost-benefit comparison requires aggregate measures. Two aggregate surplus measures are introduced below. The measures are defined generally so that they can be

⁵We assume that the proceeds from the lumpsum tax cannot be used for redistributive purposes.

⁶See subsection 8.1 for a brief discussion on shareholding.

used for comparison in the later sections. The first measure, denoted by $B(I)$ is simply the sum of consumer surplus for all y :

$$(3.3) \quad B(I) = \int_Z S(y, I) dy.$$

The second measure, aggregate social surplus, denoted by $W(I)$, is the sum of aggregate consumer surplus $B(I)$ and aggregate profits Π :

$$(3.4) \quad W(I) = B(I) + \Pi(I).$$

Note $\Pi(I) \equiv \sum_{i=1}^n \pi_i(I)$, where $\pi_i(I)$ denotes firm i 's profit for a given investment level I .

4. POLITICAL ECONOMY

At regional or local levels or even at a country level (especially if the country is small), proposals are often put forward in a popular vote or referendum.⁷ For example, in September 2003, the residents of Hampton Roads and Northern Virginia voted on whether to raise sales tax to fund the improvements and extension of existing roads in the area. In September 2002, Mexico City voted on a double deck road plan which promised to relieve the traffic crisis by building elevated free ways over a crosstown artery. Examples of referendum also exist on telecommunication related issues in Slovenia, electricity liberalization in Switzerland etc. We use referendum in our analysis, not only because some of the decision making or decision approval occur in reality in this fashion, but also theoretically it provides a useful refinement of the set of proposals in absence of *a priori* position selection mechanisms.

In the current context the referendum on infrastructure works as follows. A positive level of income tax $g = \frac{\gamma I^2}{2}$ is proposed to finance an infrastructure investment of amount I which lowers the transport cost from t_0 to $t_0 - I$. The proposal is passed in the referendum if at least 50% of the consumers/voters vote in favor of the proposal against the status quo $I = 0$.

A consumer y votes in favour of the proposed investment level I if and only if $S(y, I) - S(y, 0) \geq 0$. Let $\mu(I)$ denote the measure of consumers who vote in favour of the proposed positive level of investment I , with $\mu(0) = \frac{1}{2}$. We define R^0 as the set of investment levels which a majority of voters favour over the status quo $I = 0$, i.e.

$$(4.1) \quad R^0 = \{I : \mu(I) \geq \frac{1}{2}\}.$$

In order to understand the extent of distortion in the political outcomes, we consider two benchmarks based on the surplus measures $B(I)$ and $W(I)$

⁷There are several terms in the political science literature, e.g. initiatives and plebiscite, which are closely related to referendum. The slight differences between these terms are due to the difference in the source of the proposal — who raised the proposal and how (see Catt, 1999). These differences, however, are not important for our analysis.

introduced previously.

$$(4.2) \quad B^0 = \{I : B(I) - B(0) \geq 0\}$$

$$(4.3) \quad W^0 = \{I : W(I) - W(0) \geq 0\}$$

The set B^0 (W^0) consists of investment levels for which the aggregate consumer surplus (social surplus) is higher compared to the status quo.

Following the standard practice in the voting literature, in the pairwise voting scenario, we use the concept of a Condorcet winner. For any two investment levels I_1 and I_2 , let $m_1(I_1, I_2)$ denote the measure of consumers that prefers I_1 to I_2 and similarly let $m_2(I_1, I_2)$ denote the measure of consumers that prefers I_2 to I_1 . An investment level I^* is a Condorcet winner if for all $I \neq I^*$, $m_1(I^*, I) \geq m_2(I^*, I)$. Excluding abstention, this implies I^* is a Condorcet winner if $m_1(I^*, I) \geq \frac{1}{2}$ for all $I \neq I^*$. To determine whether political outcomes yield “underprovision” or “overprovision” of investment, we compare I^* with aggregate consumer surplus maximizing investment level

$$(4.4) \quad I_b = \arg \max_{I \geq 0} B(I)$$

and social surplus maximizing investment level⁸

$$(4.5) \quad I_w = \arg \max_{I \geq 0} W(I).$$

In the next section we apply the two variants of the political process — referendum and pairwise voting — to the single marketplace with incomplete coverage (not all consumers purchase in equilibrium). The incomplete coverage case presents rich voting behavior and shows that “infrastructure traps” can arise if the initial coverage is too low.

5. SINGLE MARKETPLACE WITH INCOMPLETE COVERAGE

Complete coverage, in which all consumers buy some variety of the product, only occurs if infrastructure levels are “high”. However this is hardly the case in developing countries and low levels of infrastructure create barriers for market participation (incomplete coverage). In such cases, additional infrastructure investment not only creates differential benefits for existing consumers but also draws new consumers to the market.⁹

⁸Two common features across the models in different sections are that (i) $B(I)$ and $W(I)$ are continuous in I and (ii) B^0 and W^0 are compact, which guarantee the existence of I_b and I_w .

⁹The need for improvement of infrastructural facilities in the developing countries to enhance market access has been highlighted by several international institutions. In the context of the Rural Roads Project in India, the World Bank state their primary objective is to “...achieve broader and more sustainable access to markets...” (source: <http://web.worldbank.org/external/projects>, visited Nov 5, 2004). Similarly International Food Policy Research Institute (IFPRI) declares that one of their key research theme is to “identify public policies and options needed for... development of competitive markets... and to improve the access of small farmers and traders to these markets” (source: <http://www.ifpri.org/themes/mp01.htm>, visited Nov 1, 2004).

Examining incomplete coverage means there are peripheral consumers, sufficiently distant from all firms, that do not purchase any variety of the product. We model this situation with a single market place: Hotelling's linear city with the firm(s) located at the center. Specifically consumers are uniformly distributed on $[-\frac{1}{2}, \frac{1}{2}]$ with the $n \geq 1$ firms located at 0.

Rather than specifying a market structure in order to determine prices, we will assume more generally that there is a unique market price, p , which is independent of the level of infrastructure. A condition which is true for a large number of standard cases.¹⁰

Since the consumers are symmetrically distributed in $[-\frac{1}{2}, \frac{1}{2}]$ around the center, hereafter we focus our analysis on the closed interval $[0, \frac{1}{2}]$.

Market Coverage Conditions: Given an investment level I determined by the political process (which implies $t = t_0 - I$) and equilibrium price p , we can, without loss of generality¹¹ rewrite indirect utility as:

$$(5.1) \quad V(y, I) = A - p - (t_0 - I)y^\beta$$

where $y \in [0, \frac{1}{2}]$. Denote $\hat{y}(I)$ as the address of the farthest consumer who buys the the product. Either everybody buys the product in which case $\hat{y}(I) = \frac{1}{2}$ or else $\hat{y}(I)$ satisfies $A - p - (t_0 - I)\hat{y}(I)^\beta = 0$ implying $\hat{y}(I) = (\frac{A-p}{t_0-I})^{\frac{1}{\beta}}$. For a given investment level I , we say market coverage is incomplete if $\hat{y}(I) < \frac{1}{2}$. We assume the necessary condition $t_0 > 2^\beta(A-p)$ holds so that the initial level of infrastructure gives incomplete coverage, $\hat{y}(0) < \frac{1}{2}$.

Assumption 1: $t_0 > 2^\beta(A-p)$.

In order to maintain the spatial character of the model reducing transport costs to zero, i.e. $I = t_0$, must be prohibitively expensive. This is achieved by assuming individual surplus must be negative for $I = t_0$, that is $S(y, t_0) = A - p - \frac{\gamma t_0^2}{2} < 0$, for all $y \in [0, \frac{1}{2}]$, which implies $t_0 > \sqrt{\frac{2(A-p)}{\gamma}}$ or equivalently the following:

Assumption 2: $\gamma > \frac{2(A-p)}{t_0^2}$.

Consumer Surplus: Corresponding to any investment level $I > 0$, the surplus for a consumer y is given by:

$$S(y, I) = \begin{cases} A - p - (t_0 - I)y - \frac{\gamma I^2}{2} & \text{if } y < \hat{y}(I) \\ -\frac{\gamma I^2}{2} & \text{otherwise} \end{cases}$$

¹⁰For $n \geq 2$ firms, the resulting Bertrand competition yields symmetric equilibrium price $p = c$, which is independent of t . In the monopoly case if the market is not fully covered then the profit maximising price is $p = \frac{\beta A + c}{1 + \beta}$, which is also independent of t .

¹¹Prices and locations are identical so the firm index i is redundant.

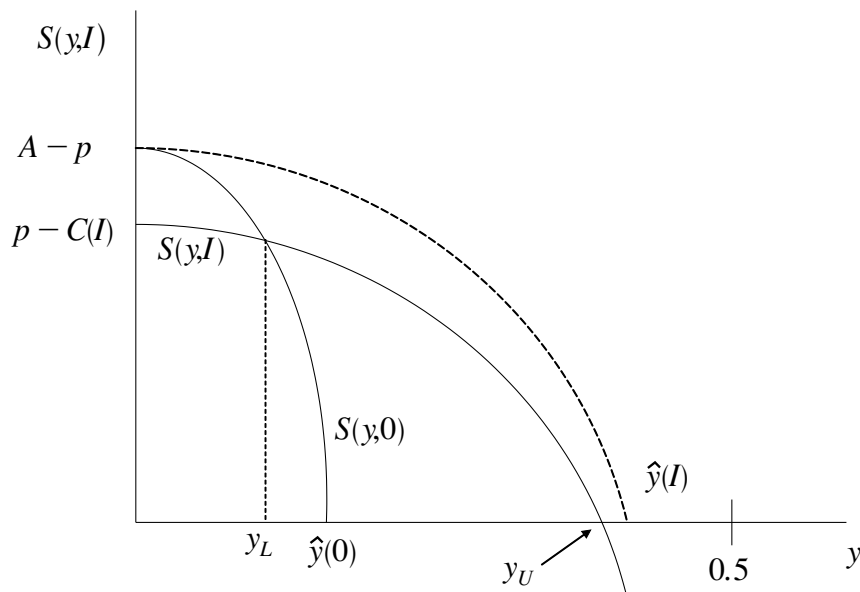


FIGURE 1. Surplus by location under the status quo and for an investment of I .

Consumer surplus as a function of location and investment level is shown in Figure 1 for convex transport costs. $S(y, 0)$ shows consumer surplus in the status quo case of no investment. Under the status quo surplus starts at $A - p$ for a consumer located at 0 and declines to zero at $\hat{y}(0)$. Consumers beyond $\hat{y}(0)$ do not consume the good and hence also have a surplus of 0. Ignoring taxes, an investment of I lowers transport costs, increasing surplus as indicated by the dotted line, increasing the measure of consumers to purchase the good to $\hat{y}(I)$. However consumers must pay for the infrastructure improvement, regardless of whether they utilise it or not, which produces an across-the-board drop in surplus of $\gamma I^2/2$. This is shown by the horizontal shift down from the dotted line to give the surplus under the positive investment level: $S(y, I)$.

Winners and Losers: We now turn to identifying the winners and losers from an infrastructure investment. As Figure 1 illustrates consumers close to zero do not have far to travel and hence do not benefit greatly from a reduction in transportation costs, however they share equally in the tax burden and are therefore worse off due to the infrastructure investment. The difference in transport costs, reflected in the slopes of the two surplus curves, becomes more important for consumers further from 0, eventually leading to a consumer y_L who is indifferent between the status quo and the investment I . That is, $y_L(I)$ is the smallest number satisfying $S(y_L(I), I) = S(y_L(I), 0)$,

i.e.

$$(5.2) \quad y_L(I) = \left(\frac{\gamma I}{2}\right)^{\frac{1}{\beta}}.$$

Now consider $y > \hat{y}(0)$. Investment increases market coverage, the number of people purchasing the good, and for the new participants indirect utility from consumption $V(y, I)$ is positive. However indirect utility $V(y, I)$ goes to zero at $\hat{y}(I)$ and therefore in the neighbourhood of $\hat{y}(I)$ gains from consumption are not sufficient to offset the increase in taxes.¹² As Figure 1 shows, we denote by $y_U(I)$ the consumer in the neighbourhood of $\hat{y}(I)$ who is indifferent between the status quo and the infrastructure investment. That is, $y_U(I)$ satisfies $S(y_U(I), I) = 0$ which implies¹³

$$(5.3) \quad y_U(I) = \left(\frac{A - p - \frac{\gamma I^2}{2}}{t_0 - I}\right)^{\frac{1}{\beta}}.$$

It follows from the discussion above that for a given level of investment, the measure of net beneficiaries, $(S(y, I) > S(y, 0))$ is given by $y_U(I) - y_L(I)$. Given that a half of the unit mass of consumers are uniformly distributed in $[0, \frac{1}{2}]$, a proposal of an investment level I is passed in referendum if and only if $y_U(I) - y_L(I) \geq \frac{1}{4}$. Thus, for the incomplete coverage case

$$(5.4) \quad R^0 = \{I : y_U(I) - y_L(I) \geq \frac{1}{4}\}.$$

The cost and the marginal cost both go to zero as investment projects become small. This negligible cost of small investments combined with the fact that all participating consumers benefit from lower transport costs means that the socially optimal level of investment is always strictly positive, as we show below. Naturally the electoral outcomes can deviate from the social optimum. Unfortunately no matter how cheap infrastructure investment is, or how large the gross surplus from consumption $(A - p)$ is, there always exist environments in which no improvement in infrastructure is politically feasible: an infrastructure trap. Furthermore, as Proposition 1 shows, these infrastructure traps occur exactly when infrastructure is poor.

Proposition 1. *Suppose Assumptions 1 and 2 hold. Then for all $A - p > 0$ and $\gamma > 0$,*

- (i) $W_0 \supseteq B_0 \supset \{0\}$ and $I_w \geq I_b > 0$, while
- (ii) $R^0 = \{0\}$ and $I^* = 0$ if and only if $t_0 \geq 4^\beta(A - p)$.

Gross of investment costs, consumers benefit from lower transport costs, as do firms since profits are constant per consumer who purchases. Since the benefits of small investments are strictly positive for consumers and while costs are zero at the margin (follows from the quadratic investment cost

¹²We consider investment levels which result in incomplete coverage, i.e. $\hat{y}(I) < 1/2$. In the proof of Proposition 1 in Appendix we show that it suffices to consider those investment levels only.

¹³We establish in the Appendix that y_L and y_U are well defined.

specification), it follows that there exists strictly positive investment levels that increases surplus and hence the surplus maximizing level of investment is strictly positive as well. The difference in $W_0(I_w)$ and $B_0(I_b)$ stems from the fact that the former takes profits into account which is increasing in the investment level.¹⁴ The electoral competition result in Proposition 1(ii) follows immediately from the referendum outcome since if no investment level can beat the status quo then the status quo must be the Condorcet winner. Thus the key to understanding Proposition 1 is the referendum result.

The sufficient condition to obtain the status quo as the referendum outcome, $t_0 > 4^\beta(A - p)$, implies that less than a majority of the consumers are covered initially ($\hat{y}_0 \equiv (\frac{A-p}{t_0})^{\frac{1}{\beta}} < \frac{1}{4}$). Given that initial coverage is low, and small investment proposals leads to a small increase in coverage, it follows that small investment levels will not receive enough support to win referendum. Since $\gamma > 0$, sufficiently large investment are not feasible either since the cost outweighs the benefits for a majority, and in some case all of the consumers. In fact, it turns out, if γ is just high enough so that reducing t to zero is unprofitable (i.e. Assumption 2 holds), then, in eliminating the extremes no middle ground is left. Thus, despite the presence of aggregate surplus enhancing investment levels, we find that the status quo might prevail if the investment levels are determined by voting.

It is possible to have strictly positive investment levels as the outcome of a political process in a single marketplace. However positive investment in infrastructure requires that the initial level of infrastructure not be too low relative to the costs of additional investment (see footnote 9). We focus on the negative outcome of an infrastructure trap because this highlights what we see as the key practical insight: for a given technology/cost of infrastructure it is exactly those countries with the lowest levels of infrastructure which will exhibit the lowest political support for improvements in infrastructure.

Competition and Infrastructure Provision: Our analysis suggests a link between market competition (captured by p here) and infrastructure provision. As competition increases (i.e. p decreases) the set of politically viable investment levels, R_0 , gets larger. More precisely the following holds:

Corollary 1. $R_0(p') \subseteq R_0(p'')$ whenever $p' > p''$.

Note that $y_L(I)$ does not change with p while $y_U(I)$ increases as p decreases implying that the measure of beneficiaries, $y_U(I) - y_L(I)$, and consequently the set of politically viable proposals gets larger as competition increases. The role of competition is strikingly borne out when we consider prices p' and p'' such that $4^\beta(A - p') < t_0 < 4^\beta(A - p'')$ holds. From Proposition 1 it follows that for low price levels (i.e. $p = p''$) there are strictly

¹⁴Note that under incomplete coverage $W_0 = B_0$ (and accordingly $I_w = I_b$) holds when profits are zero, i.e. $p = c$.

positive levels of investment which are politically viable while for $p = p'$ no such investment level exists. Since price is higher in monopoly (compared to Bertrand competition) this suggests that circumstances in which there may not be political support for infrastructure improvement under monopoly may have support for improvements under Bertrand competition. We investigate the role of competition further by considering differentiated products in the next section.

The single marketplace model with incomplete coverage has many characteristics of an underdeveloped region or country. In underdeveloped countries there is typically a separation between the “haves” and a periphery of “have-nots” who due either to poverty or distance are not able to participate in the market and must be satisfied with missing out or self provision of the good. Despite the positive payoffs of the improvements in infrastructure, as are so frequently recommended, the combination of a democratic process and insufficient initial provision of infrastructure conspired to thwart welfare enhancing projects.

6. SPATIAL COMPETITION WITH A FIXED NUMBER OF FIRMS

The central marketplace framework captures the differential benefits for consumers arising from the difference in their distances from the center. However it assumes (i) all firms are located at the same place, (ii) that some consumers miss out on participating in the market due to high transport costs and (iii) considers prices which are independent of infrastructure levels. One can argue that many markets in developed countries are characterised by a variety of products and that the level of infrastructure does not prevent consumers from participating. We address these issues in this section by adopting the circular city model *à la* Salop (1979), where firms locate at different points on the circle. In this section we assume that the number and locations of firms are fixed which is appropriate for analyzing situations involving sunk costs, entry barriers or the short run. The spatial competition between firms arising from locational differences links equilibrium prices to the level of infrastructure. Thus adopting the spatial competition model also naturally addresses point (iii), that prices may be dependent on infrastructure. As a consequence, when voting a consumer not only has to consider the effect of infrastructure investment on transport costs but also its effect on prices.¹⁵

¹⁵The link between infrastructure and prices is not only of theoretical interest but is also of practical concern to policy makers. For example consider the following statement by the South Australian Government taken from the Productivity Commission report (1999): “The obvious benefit to regional Australia lies in the continuing reduction of the cost of transporting goods into or out of the location. Such cost savings in the transportation of goods will increase the scope for competitive pricing ... lower cost of transporting goods ... should eventually result in price reductions at the consumer level.” Similar views have been expressed by The Chambers of Minerals and Energy of Western Australia.

As for the single marketplace, we assume that the government provides an infrastructure investment of I at cost $\frac{\gamma I^2}{2}$ where the choice of I is determined by the political process. Before analyzing infrastructure as the outcome of a political game we first need to determine the payoffs for the players involved arising from the circular city model.

Assume that a unit mass of consumers are uniformly distributed around a circle C of circumference 1 with density 1. The locations of consumers y are described in a clockwise manner starting from 12 o'clock. Assume there are n firms, with the location of firm i denoted by x_i . We will make the standard assumption that firms are evenly dispersed around the circle.¹⁶ Consumer preferences and production costs are the same as in section 2, with distance measured around the circumference of the circle.

6.1. Price Equilibria: We assume that the gross utility from consuming a variety, A , is high enough (or equivalently t_0 is low enough) such that each consumer buys some variety and firms directly compete with their neighbors.¹⁷ For equally spaced firms on the circle the unique symmetric price equilibrium is given by (see Anderson et al., 1992, pp. 177)

$$(6.1) \quad p^*(I) = c + \frac{\beta 2^{1-\beta} (t_0 - I)}{n^\beta}.$$

Note that $p^*(I)$ is decreasing in I reflecting the fact that an increase in investment level, i.e. a reduction in t , creates more competition among the existing firms which in turn leads to lower equilibrium prices.

6.2. Political Economy Results. Recall the individual surplus measure, $S(y, I)$, introduced in section 3, substituting $p = p^*(I)$ from equation (6.1), for a consumer $y \in C$ we have:

$$(6.2) \quad S(y, I) = A - p^*(I) - (t_0 - I)|y - x_i^*|^\beta - \frac{\gamma I^2}{2},$$

where x_i^* is the location of the firm nearest to consumer y .

Since the n firms are equally spaced around the circle and the equilibrium prices are identical it suffices to consider a mass of $\frac{1}{2n}$ consumers all located on one side of a representative firm whose location is normalised to 0. A consumer $y \in [0, \frac{1}{2n}]$ votes against the status quo if

$$(6.3) \quad S(y, I) - S(y, 0) = [p^*(0) - p^*(I)] + Iy^\beta - \frac{\gamma I^2}{2} \geq 0.$$

Observe that $S(y, I) - S(y, 0)$ exhibits single crossing in y . Thus by an application of Gans and Smart (1996) the voting behavior of the median

¹⁶Economides (1989) shows that this is the unique symmetric equilibrium in a location-then-price game.

¹⁷If A is low, then each firm becomes a local monopolist. This case is analogous to the incomplete coverage case described in section 5 with a mass $\frac{1}{n}$ of consumers evenly distributed in $[-\frac{1}{2n}, \frac{1}{2n}]$.

voter is sufficient to determine the voting behavior of the majority.¹⁸ Noting that $|y| = \frac{1}{4n}$ is the median consumer, the set of investment level that beats the status quo in pairwise voting is given by:

$$(6.4) \quad R^0 = \left\{ I : S\left(\frac{1}{4n}, I\right) - S\left(\frac{1}{4n}, 0\right) \geq 0 \right\}.$$

Solving this inequality for I characterizes the investments levels which will win in a referendum. It also follows from single crossing and Gans and Smart (1996) that the most preferred investment level of the median consumer is the unique Condorcet winner. The results are summarized in the following proposition.

Proposition 2. *In a circular city model, with $n \geq 2$, voting gives:*

$$R^0 = \left\{ I : 0 \leq I \leq \frac{2(\beta 2^{1+\beta} + 1)}{4^\beta n^\beta \gamma} \equiv 2I^* \right\},$$

$$I^* = \frac{\beta 2^{1+\beta} + 1}{4^\beta n^\beta \gamma}.$$

By inspection I^* is decreasing in γ and n . γ determines the rate at which marginal cost increases, thus quite naturally as the marginal cost of infrastructure increases the equilibrium choice decreases.

Increased n , an exogenous increase in the number of firms, lowers the distance travelled by the median consumer which in turn reduces the direct marginal benefit from I . The indirect benefit of increased I , that operates through price reduction, i.e. $\frac{d(p^*(0) - p^*(I))}{dI} = \frac{\beta 2^{1-\beta}}{n^\beta}$, is decreasing in n . Hence on both counts the incentive to invest becomes smaller as the number of firms increases.

Finally, we turn to comparative statics with respect to β , the convexity of the transport cost function. The direct marginal benefit of an increase in I is $(4n)^{-\beta}$, which is decreasing in β . This is reinforced by the indirect effect, of price reduction, $\frac{d(p^*(0) - p^*(I))}{dI} = \frac{2\beta}{(2n)^\beta}$ which becomes smaller as β increases. Thus I^* is decreasing in β .

6.3. Welfare Results. Substituting $S(y, I)$ as given by equation (6.2) into the definitions of B and W gives

$$(6.5) \quad B(I) = A - p^*(I) - \frac{t_0 - I}{(2n)^\beta(1 + \beta)} - \frac{\gamma I^2}{2},$$

$$(6.6) \quad W(I) = A - c - \frac{t_0 - I}{(2n)^\beta(1 + \beta)} - \frac{\gamma I^2}{2}.$$

We begin by determining B^0 and W^0 , respectively the set of I that improves aggregate consumer surplus and welfare compared to the status quo. Using equations (6.5) and (6.6):

¹⁸Also see pp 23, Chapter 2 in Persson and Tabellini (2000) for a definition and implication of the single-crossing property.

Proposition 3. *In a circular city model, with $n \geq 2$,*

$$\begin{aligned} B^0 &= \left\{ I : 0 \leq I \leq \frac{2(2\beta(1+\beta)+1)}{(2n)^\beta(1+\beta)\gamma} \equiv 2I_b \right\}, \\ I_b &= \frac{2\beta(1+\beta)+1}{(2n)^\beta(1+\beta)\gamma}, \\ W^0 &= \left\{ I : 0 \leq I \leq \frac{2}{(2n)^\beta(1+\beta)\gamma} \equiv 2I_w \right\}, \\ I_w &= \frac{1}{(2n)^\beta(1+\beta)\gamma}. \end{aligned}$$

Comparing W^0 and B^0 it follows that $W^0 \subset B^0$. The reasoning is simple. An increase in investment level increases $B(I)$ through two channels - reduction in equilibrium prices and reduction in aggregate transport costs. However change in prices does not affect $W(I)$. This implies that, corresponding to any change in I , the increase in $W(I)$ is less than the increase in $B(I)$ and accordingly any investment level that increases aggregate social surplus increases aggregate consumer surplus as well. In other words, $W^0 \subset B^0$. This argument, appropriately modified, applies to marginal changes in I too. Since marginal increase in $W(I)$ is less than that of $B(I)$, and $W(I)$ and $B(I)$ are strictly concave, it follows that $I_w < I_b$. A complete comparison of welfare and equilibrium outcomes is given by the following proposition.¹⁹

Proposition 4. *In a circular city model, with $n \geq 2$,*

$$(6.7) \quad W^0 \subset R^0 \subseteq B^0$$

$$(6.8) \quad I_w < I^* \leq I_b$$

where equality holds only for $\beta = 1$.

The savings in transport costs for the median consumer, due to improved infrastructure, is less than the average savings. This implies that there are investment levels I which increases $B(I)$ but are not favored by the median consumer, and accordingly not supported by the majority. Hence $R^0 \subseteq B^0$. Since the savings are valued similarly in W^0 and B^0 , the argument described above would suggest that $R^0 \subseteq W^0$ as well. However, recall that the change in aggregate social surplus, $W(I) - W(0)$, does not take into account the beneficial effect of price reduction due to improved infrastructure. This enlarges the set R^0 , and in fact for the specification chosen, it turns out that $W^0 \subset R^0$. Similar arguments can be used to establish the ordering of the I 's.

In contrast to our findings in the central marketplace framework with complete coverage, we find that there is “overprovision” of infrastructure.

¹⁹Qualitatively I_b (or I_w) vary with n , β and γ in the same way as I^* does and the arguments are similar to the ones presented immediately after Proposition 3.

However, this finding is contingent on the competitive behavior of firms as we show below.

6.4. Collusion. We model collusion over prices in the short run, that is we keep the number of firms fixed at n and assume that firms coordinate perfectly on the prices which maximise joint profits. Given the symmetric underlying structure of the model there is a unique collusive price $p^c(I) = A - (t_0 - I)(\frac{1}{2n})^\beta$, which is increasing in I . The loss from increased prices outweighs gains from transport cost savings which in turn leads to the following:

Proposition 5. *Under collusion in the circular city framework,*

$$(6.9) \quad R^0 = B^0 = \{0\} \subset W^0$$

$$(6.10) \quad I^* = I_b = 0 < I_w$$

Comparing Propositions 2 and 5 highlights the importance of market reforms in determining the willingness of representative democracies to undertake infrastructure improvements. Even though welfare improving changes exist, in absence of competition, those changes might not be politically viable. For many years, global institutions such as the World Bank have pushed for market reforms before providing any aid in terms of infrastructure improvements. Also, there is a folk wisdom that market structure and infrastructure provisions are related. Our framework provides an explicit link between the two and suggest that indeed market structure (or more generally market environment) has important bearings on support for infrastructure provision.

7. SPATIAL COMPETITION WITH FREE ENTRY

In our analysis so far, the number and locations of firms were assumed to be given. The assumption is appropriate for short run analysis, but, in the long run, firms can change locations and furthermore entry and exit may occur in the industry.²⁰ To incorporate these features into our framework and examine the consequent effects on the voting outcome we consider the standard long run free entry model.

On the production side, in addition to constant marginal cost we also assume positive fixed cost per period of production of $K > 0$. Consider a sequential game, where corresponding to a given level of infrastructure provision $t = t_0 - I$, a firm i first decides whether to enter and subsequently post-entry it chooses location (x_i) and then price (p_i). If firms chose simultaneously at each stage and n firms have entered in the first stage, the location and price of firm i in the unique symmetric equilibrium, denoted by

²⁰Note if fixed costs are sunk on entry then the short run analysis is the same as the long run because infrastructure investment increases competition lowering firm profits.

\bar{x}_i and \bar{p}_i respectively, are as follows (see Economides, 1989 and Anderson et al, 19992):

$$(7.1) \quad |\bar{x}_i - \bar{x}_{i+1}| = |\bar{x}_i - \bar{x}_{i-1}| = \frac{1}{n}$$

$$(7.2) \quad \bar{p}_i(n) = \bar{p}(n) = c + \beta 2^{1-\beta} (t_0 - I) \left(\frac{1}{n}\right)^\beta.$$

Treating n as a continuous variable, the free-entry number of firms corresponding to a given level of investment I , denoted by $n^*(I)$ is obtained from solving the zero profits condition $(\bar{p} - c) \frac{1}{n} = K$. This yields

$$(7.3) \quad n^*(I) = \left(\frac{\beta 2^{1-\beta} (t_0 - I)}{K} \right)^{\frac{1}{1+\beta}}.$$

For a given $I \geq 0$, the subgame perfect Nash equilibrium outcome of the three-stage game — entry(stage 1), location choice(stage 2) and price competition (stage 3) — can be summarized by a triplet $(n^*(I), \{x_i^*(I)\}_{i=1}^{n^*(I)}, p^*(I))$ where $n^*(I)$ is as in equation (7.3), and $x_i^*(I)$ and $p^*(I)$ are \bar{x}_i and \bar{p}_i respectively evaluated at $n = n^*(I)$.

Suppose the initial level of infrastructure provision in the economy is $t = t_0$ and the number of firms, locations and prices are given by $n^*(0)$, $\{x_i^*(0)\}_{i=1}^{n^*(0)}$ and $p^*(0)$ respectively. While voting for $I > 0$, a consumer y correctly anticipates $n^*(I)$ and $p^*(I)$. However, since any equispaced location of $n^*(I)$ firms constitutes an equilibrium, a consumer computes the expected utility over all possible distances $|y - x_i^*(I)|$ where $x_i^*(I)$ denotes the location of the nearest firm. Assuming a uniform prior for equilibrium distance $|y - x_i^*(I)|$ over the support $[0, \frac{1}{2n^*(I)}]$, the expected surplus from an investment $I > 0$ is:

$$(7.4) \quad \begin{aligned} E[S(y, I)] &= A - p^*(I) - (t_0 - I) 2n^*(I) \int_y^{y + \frac{1}{2n^*(I)}} |y - x_i|^\beta dx_i - \frac{\gamma I^2}{2} \\ &= A - p^*(I) - \frac{t_0 - I}{(2n^*(I))^\beta (1 + \beta)} - \frac{\gamma I^2}{2}, \\ &\equiv \bar{S}(I). \end{aligned}$$

We use a constrained optimal approach to welfare in considering free entry. Constrained in the sense that we take as given the way in which market forces determine equilibrium prices and the equilibrium number of firms. This seems a natural way to examine in isolation the distortions caused by the political process in determining infrastructure investments.

Since $S(y, I) = \bar{S}(I)$ for all y on the circle C , and there is a unit mass of consumers it follows that $B(I) = \bar{S}(I)$. Moreover since profits are zero in free-entry equilibrium, the two aggregate surplus measures are equivalent: $W(I) = B(I) = \bar{S}(I)$ for all $I > 0$. This equivalence in turn implies that for

all $\beta \geq 1$,

$$(7.5) \quad W^0 = B^0 \supset \{0\},$$

$$(7.6) \quad I_w = I_b = \arg \max_{I \geq 0} \bar{S}(I) > 0.$$

As in the previous sections, existence of strictly positive, surplus enhancing I , follows from the observation that infinitesimally small levels of I have zero cost and $W(I)$ and $B(I)$ are continuous in I for all $I \geq 0$. However those surplus enhancing I are politically viable only if $\bar{S}(I_b) - S(y_{median}, 0) > 0$, where y_{median} is the location of the median consumer. To check whether this inequality holds first we compute $S(y, 0)$ and then identify the median consumer.

Note that if no investment is undertaken and the status quo is preserved it is natural to assume that the firms maintain the initial locations. This yields

$$(7.7) \quad S(y, 0) = A - p^*(0) - (t_0 - I)|y - x_i^*(I)|^\beta - \frac{\gamma I^2}{2}.$$

Since $S(y, I) = \bar{S}(I)$ for all y when $I > 0$, and $S(y, 0)$ is decreasing in y it follows that $S(y, I) - S(y, 0)$ is increasing in y . Exploiting this, it can be shown that, $I > 0$ beats the status quo if and only if the median consumer votes against the status quo. The relevant median is the one with respect to initial equilibrium configuration, which means that the median consumer(s) is located at distance $\frac{1}{4n^*(0)}$ from the nearest firm.

Having identified the relevant aspects of the preferences of voters we now turn to some results. An interesting and somewhat surprising property of the free entry model is the following threshold result.

Proposition 6 (Referendum Threshold). *For all $\beta > 1$, there exists a threshold $\underline{I}(\beta) > 0$ such that investments below the threshold cannot beat the status quo in a referendum, i.e. if $I < \underline{I}(\beta)$ then $I \notin R^0$.*

Infinitesimally small levels of investment decreases the transportation costs at each location by an infinitesimal amount. At the same time it causes firms to shift in the long run so the median consumer now faces the average transportation cost which is higher than the median transportation cost. As $I \rightarrow 0$, $p^*(I) \rightarrow p^*(0)$ and $n^*(I) \rightarrow n^*(0)$, implying that the indirect effects that works through price reduction or entry/exit are negligible. However the negative effect of increased expected transport costs arising due to switching from median to average does not vanish as long as $\beta > 1$. This in turn implies that unless the proposed investment level is higher than a certain threshold it could not win a referendum. Thus, our referendum can generate an endogenous investment threshold — a feature which typically arises in the presence of fixed costs and/or increasing returns. Also note that this threshold feature is only reflected in R^0 and not in W^0 or B^0 which once again highlights the qualitative differences between socially beneficial and politically viable outcomes.

Proposition 6 shows that $I > 0$ is politically viable only if $I > \underline{I}$. On the other hand, I cannot be too large either, since $\gamma > 0$. Let $\bar{I}(\beta)$ denote the upper bound of politically viable investments. Indeed, if γ is suitably large there does not exist any I that satisfies both: $I < \underline{I}$ and $I > \bar{I}$.

Proposition 7. *For all $\beta > 1$ there exists a $\bar{\gamma}$ such that if $\gamma > \bar{\gamma}$ then $R_0 = \{0\}$ and $I^* = 0$.*

In previous sections we have shown that an infrastructure trap can arise due to incomplete coverage or collusion/monopoly. None of these features contribute to the possibility of a trap shown here. The uncertainty regarding the distance ex post — in particular the possibility that distance can increase — renders small changes politically non-viable and if γ is suitably large, the moderate or high level of investment levels are not feasible either leading to the “trap” or persistence of the status quo.²¹

A comparison of the welfare optimal results and the political economy results is given in the following proposition for a strictly convex transport cost function.

Proposition 8. *In a circular city model with free entry, if the transport cost function is strictly convex (i.e. $\beta > 1$) then there exists $\bar{\gamma}$ such that*

- (i) *if $\gamma \leq \bar{\gamma}$ then $\{0\} \subset R^0 \subset B^0 = W^0$ and $I^* = I_b = I_w > 0$,*
- (ii) *while if $\gamma > \bar{\gamma}$ then $R_0 = \{0\} \subset B^0 = W^0$ and $I^* = 0 < I_b = I_w$.*

The relationships between B_0 and W_0 , I_b and I_w as well as the “trap” for small γ (i.e. part (ii) of Proposition 8) has already been explained in this section. What remains to be explained is the political outcome when γ is large, i.e. $\gamma \leq \bar{\gamma}$. Recall that, for $I > 0$, each individual’s (and hence the median voter’s) expected consumer surplus is the same as the consumer surplus for the population. This in turn implies that the political outcome from the electoral competition setting (i.e. Condorcet winner) is socially optimal, if there exists I that wins a referendum. Such I exists if $\gamma \leq \bar{\gamma}$.

Despite the identical point outcomes (i.e. $I^* = I_b = I_w$), the set of politically viable investments, R_0 , is strictly smaller than set of welfare enhancing investments (B^0 or W^0). The median transportation costs is lower than the average transportation costs under $t = t_0$ and accordingly the net benefit from a positive investment is valued less by the median consumer. This explains the strict inclusion: $R_0 \subset B_0$ — the existence of I that improve welfare and yet immiserize the median consumer.

²¹In context of trade policy reforms in a general equilibrium set up with perfect competition Fernandez and Rodrik (1991) has obtained a similar result. The status quo bias in their framework arises from individual specific uncertainty which is true in our setup as well. However the context as well as the focus of their paper is quite different from ours. For example market environment has little role to play in their framework. Furthermore, the threshold result (Proposition 7), offers a novel insight regarding the set of politically viable outcomes.

Finally note that under linear transport costs and uniform distribution of consumers socially desirable investment are also politically viable and vice versa.

Proposition 9. *In a circular city model with free entry, if the transport cost function is linear (i.e. $\beta = 1$) then $R^0 = B^0 = W^0$ and $I^* = I_b = I_w > 0$.*

In this case the median voter's transport costs is the same as the average transport costs and hence the median voter behaves in a socially optimal way.

8. CONCLUSION

Despite the importance of public infrastructure investments, little attention has been paid to analysing the process which determines investment levels. We consider a variety of spatial competition models where we interpret the transport cost parameter as an index of infrastructure. By incorporating voting over infrastructure by consumers in these models we provide an explicit political economy foundation for infrastructure investment. As one might expect, political processes do not necessarily generate socially optimal or efficient outcomes. However, as our analysis shows, the source and magnitude of the inefficiency depend in subtle ways on the characteristics of the market environment.

We analyze a number of aspects of the market environment: market structure (competition versus collusion/monopoly); supply dispersion (single marketplace versus multiple firm locations); initial level of development (incomplete versus complete coverage); transport cost curvature (linear versus strictly convex); and entry (short run versus long-run equilibrium). Across the models, an interesting and frequent finding is that of infrastructure traps: choice of zero infrastructure investment in a referendum or election where positive investment is socially optimal. We identify a number of quite distinct causes: insufficient infrastructure provision (section 5); collusion (section 6); and uncertainty (section 7). Also common across the models is the positive effect of competition. Though traps can occur even in the presence of competition, typically the possibility of traps or the degree of inefficiency in political outcomes is lower with a higher degree of competition.

By focusing on consumers and voting, we have ignored the other side of the story: producers and the political apparatus they employ to protect their profits — lobbying. In the applied literature (e.g. trade policy literature) the presence of lobbying is often captured by considering weighted social surplus as the objective function with profits being assigned higher weights than aggregate consumer surplus.²² Our preliminary investigation suggests that inefficiencies and the possibility of an infrastructure trap exist under

²²See Grossman and Helpman (1994) and Mitra (2001) for a microfoundation of this approach.

this set up as well. Moreover the details of the market environment continue to play an important role.²³

Though we covered some distance in the analysis of market environments — from incomplete coverage with a single marketplace to full coverage with free entry — on the political economy front we have been more selective. Two recent advances, in modelling electoral competition, which we do not consider, are the citizen-candidate framework, *à la* Besley and Coate(1997) or Osborne and Slivinski(1996) and the party competition approach of Roemer(2001) and Levy(2004). However, we would like to highlight the novelty our analysis offers by considering both point outcomes (e.g. electoral competition) as well as set outcomes (e.g. referendum outcomes).

As our analysis has shown, the referendum set can display unique features which cannot be described with point outcomes (e.g. investment thresholds). Also the comparison between referendum and surplus enhancing sets does not necessarily mirror the results from the electoral competition setting. For example in Proposition 8(i), there is strict equality in the point outcomes, $I^* = I_b$, while the corresponding set outcomes do not exhibit equality, $R^0 \subset B^0$.

By endogenizing the transport cost parameter as a politically determined infrastructure investment we allow consumers, in their dual role as voters, to partially determine the environment they face when they make purchasing decisions. From the cases considered here, this approach, of allowing consumers some role in choosing the “rules of the game”, appears to produce a rich framework without a great deal of additional technical complexity. Our results highlight the importance of combining political economy and industrial organisation analysis when considering infrastructure investment.

APPENDIX

Proof of Proposition 1. The first step is to show that y_L and y_U are well defined, which follows from the following two lemmas.

Lemma 1. *For $I > 0$ on the interval $y \in [0, \hat{y}(0)]$, either $S(y, 0)$ and $S(y, I)$ exhibit single crossing or $S(y, I)$ lies beneath $S(y, 0)$.*

Proof: Due to the tax $S(0, 0) > S(0, I)$. Hence the result holds if the surplus curves cross no more than once. Now for $y < \hat{y}(0)$, $S_y(y, 0) = -t_0\beta y^{\beta-1}$ while $S_y(y, I) = -(t_0 - I)\beta y^{\beta-1}$, thus $S_y(y, 0) > S_y(y, I)$, which establishes the result. ■

It follows from this lemma that y_L is well defined if the surplus curves cross on $y \in [0, \hat{y}(0)]$, that is if $S(\hat{y}(0), 0)(= 0) \leq S(\hat{y}(0), I)$ or equivalently $I \leq \frac{2(A-p)}{\gamma t_0}$.

²³For example under incomplete coverage, financing considerations aside, a reduction in transport cost increases profits as well as consumer surplus. On the other hand, under spatial competition a reduction in transport cost lowers profits but increases consumer surplus.

Lemma 2. *If $S(\frac{1}{2}, I) < 0$ and $S(0, I) > 0$ holds then y_U is unique and $y_U < \frac{1}{2}$, and thus y_U is well defined.*

Proof: On the interval $[0, \hat{y}(I)]$, $S(y, I)$ is strictly decreasing in y (and negative and constant elsewhere), which, together with $S(\frac{1}{2}, I) < 0$ and $S(0, I) > 0$, implies that y_U is unique and $y_U < \frac{1}{2}$. ■

Next we show $y_L(I)$ and $y_U(I)$ obey the natural ranking where $y_L(I)$ and $y_U(I)$ are given by (5.2) and (5.3) respectively.

Lemma 3. *For all $I \in (0, \frac{2(A-p)}{\gamma t_0})$, $0 < y_L(I) < \hat{y}(0) < y_U(I) < \frac{1}{2}$ provided $S(\frac{1}{2}, I) < 0$.²⁴*

Proof: As mentioned earlier, for all $I \in (0, \frac{2(A-p)}{\gamma t_0})$, $S(y, 0)$ and $S(y, I)$ exhibit single crossing. Then $y_L(I) \in (0, \hat{y}(0))$ follows from the following inequality: $S(0, I) - S(0, 0) < 0 < S(\hat{y}(0), I) - S(\hat{y}(0), 0)$. That $y_U(I) \in (\hat{y}(0), \frac{1}{2}]$ follows from (i) $S(\hat{y}(0), I) > 0$ and (ii) $S(y, I)$ is strictly decreasing in y on $[0, \hat{y}(I)]$. Lemma 2 then rules out $y_U(I) = \frac{1}{2}$. ■

Now we show that it suffices to restrict attention to $I < \frac{2(A-p)}{\gamma t_0}$.

Lemma 4. *If $I > \frac{2(A-p)}{\gamma t_0}$, $S(y, I) - S(y, 0) < 0$ for all $y \in [0, \frac{1}{2}]$.*

Proof: For $y < \hat{y}(0) \equiv (\frac{A-p}{t_0})^{\frac{1}{\beta}}$ (i.e. $y \in [0, \hat{y}(0)]$), $S(y, I) - S(y, 0) \leq S(\hat{y}(0), 0) - S(\hat{y}(0), I) = \frac{\gamma I}{2} [\frac{2(A-p)}{\gamma t_0} - I] < 0$ if $I > \frac{2(A-p)}{\gamma t_0}$. For these I and $y \in [\hat{y}(0), \hat{y}(I)]$, $S(y, I) - S(y, 0) = S(y, I) - 0 \leq S(\hat{y}(0), I) - S(\hat{y}(0), 0) < 0$. The equality holds since $y > \hat{y}(0)$ while the weak inequality holds because $S(y, I) - S(y, 0)$ is strictly decreasing in y for $y \in [0, \hat{y}(I)]$. For $y > \hat{y}(I)$ (if such a region exists), $S(y, I) - S(y, 0) < -\frac{\gamma I^2}{2} < 0$. ■

Finally, for the parameterizations considered in Proposition 1(ii), i.e. $t_0 > 4^\beta(A-p)$, we show that $S(\frac{1}{2}, I) < 0$ or equivalently $y_U < \frac{1}{2}$ for all relevant I , i.e. $I \leq t_0$.

Lemma 5. *If Assumptions 1 and 2 hold, and $t_0 > 4^\beta(A-p)$ then $S(\frac{1}{2}, I) < 0$ (i.e. $y_U(I) < \frac{1}{2}$) for all $I < t_0$.*

Proof: Rearranging Assumption 2 yields $\frac{2(A-p)}{\gamma t_0} < t_0$. For $I \in (\frac{2(A-p)}{\gamma t_0}, t_0)$, $S(\frac{1}{2}, I) - S(\frac{1}{2}, 0) < 0$ (follows from Lemma 4). Also, $I > 0$ for which $\hat{y}(I) < \frac{1}{2}$ holds, $S(\frac{1}{2}, I) = -\frac{\gamma I^2}{2} < 0$. The only remaining case is the set of $I < \frac{2(A-p)}{\gamma t_0}$ such that $\hat{y}(I) = \frac{1}{2}$. Suppose such a set exists and is non-empty. Note that, for all such investment levels I , $S(\frac{1}{2}, I) = A - p - \frac{t_0}{2^\beta} + I(\frac{1}{2^\beta} - \frac{\gamma I}{2})$. Differentiation yields $\frac{dS(\frac{1}{2}, I)}{dI} = \frac{1}{2^\beta} - \gamma I \geq \frac{t_0 - 2^{1+\beta}(A-p)}{2^\beta t_0} > 0$ (note $2^{1+\beta} < 4^\beta$). The weak inequality follows from substituting the maximum possible value of

²⁴If $I = \frac{2(A-p)}{\gamma t_0}$ then $y_L(I) = \hat{y}(0) = y_U(I)$.

I from the feasible set, i.e. $I = \frac{2(A-p)}{\gamma t_0}$ and the strict inequality follows from Assumption 1 (incomplete coverage assumption). The result then follows from noting that $S(\frac{1}{2}, \frac{2(A-p)}{\gamma t_0}) = A - p - \frac{t_0}{2^\beta} + \frac{2(A-p)}{\gamma t_0} (\frac{1}{2^\beta} - \frac{(A-p)}{t_0}) = (A - p - \frac{t_0}{2^\beta})(1 - \frac{2(A-p)}{\gamma t_0^2}) < 0$. The inequality follows from rearranging Assumption 1 (this yields $A - p - \frac{t_0}{2^\beta} < 0$) and Assumption 2 (this yields $1 - \frac{2(A-p)}{\gamma t_0^2} > 0$). ■

First we prove part (ii) of Proposition 1. Observe that lemmas 1 - 5 imply that if Assumptions 1 and 2 are satisfied and $t_0 > 4^\beta(A - p)$, then indeed $R_0 = \{I : y_U(I) - y_L(I) \geq \frac{1}{4}\}$, where $y_L(I)$ and $y_U(I)$ are indeed as in (5.2) and (5.3):

$$y_L(I) = \frac{\gamma I}{2}$$

$$y_U(I) = \frac{A - p - \frac{\gamma I^2}{2}}{t_0 - I}$$

Note that (i) $y_U(I) - y_L(I)$ is continuous in I , (ii) $\lim_{I \rightarrow 0} (y_U(I) - y_L(I)) = \hat{y}(0) - 0 = (\frac{A-p}{t_0})^{\frac{1}{\beta}}$ and (iii) $y_U(I) - y_L(I)$ is strictly decreasing in γ . If $t_0 > 4^\beta(A - p)$, then $\lim_{I \rightarrow 0} y_U(I) - y_L(I) = (\frac{A-p}{t_0})^{\frac{1}{\beta}} < \frac{1}{4}$ and hence small investment levels do not belong to R^0 .

From observation (iii) it follows that $y_U(I) - y_L(I) \leq \lim_{\gamma \rightarrow \frac{2(A-p)}{t_0^2}} (y_U(I) - y_L(I))$ where $\frac{2(A-p)}{t_0^2}$ is the lower bound of γ (see Assumption 2). We find that $\lim_{\gamma \rightarrow \frac{2(A-p)}{t_0^2}} \frac{d(y_U(I) - y_L(I))}{dI} = \frac{1}{\beta} (\frac{A-p}{\beta t_0^2})^{\frac{1}{\beta}} ((t_0 + I)^{\frac{1}{\beta}-1} - I^{\frac{1}{\beta}-1})$ which is strictly negative for all $I > 0$. This, combined with the finding that $\lim_{I \rightarrow 0} y_U(I) - y_L(I) < \frac{1}{4}$ holds for all γ satisfying Assumption 2 implies, for all $I > 0$, $y_U(I) - y_L(I) < \frac{1}{4}$ and accordingly $R^0 = \{0\}$ and $I^* = 0$. ■

Now we turn to prove part (i) of Proposition 1. Recall $B^0 = \{I : B(I) - B(0) \geq 0\}$ where $B(I)$ in the incomplete coverage case is

$$B(I) = 2 \int_0^{\hat{y}(I)} (A - p - (t_0 - I)y^\beta) dy - \frac{\gamma I^2}{2} = \frac{2\beta(A-p)}{1+\beta} (\frac{A-p}{t_0 - I})^{\frac{1}{\beta}} - \frac{\gamma I^2}{2}.$$

Then, $B^0 \supset \{0\}$ follows from noting that (i) $B(I) - B(0)$ is continuous in I for all $I \geq 0$, and (ii) $\frac{d}{dI} [B(I) - B(0)]|_{I=0} = \frac{2}{1+\beta} (\frac{A-p}{t_0})^{1+\frac{1}{\beta}} > 0$. Since $B(I)$ is continuous in I , and I lies in compact interval $[0, t_0]$, $I_b = \arg \max_{I \geq 0} B(I)$ exists. That $I_b > 0$ follows from $\frac{d}{dI} B(I)|_{I=0} > 0$. Since $\Pi(I) - \Pi(0) = (p - c)\hat{y}(I) \geq 0$, $B(I) - B(0) \geq 0 \Rightarrow B(I) + \Pi(I) - B(0) - \Pi(0) \geq 0$ implying $W^0 \supset B^0$. The existence and proof of I_w is analogous to that of I_b . $I_w \geq I_b$ follows from $d\Pi(I) - \Pi(0)dI \geq 0$. ■

Proof of Proposition 2. Substituting equation (6.2) into the winning referendum equation (6.4) gives

$$(8.1) \quad [p^*(0) - p^*(I)] + \frac{I}{4n^\beta} - \frac{\gamma I^2}{2} \geq 0.$$

Substituting the equilibrium prices from equation (6.1) gives

$$(8.2) \quad I \left[\beta 2^{1-\beta} \left(\frac{1}{n} \right)^\beta + \frac{1}{(4n)^\beta} - \frac{\gamma I}{2} \right] \geq 0.$$

Solving for I gives the result. Note the upper bound on R^0 is indeed positive if, as assumed, $\beta \geq 1$. As the discussion proceeding the proposition shows the voting outcome is the median voters preferred policy, which is given by the following:

$$\begin{aligned} I^* &= \arg \max_{I \in R^0} (S(\frac{1}{4n}, I) - S(\frac{1}{4n}, 0)) \\ &= \frac{1}{\gamma} (\beta 2^{1-\beta} (\frac{1}{n})^\beta + \frac{1}{(4n)^\beta}) \end{aligned}$$

Since I^* is the maximum of the same quadratic equation which defines R^0 by two horizontal intercepts it follows the I^* is exactly half the upper bound of R^0 (since quadratic functions are symmetric). ■

Proof of Proposition 3. By definition $B^0 := \{I : I \geq 0, B(I) - B(0) \geq 0\}$. Using (6.5), it follows that

$$(8.3) \quad B(I) - B(0) = [p(0) - p^*(I)] + I \left(\frac{1}{2n^\beta(1+\beta)} - \frac{\gamma I}{2} \right)$$

$$(8.4) \quad = I \left(\beta 2^{1-\beta} \left(\frac{1}{n} \right)^\beta + \frac{1}{(2n)^\beta(1+\beta)} - \frac{\gamma I}{2} \right),$$

which is positive for all $I \leq \frac{2}{\gamma} (\beta 2^{1-\beta} (\frac{1}{n})^\beta + \frac{1}{(2n)^\beta(1+\beta)})$. Hence

$$\begin{aligned} B^0 : &= \{I : 0 \leq I \leq \frac{2}{\gamma} (\beta 2^{1-\beta} \frac{1^\beta}{n} + \frac{1}{(2n)^\beta(1+\beta)})\} \\ I_b &= \arg \max_{I \in B^0} B^0 = \frac{1}{\gamma} (\beta 2^{1-\beta} \frac{1^\beta}{n} + \frac{1}{(2n)^\beta(1+\beta)}). \end{aligned}$$

Similarly $W^0 := \{I : I \geq 0, W(I) - W(0) \geq 0\}$ thus using equation(6.6) we find that

$$\begin{aligned} W^0 : &= \{I : 0 \leq I \leq \frac{2}{(2n)^\beta(1+\beta)\gamma}\} \\ I_w &= \arg \max_{I \in W^0} W^0 = \frac{1}{(2n)^\beta(1+\beta)\gamma} \end{aligned}$$

■

Proof of Proposition 4. Direct substitution of $\beta = 1$ yields $I^* = 5/(4n\gamma) = I_b$, from which the equality result follows immediately.

From propositions (2) and (3) the upper boundaries of the appropriate sets are simply double the correspond I value (with lower boundaries all zero). Hence it suffices to establish the ranking of the I 's. First comparing I^* and I_w from propositions (2) and (3):

$$(8.5) \quad I^* = \frac{\beta 2^{1+\beta} + 1}{4^\beta n^\beta \gamma} \geq \frac{1}{(2n)^\beta (1 + \beta) \gamma} = I_w$$

$$(8.6) \quad \Leftrightarrow \frac{\beta 2^{1+\beta}}{4^\beta} + \frac{1}{4^\beta} \geq \frac{1}{2^\beta (1 + \beta)}$$

$$(8.7) \quad \Leftrightarrow 2^\beta \geq 1 + \beta.$$

Where the last condition holds by the assumption $\beta \geq 1$.

Comparing I^* and I_b from propositions (2) and (3):

$$(8.8) \quad I^* = \frac{\beta 2^{1+\beta} + 1}{4^\beta n^\beta \gamma} \leq \frac{2\beta(1 + \beta) + 1}{(2n)^\beta (1 + \beta) \gamma} = I_b$$

$$(8.9) \quad \Leftrightarrow 2 + \frac{1}{2^\beta} = 2 + \frac{1}{1 + \beta}.$$

Where again the last condition is implied by the assumption $\beta \geq 1$. ■

Proof of Proposition 5. Substituting the collusive price p^c into the change in individual surplus from equation (6.3) gives

$$(8.10) \quad -I \left(\frac{1}{2n} \right)^\beta + Iy^\beta - \frac{\gamma I^2}{2}.$$

Now on the circle with n fixed we $y \in [0, \frac{1}{2n}]$ thus $y^\beta \leq (\frac{1}{2n})^\beta$ for all y since $\beta \geq 1$. Thus the surplus change for any consumer from an increase in infrastructure under collusion is non-positive and strictly negative for all but the most distant consumer. Therefore all consumers are hurt by infrastructure improvements and hence $R^0 = B^0 = \{0\}$ and $I^* = I_b = 0$. Notice the collusive price is just sufficient to ensure that the most distant (lowest surplus from consumption) consumers still purchase. Thus under collusion all consumers still purchase and hence the effects of infrastructure improvements on social welfare are the same as under competition just with a different distribution of benefits. Thus as in proposition (3) $W^0 \neq \{0\}$ and $I_w > 0$. ■

Proof of Proposition 6. Evaluating the median consumer's change in net surplus from arbitrarily small levels of investment yields,

$$\begin{aligned} \lim_{I \rightarrow 0} (\bar{S}(I) - S(x_i^* + \frac{1}{4n^*(0)}, 0)) &= (\bar{S}(0) - S(x_i^* + \frac{1}{4n^*(0)}, 0)) \\ &= t_0 \left(\frac{1}{(4n^*(0))^\beta} - \frac{1}{(2n^*(0))^\beta (1 + \beta)} \right) \\ &\leq 0, \end{aligned}$$

where the inequality follows from the fact that $4^\beta \geq 2^\beta(1 + \beta)$ (the inequality is strict for $\beta > 1$). ■

Proof of Proposition 7. We need only consider the median voters preferences since he determine the political outcome. Furthermore the pairwise voting result is implied by the referendum result. Consider some $I > 0$, $I \in R^0$ requires

$$(8.11) \quad S(y_{median}, I) - S(y_{median}, 0) \geq 0.$$

Assume this is true for some γ' . However

$$(8.12) \quad \frac{d}{d\gamma} (S(y_{median}, I) - S(y_{median}, 0)) = -\gamma I < 0.$$

Thus the median voters payoff from an investment of I decreases without bound in γ , and hence there exist sufficiently large γ as to make the investment unattractive and hence unviable politically. ■

Proof of Proposition 8. Summing $S(y, 0)$, as given in equation (7.7) over y yields

$$(8.13) \quad B(0) = \int_{y \in C} S(y, 0) = A - p^*(0) - \frac{t_0 - I}{(2n^*(0))^\beta (1 + \beta)} - \frac{\gamma I^2}{2}$$

Since $n^*(I)$ and $p^*(I)$ are continuous in I for all $I \geq 0$, $\lim_{I \rightarrow 0} B(I) - B(0) = 0$. Furthermore, $\frac{dB(I)}{dI}|_{I=0} > 0$. This implies that there exists strictly positive investment levels which increases aggregate consumer surplus. Also, since the two surplus measures are equivalent, it follows that

$$(8.14) \quad W^0 = B^0 \supset \{0\},$$

$$(8.15) \quad I_w = I_b = \arg \max_{I \geq 0} B^0 = \arg \max_{I \geq 0} \bar{S}(I) > 0$$

Although expected utility from a positive level of investment is identical for all consumers, $\bar{S}(I)$ the expected change in utility varies according to the initial transportation cost of each consumer. Since transport costs are convex the transportation costs incurred by the median consumer is less than the average transportation costs in the status quo and hence $B(0) \leq S(x_i^* + \frac{1}{4n^*(0)}, 0)$. Now $B(I) = \bar{S}(I)$ therefore $B(I) - B(0) \geq \bar{S}(I) - S(x_i^* + \frac{1}{4n^*(0)}, 0)$ which in turn implies that $B^0 \supseteq R^0$, where equality only holds for $\beta = 1$.

Note that since $B(I) = \bar{S}(I)$, the most preferred investment level for any consumer y , amongst the strictly positive ones is $\arg \max_{I > 0} \bar{S}(I) =$

$\arg \max_{I>0} B(I) = I_b$. If $\bar{S}(I_b) - S(x_i^* + \frac{1}{4n^*(0)}, 0) > 0$ then $I_b = I^*$. Else $I^* = 0$ which occurs if γ is larger than a critical value, $\bar{\gamma}$ say. Obviously, when $I^* = 0$, $R^0 = 0$. ■

Proof of Proposition 9. If transport costs are linear in distance, $\beta = 1$, then the expected transport costs overall locations are the same as transport costs for the median voter (in the uniform case the median voter is also the mean voter). Thus in the linear case the median voters preferences are the same as the social planners and hence the outcomes of the political process are equivalent to the appropriate welfare optimal outcome. ■

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SCHOOL OF ECONOMICS, UNIVERSITY OF NEW SOUTH WALES, SYDNEY, NSW 2052, AUSTRALIA. FAX: +61-2-9313 6337

E-mail address: a.ghosh@unsw.edu.au