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Bilingualism and network externalities

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Abstract. We develop a model in which the benefit of language acquisition is increasing in the number of individuals who speak the language. This gives rise to a network externality, and if language acquisition is costly, the language acquisition decisions by individuals may be inefficient. If the available policy instruments affect all members of a language group homogeneously, then policies that effectively subsidize language acquisition are warranted only for the majority language.

Bilinguisme et effets externes de réseau. Les auteurs développent un modèle dans lequel l'avantage attaché à l'acquisition d'une langue s'accroît à proportion qu'un nombre plus grand de personnes parlent cette langue. Voilà qui donne lieu á un effet externe de réseau. Si l'acquisition de la langue est coûteuse, il se peut que la décision par les individus soit inefficace. Si les instruments de politique publique affectent tous les membres d'un groupe linguistique de façon homogène, alors les politiques qui subventionnent effectivement l'acquisition d'une langue sont légitimes économiquement seulement pour la langue majoritaire.

I. INTRODUCTION

This paper analyses the equilibrium in an economy where agents can choose to learn second languages.[1] We construct a game-theoretic model where agents have

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1 Selten and Pool (1991) independently and contemporaneously developed a similar game-theoretic model of second-language acquisition. Their model is more general than ours, since they consider an environment where there are more than two linguistic communities, agents can learn more than two languages, and learning costs differ across individuals and languages. Their emphasis is only on proving the existence of an equilibrium. The generality of their model precludes consideration

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access to two languages that are perfect substitutes but are incompatible in the sense that any two agents can communicate with each other only if they share a common language. Each individual is initially endowed with one language and can acquire the other only at some cost. Individual utility is an increasing function of the number of people with whom one can communicate. In such a setting there is a network externality. The decision by an individual to acquire a second language increases the number of people (by one) with whom every member of the acquired language group can communicate, thus increasing their utility. In essence we interpret languages as simply communication technologies and adapt the framework of technology adoption in the presence of network externalities developed by Katz and Shapiro (1986) for computers to the problem of second-language acquisition. Our setting differs from Katz and Shapiro's in that we focus on the problems that arise when individuals may acquire both technologies (languages).

Broadly speaking, the model provides some theoretical support for Carr's (1976) argument that majority languages can be thought of as natural monopolies. We provide a formal model of why they are natural monopolies (because of the network externality), determine the market allocation, and compare it with the socially optimal allocation. The efficiency of the Nash equilibrium depends on the cost of learning. For some ranges of this cost, the efficient and equilibrium outcomes coincide. However, there exists a range in which one-sided learning is efficient but no one learns in equilibrium. Also, if learning costs are small, then there are two Nash equilibria with one-sided learning, only one of which is efficient.

Section II of the paper presents the basic model. Section III characterizes the equilibrium allocation. Section IV characterizes the 'efficient' allocations. Finally, section V presents a conclusion and suggestions for possible extensions.

II. THE MODEL

There are two languages, E and F. Each person must know at least one to be able to communicate with others. There are N people in the economy. Individuals are identical except for their language endowments. Let e_0 denote the number of people whose native language (endowment) is E and f_0 denote the number whose native language is F. Initially, all agents are unilingual, so $e_0 + f_0 = N$. For convenience, let the agents who are initially endowed with language E be called 'E speakers,' and let those who are initially endowed with F be called 'F speakers.' We model the decision by agents to acquire a second language as a non-cooperative normal-form game. All individuals have two strategies. They can learn their non-native language by incurring a cost of c or they can remain unilingual. Let e_1 and f_1 denote the total number of individuals who can speak E and F, respectively, after all individuals have made their investment decisions in learning a second

of the issues we address here. Grenier (1985a, 1985b) considers the incentives for and the effects of second-language acquisition. Seminal papers that viewed second-language acquisition as an investment in human capital are Breton (1978) and Vaillancourt (1980). For a survey of the economics of languages in general, see Vaillancourt (1985b).

language. The two languages are perfect substitutes in the sense that both have the same benefit function. An individual agent obtains utility $v(e_1)$ if she knows only E, $v(f_1)$ if only F is known, and $v(N)$ if both. We assume that $v' > 0$: the utility of each individual is increasing in the number of other individuals with whom they can communicate. It is this assumption that creates the existence of the network externality that underlies all the results derived in this paper.

III. THE EQUILIBRIUM

The best-response functions in this simple model are the following decision rules:[2]

$$\text{An } E \text{ speaker learns } F \text{ iff } v(N) - v(e_0 + \hat{f}) > c \tag{3.1}$$

$$\text{An } F \text{ speaker learns } E \text{ iff } v(N) - v(f_0 + \hat{e}) > c, \tag{3.2}$$

where $\hat{f}$ and $\hat{e}$ denote the number of F speakers who choose to learn E, and the number of E speakers who choose to learn F, respectively, in the equilibrium. Notice that individuals within either language group are indifferent about the learning choices of others within their own language group, since they are already able to communicate with them. However, the learning decisions made by individuals in the other language group affect the payoff associated with learning. The greater the number of the other language group who learn the native tongue of an individual, the smaller is the benefit of second-language acquisition for that individual.

We assume that $e_0 > f_0$. This implies: $v(e_0) > v(f_0)$. In the following proposition we characterize the Nash equilibria to this game.

PROPOSITION 1

i) If $v(N) - v(e_0) < v(N) - v(f_0) < c$, *then* $(\hat{f} = 0, \hat{e} = 0)$ *is the unique pure-strategy Nash equilibrium.*

ii) If $v(N) - v(e_0) < c < v(N) - v(f_0)$, *then* $(\hat{f} = f_0, \hat{e} = 0)$ *is the unique pure-strategy Nash equilibrium.*

iii) If $c < v(N) - v(e_0)$, *then there exist two pure-strategy Nash equilibria:* $(\hat{f} = f_0, \hat{e} = 0)$ *and* $(\hat{f} = 0, \hat{e} = e_0)$.

Proof. See appendix.

Proposition 1 tells us that the amount of learning in equilibrium depends (quite naturally) on the cost of learning. If the cost is very high, then no one will learn another language. If the cost is in an intermediate range where it pays for F speakers to learn E but not for E speakers to learn F (this is possible because we assume that $e_0 > f_0$), then the unique pure-strategy Nash equilibrium involves all F speakers

2 We assume, for simplicity, that no agent learns unless there is a strictly positive net benefit from doing so.

learning E and no E speakers learning F. If the cost is very low, then there are two equilibria: in one, all F speakers learn E, and no E speakers learn F; in the other, all E speakers learn F, and no F speakers learn E.

IV. EFFICIENCY

1. Constrained efficiency

Consider first a policy maker who wishes to maximize total surplus, given e_0, f_0, and c. The policy maker is restricted in the following way: if any agents of a particular type (i.e., E speakers or F speakers) learn a new language, then all agents of that type will learn. This assumes, in effect, that the policy maker can influence only c.[3]

Let W_{NL}, W_{EF}, W_{FE}, and W_B denote total surplus if nobody learns, only E speakers learn F, only F speakers learn E, and everybody learns, respectively. Hence,

$$W_{NL} = e_0 v(e_0) + f_0 v(f_0) \tag{4.1}$$

$$W_{EF} = Nv(N) - e_0 c \tag{4.2}$$

$$W_{FE} = Nv(N) - f_0 c \tag{4.3}$$

$$W_B = Nv(N) - Nc. \tag{4.4}$$

PROPOSITION 2

i) $W_B < W_{EF} < W_{FE}$

ii) $W_{NL} < W_{FE}$ *iff* $c < (e_0/f_0)[v(N) - v(e_0)] + [v(N) - v(f_0)]$ *(4.5)*

Proof

i) Follows directly from (4.2), (4.3), and (4.4), since $f_0 < e_0 < N$.

ii) From (4.1) and (4.3):
$W_{FE} - W_{NL} = e_0[v(N) - v(e_0)] + f_0[v(N) - v(f_0)] - f_0 c$,
which is positive iff (4.5) holds. ■

Proposition 2 implies that, if the costs of learning are not so high that no one should learn, then the optimal policy involes all F speakers learning E and no E speakers learning F. The reasoning behind this is quite simple. It is never optimal for all individuals to become bilingual: once one group has become bilingual, then everyone in the economy can communicate with everyone else and there are no further gains from anyone else learning. The problem then becomes: which language group should become bilingual? Clearly, with a constant unit cost of learning, the minimum number of people should learn. Since it is assumed that $f_0 < e_0$, then this implies that (if any learning should occur) all F speakers should learn E.

3 Katz and Shapiro (1986) use this criterion for efficiency.

Range I	Range II	Range III	Range IV
FE efficient FE or EF in equilibrium	FE efficient FE in equilibrium	FE efficient NL in equilibrium	NL efficient NL in equilibrium

0 $\quad v(N) - v(e_0) \quad v(N) - v(f_0) \quad (e_0/f_0)[v(N) - v(e_0)] + v(N) - v(f_0) \quad c$

FIGURE 1

2. Comparison of equilibrium and constrained-efficient allocations

Figure 1 illustrates ranges of the cost of learning, c, for which the Nash equilibrium outcomes and the efficient outcomes coincide. If costs are extremely high (range IV), then the efficient and equilibrium outcomes coincide: nobody learns (NL) a new language. If costs are in ranges I, II, or III, then it is socially optimal that all F speakers learn E. However, in range III it is not privately optimal for anyone to learn: in the equilibrium no one will learn. This divergence between the efficient and equilibrium solutions occurs because of the existence of network externalities: when an individual makes the choice whether to learn or not, she does not take into account the benefit that others get from being able to communicate with one additional person. In range II the private and socially optimal outcomes coincide. In range I there are two possible equilibria: the efficient one, and an inefficient one where E speakers learn F instead of F speakers learning E.

3. The first-best allocation

Consider now a policy maker who is able to dictate which individuals within a language group should learn the other language. The policy maker choses $\hat{e}$ and $\hat{f}$ to maximize total surplus, given the relevant constraints. In an earlier, lengthier version of this paper (1992) we explicitly analyse this problem. For brevity, we simply summarize the main results here.

At this point we impose that $v'' < 0$, for the Kuhn-Tucker conditions to be necessary and sufficient for a unique optimum. The nature of the optimal allocation also depends on the extent of the curvature of v. Let

$$\rho \equiv -\frac{v''(x)}{v'(x)}x.$$

If $\rho < 1$, then it will never be optimal for an E speaker to learn F. The only possible optima, under these circumstances, are: no learning, some F speakers learn E, and all F speakers learn E. Figure 2 illustrates the ranges of c for which the equilibrium and first-best allocations coincide, when $\rho < 1$. When c is very large (range V), then there is no learning of either language in the equilibrium or in the optimal solution. If c is in range IV, then some F speakers should learn E, but there is no learning of either language in the equilibrium. If c is in ranges I, II, or III, then all F speakers should learn E. In range III, however, no learning of either language occurs in the equilibrium. In range II the equilibrium solution coincides

Range I	Range II	Range III	Range IV	Range V
$\hat{f} = f_0$ optimal	$\hat{f} = f_0$ optimal	$\hat{f} = f_0$ optimal	$0 \leqq \hat{f} \leqq f_0$ optimal	NL optimal
$\hat{f} = f_0$ or $\hat{e} = e_0$ in equilibrium	$\hat{f} = f_0$ equilibrium	NL in equilibrium	NL in equilibrium	NL in equilibrium

0 $\quad v(N) - v(e_0) \quad v(N) - v(f_0) \quad v(N) - v(f_0) + e_0 v'(N) \quad v(N) - v(f_0) + e_0 v'(e_0) \quad c$

FIGURE 2

with the optimal one. In range I, where c is small, there are two equilibria, only one of which is optimal (as discussed above).

When $\rho > 1$, we cannot rule out the possibility that some E speakers should learn F in the first-best solution. To understand why, consider the social marginal benefit functions of E speakers' and F speakers' learning, respectively, evaluated at the initial allocation:

$$\text{MB}_E = v(N) - v(e_0) + f_0 v'(f_0)$$

$$\text{MB}_F = v(N) - v(f_0) + e_0 v'(e_0).$$

The first two terms in both expressions represent the private return to learning. If $v' > 0$, then $e_0 > f_0$ is sufficient for the private return to an F speaker's learning to be greater than the private return to an E speaker's learning. It is the external benefit terms $f_0 v'(f_0)$ and $e_0 v'(e_0)$ that allow for the possibility that MB_E may exceed MB_F. If $\rho < 1$, then $e_0 v'(e_0) > f_0 v'(f_0)$, which unambiguously implies that $\text{MB}_F > \text{MB}_E$. If $\rho > 1$, however, then $f_0 v'(f_0)$ may exceed $e_0 v'(e_0)$. The external benefit terms have two components, the marginal utility of an individual of the other language group multiplied by the number of individuals comprising that group. When $e_0 > f_0$ then $v'(f_0) > v'(e_0)$, since $v'' < 0$. Hence, if v' decreases rapidly and e_0 is not much greater than f_0, it may be the case that $f_0 v'(f_0) > e_0 v'(e_0)$. Moreover, this external effect may be large enough that, even though the private return to having an F speaker learn is greater than the private return to having an E speaker learn, the *social* return to having an E speaker learn is greater. Although it is never optimal for all E speakers to learn F (given $e_0 > f_0$), it may be optimal under these circumstances for *some* E speakers to learn.

VI. CONCLUSIONS

In this model there are three possible Nash equilibria: no learning and complete learning by either language group. Which of the equilibria occurs depends on the cost of learning. If the policy maker can only affect this cost identically for every person in a language group, then figure 1 illustrates the possible combinations of equilibria and constrained-efficient allocations. Constrained efficiency in this setting requires that, if any learning occurs at all, then only one of the language groups should become bilingual (the smallest group). If the costs of learning are extremely high, then there will be no learning in either the equilibrium or the efficient cases. Because of the existence of network externalities, however, there exists a range of costs for which one-sided learning is optimal but does not occur in the equilibrium. Similarly, if costs are very low, then there are two possible Nash equilibria involving one-sided learning. That is, the 'wrong' language group (the largest group) may choose to learn. From a policy perspective, this suggests that it is never optimal to subsidize the learning of the minority language. Also, there exist ranges of values of the cost of learning for which subsidization of majority language acquisition may be called for. Finally, while there is no need for a policy to subsidize majority language acquisition when second language acquisition is relatively easy, there is a need for some sort of coordinating policy that ensures that the minority language group becomes bilingual.

If the policymaker can choose which particular individuals within a language group should learn, then more possibilities open up. If the curvature of the utility function is not very pronouced ($\rho < 1$) then figure 2 illustrates the combinations of equilibria and efficient allocations. As in the constrained-efficient case, if the costs of learning are very small, then the 'wrong' language group may learn. Also, there are ranges of values of c for which no learning will occur in equilibrium when some F speakers should learn, owing to the network externality effect. Range IV in figure 2 illustrates a possibility that is not open to the constrained policy makers: for some range of c, it is optimal to have some (but not all) F speakers learn.

In general, in the constrained-efficient case and in the first-best case when $\rho < 1$, E speakers should never learn F. If anything, learning of the majority language should be encouraged. In the first-best case, when $\rho > 1$, further possibilities arise. The policy implications are less clear cut. Partial learning on both sides may be optimal. However, minority language learning in this setting can be justified only if the curvature of the utility function is very pronounced, making the network externality argument for learning more important than the private benefit argument.

Our objective in this paper is to stimulate discussion among economists about the welfare effects of language policies, a topic that we feel deserves more attention than it has received so far.[4] We think of this model as being the simplest possible analytical framework in which this can be done, and as such it provides a useful benchmark. Here, languages are interpreted only as communication technologies, much like telephone networks.[5] The stark policy implications of this model reflect some key assumptions. First, we assume that the languages are perfect substitutes. This assumes away the issue discussed by Marschak (1965), where some languages are more efficient media of communication than others. It also assumes away any intrinsic value of a particular language: no one cares if one language disappears, and no one prefers communicating in one language rather than the other. Sabourin (1985) and Grin (1992) consider (quite different) models in which languages are

4 The issue, however, has not been ignored. See, for example, Vaillancourt (1978).
5 Thanks to Dan Usher for making this analogy at the CEA meetings.

not perfect substitutes and individuals have preferences regarding language use. However, our assumption that languages are perfect substitutes serves to highlight the importance and necessity of these factors in any argument for minority language subsidies.

Another key assumption is that the cost of learning is the same for both languages and for all individuals. Clearly, if the cost of learning one language is smaller than the cost of learning the other, the above results would be modified in a straightforward fashion. Allowing for heterogeneity within language groups, however, opens up more interesting possibilities. Suppose, for example, that the average cost of learning is the same for both languages, but within each language group some individuals have a lower cost of learning than others. Under these circumstances, Selten and Pool (1991) suggest that in equilibrium some (but not all) individuals within both language groups will learn a second language. Moreover, if the costs were distributed in a continuous fashion across individuals within a language group, it may be possible to attain the first-best allocation by using universally accessible subsidies alone.[6]

This analysis could also be usefully extended to a setting in which there are two different regions within an economy, with a moving cost and different initial distributions of E and F people within each region. Individuals could then choose either to move or to learn, or both, or neither. This is clearly a problem that Canadians face.

APPENDIX

Proof of proposition 1

We begin by ruling out strategy combinations where $0 < \hat{e} < e_0$ or $0 < \hat{f} < f_0$. Consider the case where $0 < \hat{f} < f_0$. Since $\hat{f} > 0$, then (3.2) holds with strict inequality and any F speakers who remained unilingual could increase their payoff by learning E: $0 < \hat{f} < f_0$ is not a Nash equilibrium. Thus, in equilibrium, either $\hat{f} = 0$ or $\hat{f} = f_0$. A similar analysis holds for $\hat{e}$.

We now rule out the strategy combination where *both* $\hat{f} = f_0$ and $\hat{e} = e_0$. If $\hat{f} = f_0$, then there is no benefit to an E speaker from learning F: the left-hand side of (3.1) will equal $V(N) - V(N) = 0 < c$. Hence, in this case, E speakers would be better off by not learning: $(\hat{e} = e_0, \hat{f} = f_0)$ cannot be a Nash equilibrium.

Now consider (i) in the proposition. Given that $e_0 > f_0$, and $v' > 0$, so $v(e_0) > v(f_0)$, then $v(N) - v(f_0)$ will be no smaller than the left-hand side of either (3.1) or (3.2). Since $V(N) - V(f_0) < c$, then neither inequalities (3.1) or (3.2) can be satisfied. No learning is the only possible Nash equilibrium in this case.

Now consider case (ii). Since $v(N) - v(e_0) < c$, then (3.1) can never be satisfied for any $\hat{f}$. Hence, no E speakers will learn F: $\hat{e} = 0$. Given that $\hat{e} = 0$, then the assumption that $c < V(N) - v(f_0)$ guarantees that (3.2) will be satisfied, so all F speakers learn E: $\hat{f} = f_0$.

6 Thanks to Peter Kennedy for making this last point in a seminar.

Now consider case (iii). If $\hat{f} = f_0$, then the left-hand side of (3.1) equals $V(N) - V(N) = 0 < c$, so no E speakers will learn F: $\hat{e} = 0$. If $\hat{e} = 0$, then the left-hand side of (3.2) becomes: $V(N) - V(f_0)$. Since this is greater than $V(N) - V(e_0)$, then assuming that $V(N) - V(e_0) > c$ ensures that (3.2) will be satisfied, so all F speakers will learn E: $\hat{f} = f_0$. Hence, ($\hat{f} = f_0$, $\hat{e} = 0$) is a Nash equilibrium. Also, if $\hat{f} = 0$, then the left-hand side of (3.1) becomes $V(N) - V(e_0)$, which is greater than c by assumption in this case. Hence, (3.1) will be satisfied and all E speakers will learn F: $\hat{e} = e_0$. If $\hat{e} = e_0$, then the left-hand side of (3.2) becomes $V(N) - V(N) = 0 < c$, so no F speakers will learn E: $\hat{f} = 0$. Hence, ($\hat{f} = 0$, $\hat{e} = e_0$) is also a Nash equilibrium. ∎

REFERENCES

Breton, A. (1978) *Bilingualism: An Economic Approach* (Montreal: C.D. Howe Institute)

Carr, J. (1976) 'Le bilinguisme au Canada: l'usage consacre-t- il l'anglais monopole naturel?' Reprinted in Vaillancourt (1985a)

Grenier, G. (1985) 'The effects of language characteristics on the wages of Hispanic-American males.' *Journal of Human Resources* 19, 35–52

— (1985b) 'Bilinguisme, transferts linguistiques et revenues de travail au Québec: quelques éléments d'interaction.' In Vaillancourt (1985a)

Grin, F. (1992) 'Towards a threshold theory of minority language survival.' *Kyklos* 45, 69–97

Katz, M., and C. Shapiro (1986) 'Technology adoption in the presence of network eternalities.' *Journal of Political Economy* 94, 822–41

King, I., and J. Church (1992) 'Languages as communication technologies.' University of Victoria Discussion Paper No. 92–03

Marschak, J. (1965) 'Economics of language.' *Behavioural Science* 10, 135–40

Sabourin, C. (1985) 'La théorie des environnements linguistiques.' In Vaillancourt (1985a)

Setten, R., and J. Pool (1991) 'The distribution of foreign language skills as a game equilibrium.' In *Cone Equilibrium Models*, vol. 4, ed. R. Setten (Berlin: Springer-Verlag)

Vaillancourt, F. (1978) 'La charte de la langue française au Québec: un essai d'analyse.' *Canadian Public Policy / Analyse de Politiques* 4, 284–308

— (1980) *Differences in Earnings by Language Group in Quebec, 1970: An Economic Analysis* (Quebec: International Centre for Research on Bilingualism)

— (1985a) *Économie et langue* (Montréal: Éditeur Officiel du Québec)

— (1985b) 'Les écrits en économie et langue.' In Vaillancourt (1985a)