ELEMENTARY MODELS FOR SOLVING THE PROBLEM OF LINGUISTIC DIVERSITY

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Introduction

Linguistic diversity--the fact that different people know different languages--is an ancient and familiar problem. When language barriers prevent communication, people either (1) lose the benefits they could have obtained through communication or (2) suffer extra costs to circumvent the barriers. And in the latter case the problem is exacerbated by the question of who should bear what proportion of the costs. This study applies some basic decision-theoretic principles to determine whether and how linguistic diversity can optimally be overcome.

Many persons and institutions have tried to solve the problem of language diversity. Their solutions have included the invention of hundreds of synthetic universal languages, the learning of one person's language by another, the reform of languages to make them easier to learn, the creation of non-linguistic means of communication, the use of translation and interpretation, the adoption of rules for allocating the burdens of linguistic diversity, and the reorganization of societies so as to reduce the penalties that language differences make people pay.

In some cases, certain interests are benefitted rather than harmed by linguistic diversity. Persons possessing scarce linguistic skills, persons who wish their messages to be understood only by limited audiences, those who gain from the inability of certain groups to coordinate activity, and those who want to preserve cultural differences that inter-group communication would erode are examples. To them, linguistic assimilation or language learning is the problem instead. Their solutions include preventing inter-group contact, creating semantically divergent varieties of the same language to prevent understanding, using cryptography, (re)organizing society to increase the demand for their linguistic skills, etc.

A rational approach to solving the problem--whether the problem is the excessive or insufficient diversity of languages--would be to compare the various possible solutions and choose the best one (see, e.g., Zeckhauser and Schaefer, 1968). Doing this requires a set of possible solutions and a rule for determing how "good" each one is. In addition, the situation must be well enough known that the rule can be applied to it.

In this study, we shall examine three closely related models of linguistic diversity. Each contains one or more optimization rules for solving the problem and some simple but adequate assumptions about the characteristics of the problematic situation. Formulae will be derived which allow one to find a solution for any situation of the specified kind. These formulae will then be applied to illustrative examples.

Before we continue, a brief digression is in order. Language problems are not usually solved in an overtly calculating fashion. Several studies of the politics of language in various countries leave the impression that language policies, like ethnic policies in general, are made in highly emotional and symbolic ways, sometimes leaving virtually everyone worse off than if other decisions had been reached instead (Harrison, 1960; Laitin, 1977; Lorwin, 1966: 174-176; Madgwick, 1973: 121; Pool, 1976; Rabushka and Shepsle, 1972). Some observers of language policy argue that it is peculiarly likely to be irrational, or at least inelegant, because of the extremely limited degree of compromise or of egalitarianism that the nature of language itself makes possible (Kloss, 1966: 7-8; Rustow, 1970: 359-360).

On the other hand, there is nothing inherently irrational about symbolic attachments to particular languages, since rationality, as the term is used here, refers to the making of choices that satisfy preferences, not to the way preferences originally arise. Furthermore, even where language is a heated symbolic issue, apparently calculating behavior towards it by political entrepreneurs has been observed (Brass, 1974: 404-410; O'Barr and O'Barr, 1976). There is also reason to believe that people in labor markets, stratification systems, and other social structures throughout the world generally make the language learning and using choices that one would predict from analyzing the differential economic and status benefits of knowing various languages, and that some earlier conclusions about apparently self-harmful language behaviors may have been mistaken (Eidheim, 1969; Fishman, 1976: 70-72, 96-97; Jacobson, 1978; Vaillancourt, 1978; cf. also Hechter, 1975: chs. 2, 6).

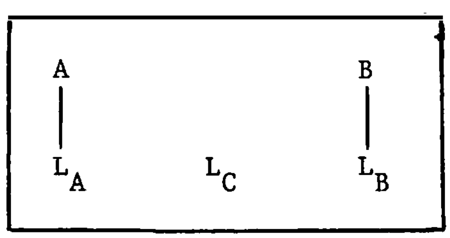
Finally, even when people do not make rationally calculated decisions about language, a rational-decision perspective on linguistic diversity can be useful. It can add new methods and criteria to the repertoire for decision-makers, while giving analysts a fuller perspective on the alternatives from which decision-makers are choosing. These points will be discussed further in the conclusion.

The Situation of Linguistic Diversity

Unlike some proponents of economic analysis for language policy (Jernudd, 1971; Thorburn, 1971), I shall present very simple models of linguistic diversity, which make no attempt to represent all the important features of any real case. We shall soon discover that even the simplest imaginable problem leads to considerable calculations if we make reasonable assumptions about what the possible solutions are. After deriving and illustrating the solutions, I shall discuss some new elements that could be added to the models constructed here.

What, then, is the simplest situation of linguistic diversity that one could imagine? It is the situation of two actors, each of which knows one language. The language known by one is different from (here implying mutually unintelligible with) the language known by the other. "Actor", here, can refer to an individual, a group, or an organization.

If we assume that a given actor either knows or does not know a given language, then in a dyadic situation there can exist three kinds of languages: (1) those known by both, (2) those known by one, and (3) those known by neither of the actors. We have already posited, as a basic characteristic of "linguistic diversity" in our model, that there is no language of the first type. Let us now assume that, even though there must be many languages of the third type, only one of them is relevant, at least at any one time. In this case our situation contains two actors (A and B) and three languages (L_A, L_B, and L_C), which we may represent graphically



or in matrix form.

Languages

		L_A	L_B	L_C
Actors	A	1	0	0
	B	0	1	0

If either actor would benefit from communication with the other actor, then this inability to communicate is a problem. It raises the question whether to make communication possible and, if so, how. In the models to be presented below, there are two basic procedures available for making communication possible: language learning and translation. ("Translation" here should be understood to include interpretation, as appropriate to the mode of communication.) Singly and in combination, these procedures give rise to 8 different minimally sufficient methods of achieving communication or not achieving communication:

1. A learns L_B

2. B learns L_A

3. A and B learn L_C

4_{AB}. Translation is performed between L_A and L_B

4_{ACB}. Translation is performed between L_A and L_C and between L_C and L_B

4_{AC}. B learns L_C and translation is performed between L_A and L_C

4_{BC}. A learns L_C and translation is performed between L_B and L_C

5. A and B do nothing to achieve communication

All other combinations of these procedures are either insufficient to achieve communication (e.g., A learns L_C and translation is performed between L_A and L_C) or more than sufficient (e.g., A learns L_B and B learns L_A).

Assumptions of the Models

The three models below share some assumptions about the nature of communication and about the costs and benefits that language learning, translation, and communication bring to the actors. Communication is measured only as a cumulative quantitative variable, k, expressing the total quantity of communication that transpires between A and B. The content, the time, the rate, and the direction of communication are ignored. The benefit derived by one actor from communication with the other actor is an actor-specific, single-peaked function of the amount of communication, k. Until a certain amount of communication is reached, the actor continues to gain something from each additional increment of communication. After the point of maximal gain, each further increment of communication decreases the total benefit. This point of maximal gain may be thought of as the point where the opportunity cost of communicating (i.e. the benefits that are lost because communicating takes time away from other pursuits) begin to outweigh the (marginally decreasing) benefits. Communication past any point requires not only the fulfillment of language-learning and/or translation prerequisites, but also the consent of both communication partners; each partner will veto further communication once the point of maximal net gain for that partner has been reached. Both procedures for achieving communication impose costs, but in different ways. Learning a language imposes a one-time fixed cost. Translation, on the other hand, imposes a cost which is directly proportional to the quantity of communication translated. Both costs are language-specific; i.e. learning one language may cost more than learning another, and translating between two languages may cost more per unit of communication than translating between a different pair of languages.

The three models to be presented reflect three possible decision circumstances. The first model assumes that the actors make their decisions sequentially, and that the second actor knows what the first one has decided to do before the second must make its decision. This is our <u>individual decision model</u>. The second model assumes that the actors both make their decisions in a state of uncertainty about each other's decisions, as if they were deciding simultaneously. This is our <u>game model</u>. The third model assumes that there is an authority, such as a political representative, that makes both actors' decisions for them. This is our social welfare model.

The Individual Decision Model

In the individual decision model, we begin with some already made decision by B and ask what A should now do to maximize its own welfare. An infinite number of different decisions seem to be open to both A and B, so we must restrict their options if the solution to A's problem is to be calculable. Let us first posit that all decisions are carried out immediately, and that any decision to translate takes the form of a nonrefundable prepayment to translators who can translate (bidirectionally) only between a particular pair of languages, and who will do so whenever asked by either A or B.[2] This assumption reduces the infinity of options to 12 for each actor. If we let M_i stand for learning L_i, and T_{ij} for ordering some translation between L_i and L_j, the non-redundant alternatives are:

For A	For B
1. M_B	2. M_A
3. M_C	3. M_C
4_{AB}. T_{AB}	4_{AB}. T_{AB}
4_{AC}. T_{AC}	4_{BC}. T_{BC}
4_{BC}. $M_C + T_{BC}$	4_{AC}. $M_C + T_{AC}$
5. --	5. --
4_{BC_T}. T_{BC}	4_{AC_T}. T_{AC}
4_{ACB}. $T_{AC} + T_{BC}$	4_{ACB}. $T_{AC} + T_{BC}$
$4_{AB,AC}$. $T_{AB} + T_{AC}$	$4_{AB,BC}$. $T_{AB} + T_{BC}$
$4_{AB,BC}$. $T_{AB} + T_{BC}$	$4_{AB,AC}$. $T_{AB} + T_{AC}$
3_{AB}. $M_C + T_{AB}$	3_{AB}. $M_C + T_{AB}$
$3_{AB,BC}$. $M_C + T_{AB} + T_{BC}$	$3_{AB,AC}$. $M_C + T_{AB} + T_{AC}$

To avoid the tedium of presenting all 144 decision pairs, I shall consider only the first 6 options of A and B, since these seem the most interesting and plausible.[3]

A's problem is then to find which alternative, given B's already known decision, maximizes A's net benefit. The net benefit to A is the (gross) benefit A obtains from the communication that will take place with B if a given alternative is selected, less the cost to A under that alternative of achieving that quantity of communication.

Let R(k) represent the gross benefit to A of k units of communication with B. As mentioned above, R is single-peaked. Let C_1 and C_3 represent the (fixed) costs to A of learning L_B and L_C, respectively. Let $C_{4_{ij}}(k)$ represent the cost (on the same scale of measurement) of having k units of communication translated between languages L_i and L_j. Since this cost is proportional to the amount translated, $C_{4_{ij}} = t_{ij}k$, where t_{ij} is a positive constant. Finally, let $V_i(k)$ represent the net benefit to A of engaging in k units of communication with B after choosing alternative i; this is the gross benefit, R(k), reduced by the cost to A of achieving this much communication under this alternative.

The scales of measurement for communication and for costs and benefits are arbitrary, so we can select their units for convenience. Let us set the point of maximum benefit for A, i.e. the amount of communication that maximizes R(k), as 1 unit of k. Let us set that maximum gross benefit as 1 unit on the scale of costs and benefits. Thus $R(1) = 1 = R_{max}(k)$.

Once B has made its decision, three facts about B are relevant for A. One is B's language repertoire: what language(s) B knows. The second is whether B has ordered any translation services and, if so, what kind and how much B has paid for them (in terms of A's cost scale). We shall call this quantity C_{4_B} and the amount of communication that it can buy the translation of, k_{4_B}, which is equivalent to $\frac{C_{4_B}}{t_{ij}}$, where ij is the pair of languages between which B has ordered translation. If B has not ordered any translation, $k_{4_B} = 0$. And the third fact is B's point of maximum benefit, i.e. the amount of communication (again in terms of A's scale) that maximizes B's own R(k) function. We shall call this quantity k_B. It can never be beneficial for B to pay for translation of more than this amount of communication, so $k_{4_B} \leq k_B$. Since B commits all the resources it is going to spend before communication begins, k_B will always be the point of maximum net benefit as well as maximum gross benefit for B. A therefore knows that B will veto all communication exceeding k_B but never veto communication before that point. Hence the point of maximum available gross benefit to A, which we shall call k_H, is the lesser of $(1, k_B)$.

For each possible decision of B, we must now determine the net benefit that A would obtain if it selected each of its own 6 alternatives. We can do this in 2 steps: first calculate $V_i(k)$ for each i, and then determine the maximum value that each such V_i reaches over the range of k that A can select points from. The solution for A then consists of that alternative whose $V_{i_{max}}$ is greatest. For convenience, let us consider the alternatives in the following order of B's 6 possible decisions: 5, 2, 4_{AB}, 4_{AC}, 4_{BC}, 3.

<u>Condition 1: B has made decision 5</u>. The net benefits to A from the various alternatives, if B has decided to do nothing (decision 5), are:

$$V_1(k) = R(k) - C_1$$

$$V_{4_{AB}}(k) = R(k) - C_{4_{AB}}(k) = R(k) - t_{AB}k$$

$$V_{4_{BC}}(k) = R(k) - C_3 - C_{4_{BC}} = R(k) - C_3 - t_{BC}k$$

$$V_5(k) = 0$$

V_3 and $V_{4_{AC}}$ need not be considered since these 2 alternatives yield results which are evidently inferior to alternative 5: costs are incurred and still no communication is rendered possible.

Where V is a constant, V_{max} is obviously the same as V. Thus, in this condition,

$$V_{5_{max}} = V_5 = 0$$

Where the alternative chosen involves language learning but no translation, V_{max} is merely the maximum attainable benefit from communication less the fixed language learning cost. Thus

$$V_{1_{max}} = R(k_H) - C_1$$

When A chooses to order translation, however, both the cost and the benefit of communication rise together, and the maximum difference between them will depend on the shape of A's benefit curve as well as the slope of the translation-cost curve. There will always be some amount of communication, within the range open to selection by A, that maximizes this net benefit. Let us call this quantity $k_{4_{ij}}$, where i and j are the pair of languages between which A is paying for translation. $k_{4_{ij}}$ can be expressed as follows:

$$\exists\, k_{4_{ij}} \Big| \; k_L \leq k_{4_{ij}} \leq k_H \;\ni\; V_{4_{ij}}(k_{4_{ij}}) = V_{4_{ij_{max}}}(k) \Big| \; k_L \leq k \leq k_H,$$

where

$k_L = \min(1, k_{4_B})$ if {B has ordered translation between L_i and L_j} and

{{A knows L_i and B knows L_j} or {A knows L_j and B knows L_i}}

$k_L = 0$ otherwise[4]

Making use of $k_{4_{ij}}$, we find that

$$V_{4_{AB_{max}}} = V_{4_{AB}}(k_{4_{AB}}) = R(k_{4_{AB}}) - t_{AB}k_{4_{AB}}$$

$$V_{4_{BC_{max}}} = V_{4_{BC}}(k_{4_{BC}}) = R(k_{4_{BC}}) - t_{BC}k_{4_{BC}} - C_3$$

If B has decided to do nothing to make communication possible, A's solution is alternative 1, 4_{AB}, 4_{BC}, or 5, whichever has the largest V_{max}.

We may now proceed more directly to the derivation of V and V_{max} for each of A's alternatives in the other five conditions, after which we shall consider an illustrative example.

Condition 2: B has made decision 2.

$$V_5(k) = R(k)$$

$$V_{5_{max}} = R(k_H)$$

Since B has already learned L_A, communication is possible at no cost to A, so A need not consider anything but alternative 5.

Condition 3: B has made decision 4_{AB}.

$$V_1(k) = R(k) - C_1$$

$$V_{4_{AB}}(k) = R(k) - t_{AB} \cdot (k - k_{4_B}) \text{ if } k_{4_B} < k$$

$$V_{4_{BC}}(k) = R(k) - t_{BC} \cdot (k - k_{4_B}) - C_3 \text{ if } k_{4_B} < k$$

$$V_5(k) = R(k)$$

$$V_{1_{max}} = R(k_H) - C_1$$

$$V_{4_{AB_{max}}} = R(k_{4_{AB}}) - t_{AB} \cdot (k_{4_{AB}} - k_{4_B}) \text{ if } k_{4_B} < k_{4_{AB}}$$

$$V_{4_{BC_{max}}} = R(k_{4_{BC}}) - t_{BC} \cdot (k_{4_{BC}} - k_{4_B}) - C_3 \text{ if } k_{4_B} < k_{4_{BC}}$$

$$V_{5_{max}} = R(\min(1, k_{4_B}))$$

<u>Condition 4: B has made decision 4_{AC}.</u>

$$V_1(k) = R(k) - C_1$$

$$V_3(k) = R(k) - C_3$$

$$V_{4_{AC}}(k) = R(k) - t_{AC} \cdot (k - k_{4_B}) \text{ if } k_{4_B} < k$$

$$V_5(k) = R(k)$$

B's decision implies that $t_{AC} < t_{AB}$; given this, A need not consider alternative 4_{AB}.

$$V_{1_{max}} = R(k_H) - C_1$$

$$V_{3_{max}} = R(k_H) - C_3$$

$$V_{4_{AC_{max}}} = R(k_{4_{AC}}) - t_{AC} \cdot (k_{4_{AC}} - k_{4_B}) \text{ if } k_{4_B} < k_{4_{AC}}$$

$$V_{5_{max}} = R(\min(1, k_{4_B}))$$

<u>Condition 5: B has made decision 4_{BC}.</u>

$$V_1(k) = R(k) - C_1$$

$$V_3(k) = R(k) - C_3$$

$$V_{4_{AB}}(k) = R(k) - t_{AB}k$$

$$V_{4_{AC}}(k) = R(k) - t_{AC}k$$

$$V_{4_{BC}}(k) = R(k) - t_{BC} \cdot (k - k_{4_B}) - C_3 \text{ if } k_{4_B} < k$$

$$V_5(k) = 0$$

$$V_{1_{max}} = R(k_H) - C_1$$

$$V_{3_{max}} = R(\min(1, k_{4_B})) - C_3$$

$$V_{4_{AB_{max}}} = R(k_{4_{AB}}) - t_{AB}k_{4_{AB}}$$

$$V_{4_{AC_{max}}} = (R(k) - t_{AC}k)_{max} \Big| \, 0 \le k \le k_{4_B}$$

$$V_{4_{BC_{max}}} = R(k_{4_{BC}}) - t_{BC} \cdot (k_{4_{BC}} - k_{4_B}) - C_3 \text{ if } k_{4_B} < k_{4_{BC}}$$

$$V_{5_{max}} = 0$$

In this condition, A also has one more reasonable alternative to consider. If translation between L_A and L_C costs less than between L_A and L_B, A might find it optimal to order translation between L_A and L_C for exactly the quantity of communication that B has ordered translated between L_B and L_C (L_C is here being used as a "translation bridge" by the two sets of translators, though neither partner knows the language), and in addition order some translation between L_A and L_B up to the point of maximum net benefit. Thus:

$$V_{4_{AC+AB}}(k) = R(k) - t_{AC}k_{4_B} - t_{AB} \cdot (k - k_{4_B}) \text{ if } k_{4_B} < k$$

$$V_{4_{AC+AB_{max}}} = (R(k) - t_{AB}\,k\,)_{max} \Big|_{k_{4_B} \le k \le k_H} + k_{4_B} \cdot (t_{AB} - t_{AC})$$

<u>Condition 6: B has made decision 3</u>.

$$V_1(k) = R(k) - C_1$$

$$V_3(k) = R(k) - C_3$$

$V_{4_{AB}}(k) = R(k) - t_{AB}k$

$V_{4_{AC}}(k) = R(k) - t_{AC}k$

$V_5(k) = 0$

$V_{1_{max}} = R(k_H) - C_1$

$V_{3_{max}} = R(k_H) - C_3$

$V_{4_{AB_{max}}} = R(k_{4_{AB}}) - t_{AB}k_{4_{AB}}$

$V_{4_{AC_{max}}} = R(k_{4_{AC}}) - t_{AC}k_{4_{AC}}$

$V_{5_{max}} = 0$

An Individual Decision Example

This gives us the formulae necessary for A to solve its problem, once the relevant functions and constants are known. Let us apply these formulae to a specific example. A has the following situation:

$R(k) = k \cdot (2 - k)$

$C_1 = 0.8$

$C_3 = 0.4$

$t_{AB} = 1.2$

$t_{AC} = 0.8$

$t_{BC} = 0.8$

$k_B = 1.3$

From the last equation it follows that

$k_H = 1$

In this situation, A's benefit curve has a simple form satisfying the requirement of single-peakedness; A can learn the third language with half the expenditure of resources that would be required to learn B's language; and translation between L_A and L_B costs 50 percent more than translation between either of them and L_C. B's point of maximum benefit is beyond A's, so B will not veto any communication that A desires. These relations can be seen graphically in figure 1.

Figure 1 about here

<u>If B makes decision 2</u>:

$$* \quad V_{5_{max}} = R(k_H) = k_H \cdot (2 - k_H) = 1 \cdot (2 - 1) = 1$$

In other words, by doing nothing, A obtains 1, which is the maximum conceivable benefit, since A and B can and will communicate (in L_A) until A (at 1 unit of communication) vetoes further communication, and this costs A nothing.

<u>If B makes decision 3</u>:

$$V_{1_{max}} = R(k_H) - C_1 = 1 - 0.8 = 0.2$$

$$* \quad V_{3_{max}} = 1 - 0.4 = 0.6$$

$$V_{4_{AB_{max}}} = k_{4_{AB}} \cdot (2 - k_{4_{AB}}) - t_{AB}k_{4_{AB}} = k_{4_{AB}} \cdot (2 - k_{4_{AB}} - t_{AB})$$

Solving this requires knowing $k_{4_{AB}}$. By our earlier formula,

$$V_{4_{ij}}(k) = V_{4_{ij_{max}}}(k)\Big|_{k_L \leq k \leq k_H}$$

Since $V_{4_{ij}}(k) = k \cdot (2 - k - t_{ij})$ plus some constant, and since $R''(k)$ is everywhere negative, it follows that $V_{4_{ij}}$ must attain its maximum over any

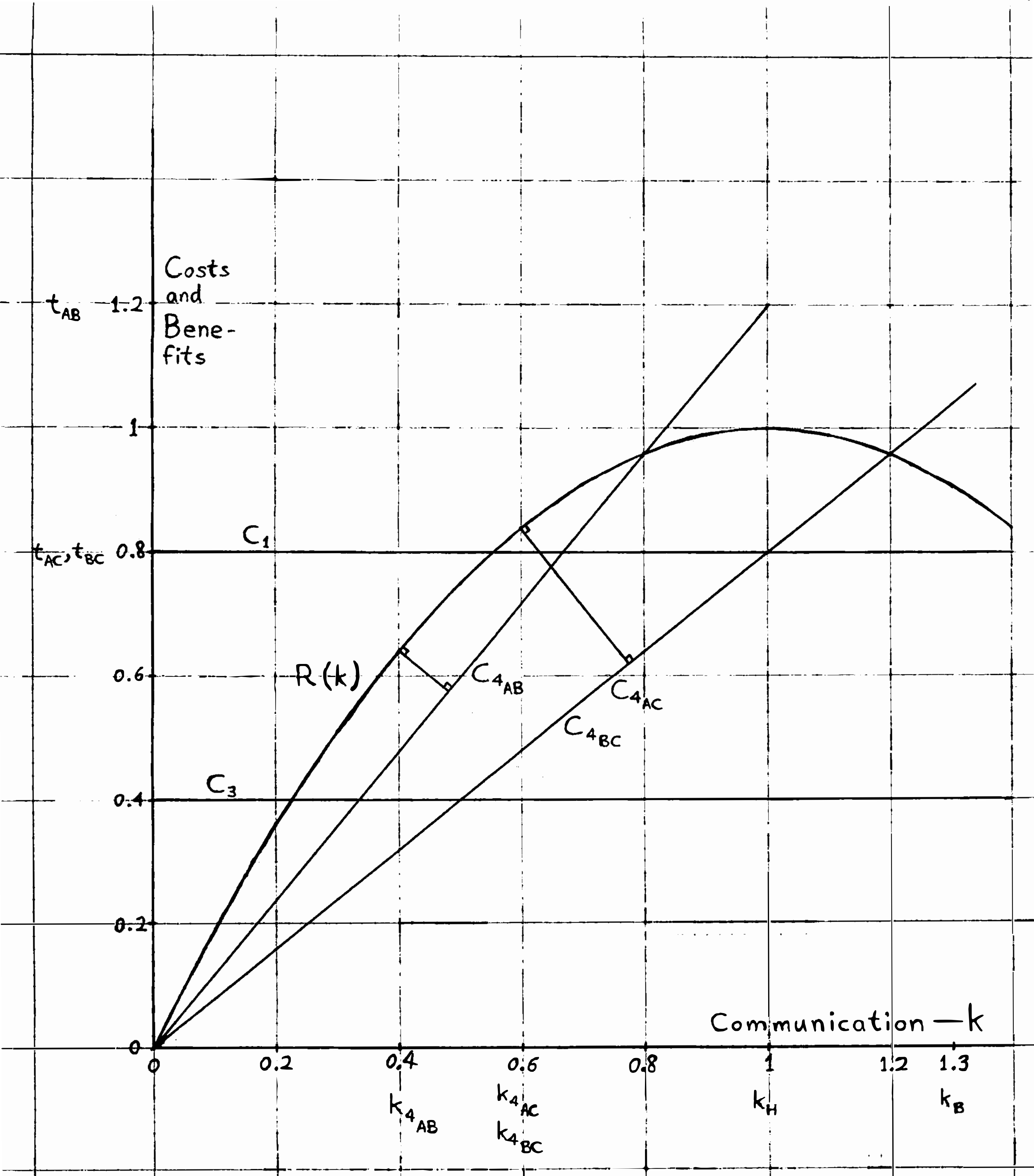


Figure 1. Example of an Individual Decision Situation of Language Diversity

range where $V'_{4_{ij}} = 0$ and, if there is no such k, then at one end of the range.

$$V'_{4_{ij}}(k) = 2 - 2k - t_{ij}$$

When $V'_{4_{ij}}(k) = 0$,

$$k = 1 - \frac{t_{ij}}{2}.$$

Hence $k_{4_{ij}} = 1 - \frac{t_{ij}}{2}$ if $k_L \leq 1 - \frac{t_{ij}}{2} \leq k_H = 1$. In the present case, when this inequality is satisfied,

$$k_{4_{AB}} = 1 - 0.6 = 0.4$$

$$k_{4_{AC}} = 1 - 0.4 = 0.6$$

$$k_{4_{BC}} = 0.6$$

Returning to the condition when B makes decision 3:

$$V_{4_{AB_{max}}} = 0.4 \cdot 0.4 = 0.16$$

$$V_{4_{AC_{max}}} = 0.6 \cdot (2 - 0.6 - 0.8) = 0.36$$

$$V_{5_{max}} = 0$$

<u>If B makes decision 4_{AB}, ordering the translation of 0.3 units of communication</u>:

$$V_{1_{max}} = 0.2$$

* $$V_{4_{AB_{max}}} = 0.4 \cdot 1.6 - 1.2 \cdot 0.1 = 0.52$$

$$V_{4_{BC_{max}}} = 0.6 \cdot 1.4 - 0.8 \cdot 0.3 - 0.4 = 0.2$$

$$V_{5_{max}} = 0.3 \cdot 1.7 = 0.51$$

<u>If B makes decision 4_{BC}, ordering the translation of 0.5 units of communication</u>:

$$V_{1_{max}} = 0.2$$

$$V_{3_{max}} = 0.5 \cdot 1.5 - 0.4 = 0.35$$

$$V_{4_{AB_{max}}} = 0.4 \cdot 0.4 = 0.16$$

$$V_{4_{AC_{max}}} = (k \cdot (1.2 - k))_{max}\Big|_{0 \leq k \leq 0.5}$$

Since this expression attains a local maximum only outside the range and equals 0 at the lower bound of the range, the maximum is reached when k = 0.5. Thus

$$V_{4_{AC_{max}}} = 0.35$$

* $$V_{4_{BC_{max}}} = 0.6 \cdot 1.4 - 0.8 \cdot 0.1 - 0.4 = 0.36$$

$$V_{5_{max}} = 0$$

$$V_{4_{AC+AB_{max}}} = 0.35,$$

which results from the fact that under these conditions any L_A-L_B translation is harmful to A once A has completed the translation bridge (for 0.5k) started by B.

<u>If B makes decision 4_{AC}, ordering the translation of 0.4 units of communication</u>:

$$V_{1_{max}} = 0.2$$

$$V_{3_{max}} = 0.6$$

* $$V_{4_{AC_{max}}} = 0.6 \cdot 1.4 - 0.8 \cdot 0.2 = 0.68$$

$$V_{5_{max}} = 0.4 \cdot 1.6 = 0.64$$

<u>If B makes decision 5</u>:

* $$V_{1_{max}} = 0.2$$

$$V_{4_{AB_{max}}} = 0.4 \cdot 0.4 = 0.16$$

$$V_{4_{BC_{max}}} = 0.6 \cdot 0.6 - 0.4 = -0.04$$

$$V_{5_{max}} = 0$$

The above calculations show that, with the learning and translation costs and A's communication benefit curve as postulated, the 6 decisions of B that have been presented above dictate 6 different rational responses of A. If B learns A's language, A should do nothing. If B learns the third language, A should also learn it. If B buys the services of translators between their two languages to cover 0.3 communication units, A should buy 0.1 unit more of this same kind of translation. If B buys 0.5 communication units of translation between his own language and the third language, A should learn that third language and then buy 0.1 unit more of the same kind of translation. If B learns the third language and buys 0.4 communication units of translation between that language and A's language, A should buy 0.2 more units of such translation. And if B does nothing, A should learn B's language. For ease of reference, the solutions are asterisked above.

This example illustrates the fact that, from the point of view of a single actor maximizing its own benefits in the face of another actor's decision about how to cope with a language barrier between them, there may be no one alternative that is always optimal. What is optimal may depend entirely on what the other actor has decided to do.

The example also illustrates that the actor that first decides what to do may affect the optimum that the other actor is capable of attaining in the face of this decision. In the example, by learning A's language B makes it possible for A to get 1 unit of benefit, while, at the other end, by doing nothing B makes it impossible for A to gain anything above 0.2.

Another thing that B influences by its decision is the total amount of communication that will take place if A responds rationally. In our example, 0.4 units of communication will follow B's decision to translate 0.3 units between L_A and L_B; 0.6 units will take place if B decides to translate 0.5 units between L_B and L_C or to learn L_C and translate 0.4 units between L_A and L_C; and 1 unit will be communicated if B makes any of the other decisions. In general, whenever the partners have by language learning made communication possible without translation, it will then be in their interest to communicate until one of their veto points is reached. No matter how cheap translation is--even if translation provides the optimal solution--the amount of communication that is translated will never be as great as the amount that transpires through learned languages.

The Game Model

In many real situations of linguistic diversity, one actor does not know what decision another has reached. For one thing, they may make their decisions simultaneously. If not, the one which decides first may be uncertain about the decision that will be made by the one which decides later, especially if the former lacks some of the information (e.g., about the other's benefit curve) needed to predict what a rational response would be. In addition, decisions about language (particularly about language learning) generally take years, often decades, to carry out, and this increases the uncertainty about the conditions that will obtain when a decision that is being made today comes into effect. Finally, one may well know what decisions various actors are making about language but be uncertain which of these actors will turn into one's potential communication partners in years to come.

In situations of such uncertainty, the individual decision model presented above becomes inadequate. There are several ways to take uncertainty into account by revising such a model, and I shall attempt only one such modification here. Let us now interpret the problem of responding to linguistic diversity as if our two actors were involved in a game (see Luce and Raiffa, 1957: chs. 1-6).

Our two-person game model of linguistic diversity differs from our individual decision model in a few important ways. We now consider that neither actor, when it makes its decision, knows what the other's decision is going to be. Each actor does, however, know what situation the other is in, including the costs and benefits that the other would incur under every possible condition, though we shall still assume that each actor is motivated to maximize its own net benefit. Given the (logical) simultaneity of their decisions, the actors no longer know what the outcome of each of their own possible decisions will be. Instead, for each decision that one actor makes, there are 6 possible outcomes, depending on which of the 6 possible decisions the other actor makes. For this reason, in choosing an alternative an actor must compare 6 sets of 6 possible outcomes, and the very notion of the "best" decision becomes problematic (e.g., Lave and March, 1975: 140-143).

Since each actor can make any of 6 decisions, there are 36 possible alternatives in the game, and each alternative yields an outcome consisting of 2 quantities: the net benefit to A and the net benefit to B. The set of formulae for these 72 quantities is shown, in the form of a payoff matrix, in Table 1.

Table 1 about here

The formulae for V_A and V_B represent the payoffs to A and B, respectively, if they make the combination of decisions indicated by the row and column headings and once having made these decisions then communicate until the amount of communication reaches A's or B's point of maximum gross (and, since all resources are committed before communication begins, therefore maximum net) benefit. It is important to note that V_B and the quantities shown in the equations for V_B are not comparable with V_A and the quantities in the equations for V_A. Unless otherwise subscripted, all terms refer to the perspective of the actor in whose equations they appear. C_3 is the cost to <u>this</u> actor of learning L_C, for example. The term k_H, as defined earlier, refers to the lesser of 1 or the amount of communication that the other actor permits, i.e. the maximum amount of communication that <u>this</u> actor is able to enjoy if the language barrier has been overcome. All terms referring to the other actor are still expressed in units of <u>this</u> actor's communication scale or cost and benefit scale.

Rather than allowing us to compare what A and B would gain under a given combination of decisions, quantities derived from Table 1 permit us to compare the 36 different benefits that each actor could obtain, depending on what both that actor and the other one decide. In order to turn this information

Table 1

Generalized Payoff Matrix for Game Model

		B					
		2	3	4_{AB}	4_{BC}	4_{AC}	5
A	1	$V_B = R(k_H) - C_2$ $V_A = R(k_H) - C_1$	$V_B = R(k_H) - C_3$ $V_A = R(k_H) - C_1$	$V_B = R(k_H) - C_{4_B}$ $V_A = R(k_H) - C_1$	$V_B = R(k_H) - C_{4_B}$ $V_A = R(k_H) - C_1$	$V_B = R(k_H) - C_{4_B} - C_3$ $V_A = R(k_H) - C_1$	$V_B = R(k_H)$ $V_A = R(k_H) - C_1$
	3	$V_B = R(k_H) - C_2$ $V_A = R(k_H) - C_3$	$V_B = R(k_H) - C_3$ $V_A = R(k_H) - C_3$	$V_B = R(\min(k_{4_B}, k_A)) - C_{4_B}$ $V_A = R(\min(1, k_{4_B})) - C_3$	$V_B = R(\min(k_{4_B}, k_A)) - C_{4_B}$ $V_A = R(\min(1, k_{4_B})) - C_3$	$V_B = R(k_H) - C_{4_B} - C_3$ $V_A = R(k_H) - C_3$	$V_B = 0$ $V_A = -C_3$
	4_{AB}	$V_B = R(k_H) - C_2$ $V_A = R(k_H) - C_{4_A}$	$V_B = R(\min(1, k_{4_A})) - C_3$ $V_A = R(\min(k_{4_A}, k_B)) - C_{4_A}$	$V_B = R(\min(1, k_{4_A} + k_{4_B}, k_A)) - C_{4_B}$ $V_A = R(\min(1, k_{4_A} + k_{4_B}, k_B)) - C_{4_A}$	$V_B = R(\min(1, k_{4_A})) - C_{4_B}$ $V_A = R(\min(k_{4_A}, k_B)) - C_{4_A}$	$V_B = R(\min(1, k_{4_A} + k_{4_B}, k_A)) - C_{4_B} - C_3$ $V_A = R(\min(1, k_{4_A} + k_{4_B}, k_B)) - C_{4_A}$	$V_B = R(\min(1, k_{4_A}))$ $V_A = R(\min(k_{4_A}, k_B)) - C_{4_A}$
	4_{AC}	$V_B = R(k_H) - C_2$ $V_A = R(k_H) - C_{4_A}$	$V_B = R(\min(1, k_{4_A})) - C_3$ $V_A = R(\min(k_{4_A}, k_B)) - C_{4_A}$	$V_B = R(\min(k_{4_B}, k_A)) - C_{4_B}$ $V_A = R(\min(1, k_{4_B})) - C_{4_B}$	$V_B = R(\min(k_{4_B}, k_{4_A})) - C_{4_B}$ $V_A = R(\min(k_{4_A}, k_{4_B})) - C_{4_A}$	$V_B = R(\min(1, k_{4_A} + k_{4_B}, k_A)) - C_{4_B} - C_3$ $V_A = R(\min(1, k_{4_A} + k_{4_B}, k_B)) - C_{4_A}$	$V_B = 0$ $V_A = -C_{4_A}$
	4_{BC}	$V_B = R(k_H) - C_2$ $V_A = R(k_H) - C_{4_A} - C_3$	$V_B = R(k_H) - C_3$ $V_A = R(k_H) - C_{4_A} - C_3$	$V_B = R(\min(1, k_{4_A} + k_{4_B}, k_A)) - C_{4_B}$ $V_A = R(\min(1, k_{4_A} + k_{4_B}, k_B)) - C_{4_A} - C_3$	$V_B = R(\min(1, k_{4_A} + k_{4_B}, k_A)) - C_{4_B}$ $V_A = R(\min(1, k_{4_A} + k_{4_B}, k_B)) - C_{4_A} - C_3$	$V_B = R(k_H) - C_{4_B} - C_3$ $V_A = R(k_H) - C_{4_A} - C_3$	$V_B = R(\min(1, k_{4_A}))$ $V_A = R(\min(k_{4_A}, k_B)) - C_{4_A} - C_3$
	5	$V_B = R(k_H) - C_2$ $V_A = R(k_H)$	$V_B = -C_3$ $V_A = 0$	$V_B = R(\min(k_{4_B}, k_A)) - C_{4_B}$ $V_A = R(\min(1, k_{4_B}))$	$V_B = -C_{4_B}$ $V_A = 0$	$V_B = R(\min(k_{4_B}, k_A)) - C_{4_B} - C_3$ $V_A = R(\min(1, k_{4_B}))$	$V_B = 0$ $V_A = 0$

into a solution for the game, we must define what "solution" means. There are several different ideas about this question, however, which depend in part on the further assumptions one makes about how the game is played, e.g. whether the actors are allowed to discuss the game before making their decisions, whether they are allowed to obligate themselves to give valuables to each other as a way of inducing each other to make certain decisions, and whether they play the game once or repeatedly (Luce and Raiffa, 1957: chs. 5, 6). The information in Table 1, then, does not provide a solution; it permits finding the solution (or finding that there is no solution) once one has defined one's solution concept.

A Game Example

Let us illustrate some of these problems with another example. This time we shall see what happens if: (1) the actors are collectivities rather than individuals; and (2) some claims about large differences in the learning and translation costs of different languages are assumed to be true.

Our society contains two monolingual speech communities with 1,000 members each. The average member lives 600,000 hours (about 69 years), and the average lifetime income (earned at the rate of $3 per hour for 40 years) is $240,000. Communication across group boundaries to the optimal extent--30,000 hours per person--would increase the welfare of the average citizen by 10 percent of the average lifetime income, i.e. $24,000. Learning the other group's language would take the average person 2 years of full-time work and exact an opportunity cost of $12,000.

According to several studies on artificial languages, communicative competence can be achieved in them in about 1/3 to 1/15 as much time as the same competence in natural languages (Janton, 1973: 118; Markarian, 1963: 6; Rakuša, 1970: 38-39). If this is true for the society in question, let us say (somewhat conservatively) that there is an L_C which can be learned at an opportunity cost of \$2,400, i.e. in 1/5 the time of L_A or L_B.

Translators between L_A and L_B in our society are paid \$5 per hour of translated communication, but a large proportion of all translated material has group or mass audiences, which substantially reduces the per-capita average cost of translation. Let us (for subsequent ease of calculation) say that the resulting rate is \$1.28 per hour, or \$38,400 for 1 k. Since it is less expensive to train translator manpower for languages that are less expensive to learn, we shall assume that translation between L_C and either of the other languages costs 1/4 less, i.e. \$28,800 per k (cf. United Nations, 1977). These assumptions yield the following constants, required to use the formulae in Table 1:

$$C_1 = 0.5$$
$$C_2 = 0.5$$
$$C_3 = 0.1$$
$$t_{AB} = 1.6$$
$$t_{AC} = t_{BC} = 1.2$$

To these we add the assumption that for each actor $R(k) = k \cdot (2 - k)$. Hence $k_H = 1$ in both cases.

In contrast to the individual decision model, both actors here must commit themselves to a definite expenditure whenever they make a decision involving translation. In principle we could consider every amount of translation commitment to constitute a distinct alternative, in which case each actor would have an infinity of possible decisions instead of only 6. For the sake of simplicity, however, let us assume that in such cases each actor always decides to pay for the translation of whatever amount of communication will provide it with the greatest net benefit if the translation ordered by that actor turns out to be necessary and sufficient for all communication, given the other actor's decision. Since $k_{4_{ij}} = 1 - \frac{t_{ij}}{2}$,

$$\left.\begin{aligned} k_{4_{ij}} &= 0.2 \\ C_4 &= 0.32 \end{aligned}\right\} \text{ when } t_{ij} = 1.6$$

$$\left.\begin{aligned} k_{4_{ij}} &= 0.4 \\ C_4 &= 0.48 \end{aligned}\right\} \text{ when } t_{ij} = 1.2$$

Making use of these assumptions and assuming further that all 1,000 members of a given speech community must act in unison, we turn Table 1 into the payoff matrix shown in Table 2.

Table 2 about here

Of the 36 decision combinations in this matrix, 3 are "equilibrium pairs": neither actor can benefit by changing from such an alternative to any of the other 5 alternatives that it has the power to move the game to singlehandedly. The 3 equilibrium pairs are (A_1, B_5), (A_5, B_2), and (A_3, B_3). These appear to be attractive possible solutions, since if the actors were alternately making tentative choices and jockeyed into any one of these positions, any further movement by either actor would decrease its own payoff.

On the other hand, it is not clear which of the 3 equilibrium pairs, if any, would be reached by two profit-oriented actors in this game. Each is assumed to prefer most of all the alternative that allows it to sit

Table 2

Payoff Matrix for Game Example

A \ B	2	3	4_{AB}	4_{BC}	4_{AC}	5
1	$V_B = 0.5$ $V_A = 0.5$	$V_B = 0.9$ $V_A = 0.5$	$V_B = 0.68$ $V_A = 0.5$	$V_B = 0.52$ $V_A = 0.5$	$V_B = 0.42$ $V_A = 0.5$	$V_B = 1$ $V_A = 0.5$
3	$V_B = 0.5$ $V_A = 0.9$	$V_B = 0.9$ $V_A = 0.9$	$V_B = 0.04$ $V_A = 0.26$	$V_B = 0.16$ $V_A = 0.54$	$V_B = 0.42$ $V_A = 0.9$	$V_B = 0$ $V_A = -0.1$
4_{AB}	$V_B = 0.5$ $V_A = 0.68$	$V_B = 0.26$ $V_A = 0.04$	$V_B = 0.32$ $V_A = 0.32$	$V_B = -0.12$ $V_A = 0.04$	$V_B = 0.26$ $V_A = 0.52$	$V_B = 0.36$ $V_A = 0.04$
4_{AC}	$V_B = 0.5$ $V_A = 0.52$	$V_B = 0.54$ $V_A = 0.16$	$V_B = 0.04$ $V_A = -0.12$	$V_B = 0.16$ $V_A = 0.16$	$V_B = 0.38$ $V_A = 0.48$	$V_B = 0$ $V_A = -0.48$
4_{BC}	$V_B = 0.5$ $V_A = 0.42$	$V_B = 0.9$ $V_A = 0.42$	$V_B = 0.52$ $V_A = 0.26$	$V_B = 0.48$ $V_A = 0.38$	$V_B = 0.42$ $V_A = 0.42$	$V_B = 0.64$ $V_A = 0.06$
5	$V_B = 0.5$ $V_A = 1$	$V_B = -0.1$ $V_A = 0$	$V_B = 0.04$ $V_A = 0.36$	$V_B = -0.48$ $V_A = 0$	$V_B = 0.06$ $V_A = 0.64$	$V_B = 0$ $V_A = 0$

back while the other actor learns its language. If one actor is in some sense more powerful than the other, the former may be able to make the latter accept this alternative. If A and B both consider making decision 5, but one succeeds in convincing the other that it will stick with this intention, then the former can compel the latter, if rational, to abandon its intention and move to decision 1 or 2, the best under the circumstances. If the actors are of roughly equal power, we might expect them either to call each other's bluff and end the game winning nothing at (A_5, B_5), or to agree on the third equilibrium pair (A_3, B_3). The latter would be especially likely if pre-game bargains were enforceable, since even a less powerful actor could profitably agree to compensate the other for the loss of 0.1 in moving from (A_5, B_2) or (A_1, B_5) to (A_3, B_3).

More realistically, however, the actors are likely to be unable to make any enforceable bargains and unable to rely confidently on assumptions about each other's strategic thinking. In this case decisions 3 and 5, while they are each actor's contribution to that actor's 2 most preferred alternatives, are also components of that same actor's 2 worst alternatives, if we limit our attention to the 3 columns containing the equilibrium pairs, as Table 3 makes clearer. There is an obvious trade-off here:

Table 3 about here

the greater one's best possible outcome, the greater the chance of obtaining a zero or negative outcome instead. Two actors, each distrustful of the other and therefore insistent on the decision whose worst possible benefit is as large as possible, would bring about the alternative (A_1, B_2), which is worse for both actors than (A_3, B_3) and is thus not even an equilibrium pair.

Table 3

Partial Payoff Matrix for Game Example

		B: 2	B: 3	B: 5
A	1	$V_B = 0.5$ $V_A = 0.5$	$V_B = 0.9$ $V_A = 0.5$	$V_B = 1$ $V_A = 0.5$
A	3	$V_B = 0.5$ $V_A = 0.9$	$V_B = 0.9$ $V_A = 0.9$	$V_B = 0$ $V_A = -0.1$
A	5	$V_B = 0.5$ $V_A = 1$	$V_B = -0.1$ $V_A = 0$	$V_B = 0$ $V_A = 0$

Mixed strategies, i.e. decisions to select randomly among one's possible decisions, are sometimes able to guarantee greater minimal benefits than pure strategies such as these. This is not so here, however, because of the invariant payoff of 0.5 that will always accompany a decision of 1 or 2. Furthermore, the fact that decisions to learn a language are practically irrevocable makes the notion of iterative play and hence randomization of decisions seem inappropriate. But what about another kind of "mixed" decision, namely a decision by the speech community that some but not all of its members shall learn a certain language and perform translations for all the rest? This question deserves a separate analysis, since a new set of assumptions is required. In particular, it would seem that the cost of training translators is already reflected in the price of their services, so any decision by a speech community to delegate some of its members as translators either would be coercive or, if these individuals had to be economically induced to change roles, would be no more profitable to the speech community than the use of existing translation services. If, however, one assumed that member-translators derive some benefit from the very communications that they are translating while professional translators must rely wholly on other compensation, then a decision of this sort might well have advantages.

The Social Welfare Model

The previous discussion suggests that in some circumstances rational actors will make different decisions about language learning and translation, engage in different amounts of communication, and derive different benefits if they are able to make binding agreements than if they can not trust each other to behave as promised. Whenever an authority is empowered to enforce agreements, however, the possibility arises that it will attempt to go beyond this limited competence and actually make the decisions itself. Indeed, governments often make decisions about whether and how the actors under their jurisdiction shall overcome the language barriers that separate them (Québec, in press). These decisions can be justified by the claim that the decision-makers are legitimate representatives of the actors; that such decisions save the actors the costs of arriving at bargains; that authoritative decisions can counteract inequitable power differences between the actors; etc.

Let us assume that a decision-maker authorized to choose one of the 36 alternatives presented above wishes to do so in some way that reflects the preferences of the two actors and, to the extent that these conflict, also reflects the authority's evaluation of which actor's preferences are more important and how close to equality the two actors' benefits should be. How should the authority proceed?

The first step can be to eliminate from consideration those alternatives that are clearly inferior to other alternatives. We may thus ignore all "jointly inadmissable" alternatives, i.e. those to which both actors prefer the same other alternative. Further, we can assume that any translation that is ordered should be carried out the cheapest possible way, which must eliminate from consideration any alternatives that involve translation between two different pairs of languages, except for bridge translation.

Inspection of Table 1 reveals that 5 alternatives can be eliminated on the latter basis, and that 17 more are jointly inadmissable. An additional 6 alternatives, which involve translation by one actor only, can be considered special cases of others which provide for translation by both, since the authority in any case will decide how much translation to order and then how to divide the cost between the two actors.

These eliminations leave the authority with only 8 alternatives:

	A	B
1.	1	5
2.	3	3
3.	4_{AB}	4_{AB}
4.	4_{AC}	4_{BC}
5.	4_{AC}	4_{AC}
6.	4_{BC}	4_{BC}
7.	5	2
8.	5	5

For the first time, we now want A and B to adopt commensurable scales of communication and of costs and benefits. The criteria of commensurability are that (1) a given amount of communication has the same k on both scales, and (2) translating 1 k of communication between the same pair of languages costs the same t_{ij} on both scales. If p_1 = the proportion of the cost of any translation that is paid by A, and $1 - p_1 = p_2$ = the proportion paid by B, then the net benefits to A and B from these 8 alternatives are as follows:

<u>Alternative 1</u>

$$V_A(k) = R_A(k) - C_1$$

$$V_B(k) = R_B(k)$$

<u>Alternative 2</u>

$$V_A(k) = R_A(k) - C_{3_A}$$

$$V_B(k) = R_B(k) - C_{3_B}$$

<u>Alternative 3</u>

$$V_A(k) = R_A(k) - p_1 t_{AB} k$$

$$V_B(k) = R_B(k) - p_2 t_{AB} k$$

Alternative 4

$$V_A(k) = R_A(k) - p_1 \cdot (t_{AC} + t_{BC})k$$

$$V_B(k) = R_B(k) - p_2 \cdot (t_{AC} + t_{BC})k$$

Alternative 5

$$V_A(k) = R_A(k) - p_1 t_{AC} k$$

$$V_B(k) = R_B(k) - C_{3_B} - p_2 t_{AC} k$$

Alternative 6

$$V_A(k) = R_A(k) - C_{3_A} - p_1 t_{BC} k$$

$$V_B(k) = R_B(k) - p_2 t_{BC} k$$

Alternative 7

$$V_A(k) = R_A(k)$$

$$V_B(k) = R_B(k) - C_2$$

Alternative 8

$$V_A(k) = 0$$

$$V_B(k) = 0$$

A Social Welfare Example

Let us consider the authority's decision problem when the two actors are rich and poor, respectively, in resources. Typically, in such a case, once the scales of value have been standardized around the cost of translation, it will be more costly for the rich actor to learn a language than for the poor actor to learn the same language, because the opportunity cost in monetary terms for a given expenditure of time rises with wealth.[5] In addition, popular attitudes toward intergroup communication, at least in non-revolutionary situations, would lead us to assume that the poor actor perceives greater value in communication with the rich one then vice versa (Haugen, 1966: 168; Social Research Group, 1965: Questions 210, 218, 240, 252).[6]

As an example reflecting these assumptions, consider the case where

$$C_1 = 0.6$$

$$C_2 = 0.3$$

$$C_{3_A} = 0.2$$

$$C_{3_B} = 0.1$$

$$t_{AB} = 1.6$$

$$t_{AC} = t_{BC} = 1.2$$

$$R_A(k) = 2k \cdot (1 - k)$$

$$R_B(k) = k \cdot (2 - k)$$

$$k_A = 0.5$$

$$k_B = 1$$

Figure 2 presents this situation graphically. The authority has an infinity

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Figure 2 about here

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of social welfare functions to choose from, but probably the simplest is one which just adds A's and B's benefits together and subtracts their costs, using the t_{ij}-commensurated scales. Such a function permits the authority to postpone the decision on how to divide the cost of translation, together with other decisions about transfer payments, until after the selection of one of the 8 alternatives. If, then, the social welfare function is

$$V_S(k) = V_A(k) + V_B(k)$$

the authority computes V_S and $V_{S_{max}}$ for each of the 8 alternatives:

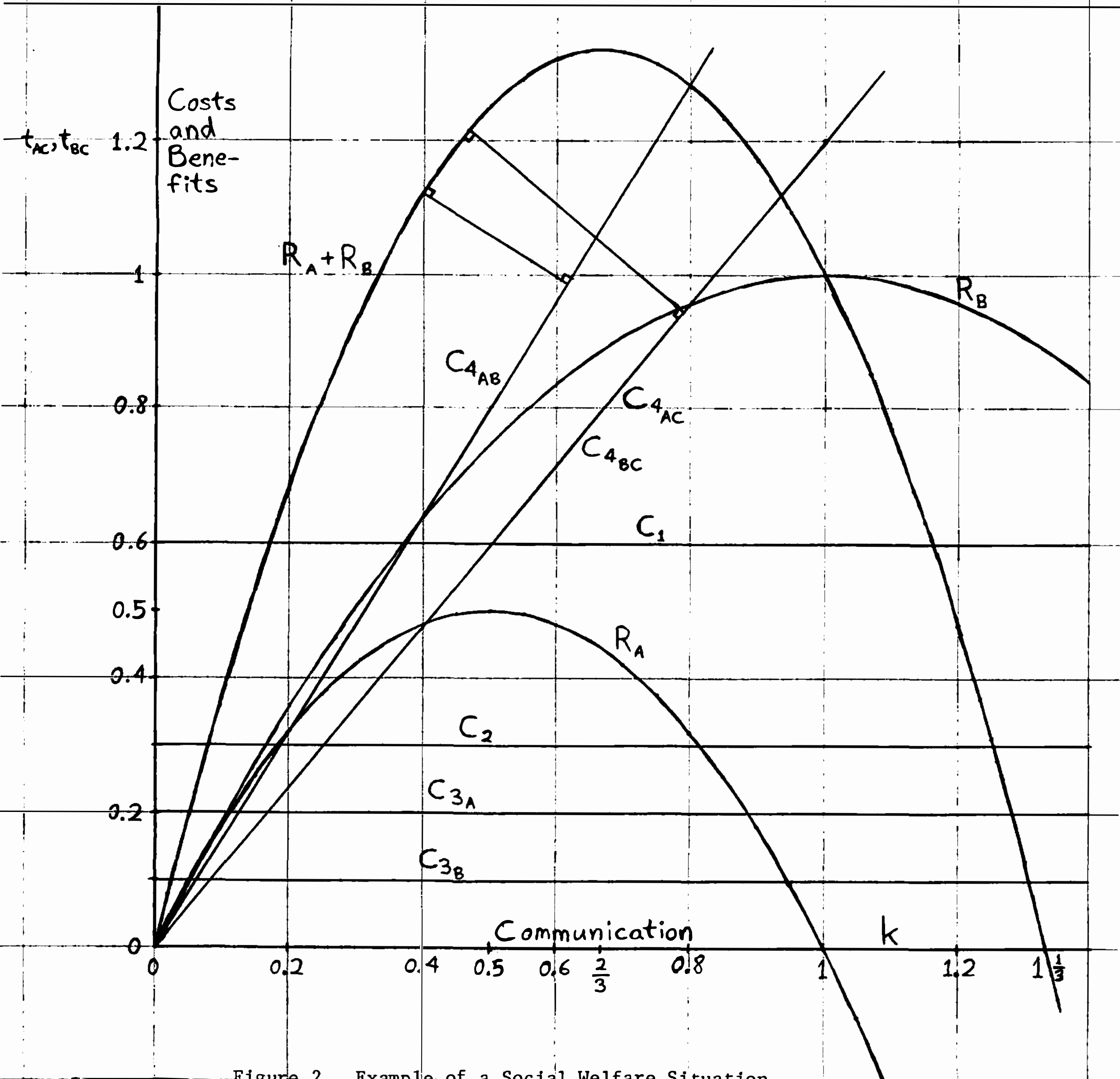

Figure 2. Example of a Social Welfare Situation of Language Diversity

Alternative 1

$$V_S(k) = R_A(k) + R_B(k) - C_1 = 2k \cdot (1 - k) + k \cdot (2 - k)$$

$$- 0.6 = 4k - 3k^2 - 0.6$$

$$V_S'(k) = 4 - 6k$$

$$V_{S_{max}} = V_S(\tfrac{2}{3}) = \frac{8}{3} - \frac{12}{9} - 0.6 = 0.7333\tfrac{1}{3}$$

Alternative 2

$$V_S(k) = 4k - 3k^2 - 0.3$$

$$V_S'(k) = 4 - 6k$$

$$V_{S_{max}} = V_S(\tfrac{2}{3}) = 1.0333\tfrac{1}{3}$$

Alternative 3

$$V_S(k) = 4k - 3k^2 - 1.6k = 2.4k - 3k^2$$

$$V_S'(k) = 2.4 - 6k$$

$$V_{S_{max}} = V_S(0.4) = 0.96 - 0.48 = 0.48$$

Alternative 4

$$V_S(k) = 4k - 3k^2 - 2.4k = 1.6k - 3k^2$$

$$V_S'(k) = 1.6 - 6k$$

$$V_{S_{max}} = V_S(\tfrac{4}{15}) = \frac{6.4}{15} - \frac{48}{225} = 0.2133\tfrac{1}{3}$$

Alternative 5

$$V_S(k) = 4k - 3k^2 - 1.2k - 0.1 = 2.8k - 3k^2 - 0.1$$

$$V_S'(k) = 2.8 - 6k$$

$$V_{S_{max}} = V_S(\tfrac{7}{15}) = \frac{19.6}{15} - \frac{147}{225} - 0.1 = 0.5533\tfrac{1}{3}$$

Alternative 6

$V_S(k) = 4k - 3k^2 - 1.2k - 0.2 = 2.8k - 3k^2 - 0.2$

$V_S'(k) = 2.8 - 6k$

$V_{S_{max}} = V_S(\frac{7}{15}) = 0.4533\frac{1}{3}$

Alternative 7

$V_S(k) = 4k - 3k^2 - 0.3$

$V_S'(k) = 4 - 6k$

$V_{S_{max}} = V_S(\frac{2}{3}) = 1.0333\frac{1}{3}$

Alternative 8

$V_{S_{max}} = V_S(0) = 0$

Comparing the 8 values for $V_{S_{max}}$, the authority finds in this example that two different alternatives (2 and 7) equally maximize the social welfare function: A and B can learn L_C or B can learn L_A. These alternatives eliminate the need to translate and therefore no decision on allocating translation costs is necessary. But the problem of compensation is not eliminated, since if left to their own devices A and B will not communicate to the extent ($\frac{2}{3}k$) that maximizes the function. A's veto point, k_A, is 0.5. If A exercises its veto, V_S will attain a value of 0.95 rather than $1.0333\frac{1}{3}$. In expanding their communication from 0.5k to $\frac{2}{3}k$, A would lose $\frac{2}{36}$ and B would gain $\frac{5}{36}$ in benefits. Thus it is in the interest of both parties for the authority to exact from B and transfer to A a communications tax greater than $\frac{2}{36}$ and less than $\frac{5}{36}$ for their increase in communication from $\frac{1}{2}k$ to $\frac{2}{3}k$, since this transfer will induce A to withhold its veto.

Implementing such a transfer payment, is the authority still indifferent between alternatives 2 and 7? If we assume that the transfer is 0.1, then the alternatives affect A and B in the following ways:

<u>Alternative 2</u>

$$V_A = \frac{4}{3} \cdot \frac{1}{3} - 0.2 + 0.1 = 0.3444\frac{2}{5}$$

$$V_B = \frac{2}{3} \cdot \frac{4}{3} - 0.1 - 0.1 = 0.6888\frac{4}{5} = 2V_A$$

<u>Alternative 7</u>

$$V_A = \frac{4}{9} + 0.1 = 0.5444\frac{2}{5}$$

$$V_B = \frac{8}{9} - 0.3 - 0.1 = 0.4888\frac{4}{5}$$

Evidently, A, the rich actor, much prefers alternative 7 in which B learns L_A, since this gives A more benefits than it gives B and also more than alternative 2 would have given A. B, on the contrary, prefers alternative 2, in which both actors learn L_C, since this gives B twice the benefits that it gives A and more than B would have received under alternative 7. If the authority prefers the alternative that minimizes the discrepancy in benefits between A and B, then 7 is the solution. If, on the other hand, the authority prefers the alternative that most transfers resources from the rich to the poor, then the solution is alternative 2. And to the extent that such considerations are part of the authority's social welfare function, the solution may turn out to be one of the alternatives that do not maximize the sum of A's and B's benefits.

In effect, choosing between such alternatives as these constitutes a kind of ethnic taxation policy. Ethnicity taxes are an obvious way to redistribute wealth without lowering incentivesto produce. Overt ethnicity taxes, however, whether they take the form of transfer payments or "Affirmative Action" programs, are widely resisted as illegitimate by those so taxed. Since language policies are, on the contrary, widely regarded as necessary and the different treatments that they subject different groups to are seen as inevitable and therefore legitimate (Van Dyke, 1976), there may be some opportunities for the efficient alteration of ethnically related wealth differences in the course of selection among alternative public policies regarding language. Currently, however, the discussions of costs and benefits in language policy often ignore certain dimensions of the problem, and conclusions that this or that policy would be "prohibitively expensive" are drawn without the benefit of comparisons between it and the major alternatives, and without consideration of the costs to the citizenry as well as to the government (e.g., van den Berghe, 1968: 222-223).

Conclusion

Whether decisions about language learning and translation investment are being made by one actor after the other's decision is already known, made by both actors without knowledge of each other's choices, or made by an authority that can coordinate the behavior of the two actors, we have seen that rational solutions can be derived for the problem of linguistic diversity. These require defining the function which is to be maximized, calculating the relevant costs and benefits, and determining what amount of communication will yield the greatest benefit under each of the possible alternatives. What is rational for one actor may depend entirely on what the other has decided to do. If they are making simultaneous decisions, the alternatives they select may be affected by their ability to trust or obligate each other to behave as expected or promised. If a third party is making authoritative decisions for them, these may have redistributive consequences as well as effects on efficiency. In all cases, the alternative solutions affect interests differently not just by conferring different benefits when communication takes place but also by making different quantities of communication optimal. Thus the desire for communication affects the solution chosen, but the solution chosen also affects the desire for communication.

The notions of "rationality" and "solution" should not be misunderstood, however, to suggest that situations of language diversity constitute merely technical rather than political problems. The fact that different people speak different languages clearly puts them into a fundamental conflict of interest. Even if they would both benefit from communication, they would not equally benefit from the various methods of making communication possible. The substantial cost of learning non-native languages is an ever-present factor that makes situations of linguistic diversity inevitably competitive. At the same time, the fact that some languages can be learned and translated more easily than others gives an element of common interest to those separated by language barriers, rendering their situation non-strictly, i.e. only partly, competitive.

A much broader class of models can be built by relaxing various assumptions. For example, benefits may accrue to A and B not merely as a result of communication with each other but also as a consequence of the language in which it takes place. Reasons for such differentials would include the greater effort to communicate in one's second language, the phenomenon of linguistic pride, and the greater efficiency of some languages than others for communication in certain domains. Benefits could also be posited for the mere fact of knowing another language, although these can be considered to have been incorporated (by subtraction) into the language learning costs used in the models of this study. A second complication could be to allow communication benefit curves that are not single-peaked. Language learning could also be treated as a gradual process, the cost of communication could vary with the degree of second-language competence possessed by the actor in question, and the cost of each additional unit of language learning could vary with the amount of communication experienced during the learning period. The resulting model would be expected to show that it is optimal to learn a language partially but not perfectly (cf. Traunmüller, n.d.: 11). New uncertainties could be introduced into the model, e.g. as to the veto point of the other actor. The number of third languages could be increased beyond 1, and, of course, the number of actors could be made greater than 2.

In applying such models to the real world one can add whatever complexities are fundamental enough to deserve inclusion. Thus their oversimplification should not be considered an inherent defect of rational decision models as applied to problems of language policy. The more basic query is whether language attitudes, language behavior, and language politics are essentially irrational. This is a possibility that I shall not examine further here. It is appropriate, however, to note that language policies are often justified through the invocation of rationalistic "principles" and the derivation of "language needs" from observed circumstances (Canada, 1977; Pool, 1976; Pool, 1978; Van Els, 1978). Formal models can help us evaluate whether these "principles" and "needs" have any policy implications and, if so, how closely the policies they imply come to the policies that are in effect. In some (e.g., commercial) situations the actors appear genuinely interested in calculating optimal solutions, and such models can help them. Even if some known considerations are left out of the model being used for the sake of simplicity, the model's implications can be useful whenever they can be assumed to be conservative in light of what has been omitted.

It should, finally, be remembered that not only policy-makers and planners are capable of making rational decisions about language. As mentioned at the beginning of this study, recent research in sociolinguistics suggests that mass language behaviors formerly regarded as harmful to those that exhibit them, such as the failure of members of linguistic and dialectal minorities to learn and use the standard pronunciation of the majority language, may in fact be rational responses to the incentives in the actors' environments. Thus the modeling of rational decisions among alternatives, as yet hardly tried in the study of language policy, may be particularly suited to that arena if the same approach helps us predict individual responses to the linguistic incentives that policy-makers are able to provide.

NOTES

1. Presented at the 5th International Congress of Applied Linguistics, Montréal, August, 1978. This is a revised version of "Modeloj por solvi la lingvan problemon", presented at the 31st Internacia Somera Universitato, Varna, Bulgaria, July-August, 1978.

2. If A and B both order translation, they are assumed to coordinate, if necessary, so they use these services non-redundantly.

3. The last 4 in each list are excluded because they could not be part of any of the 8 minimal methods of achieving communication or non-communication described earlier. 4_{ACB} is excluded because whenever it is preferable to 4_{AB} we can assume the translation market will provide A-B translation in a two-step process through L_C, and that the price of A-B translation will thus equal the sum of A-C and B-C translation. Finally, 4_{BC_T} and 4_{AC_T} are excluded because they seem unlikely to be preferred to 4_{AC} and 4_{BC}, respectively. The latter allow the other actor two ways of complementing them (learning or translation) rather than just one (translation), and, as soon as our assumption of an isolated dyadic system is relaxed, they are also of possible use for communication with additional actors, while the former decisions are not. I am not, however, claiming that a rational actor would never make one of the six excluded decisions. At least for strategic reasons some of them could be attractive under certain conditions.

4. "A knows" refers to the post-decision situation.

5. I am ignoring the possible positive association between wealth and language-learning-conducive skills, which would counteract this difference.

6. There are, however, kinds of communication, e.g. advertizing, for which the opposite order often seems to hold.

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