Productivity, Social Interaction and Communication

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1 Introduction

People spend most of their time at the workplace communicating. Their ability to do so efficiently must have a large influence on productivity. In this paper, we study how, depending on the sociological and technological characteristics of the economy, a "unified" or, on the contrary, a stratified way of communicating may emerge. Communication takes place less efficiently in the stratified case, because people who speak different languages cannot communicate with each other.

The model has various levels of interpretation. At the most literal level, "stratification" means that people from different communities speak different languages, and the paper captures how ethnic and social stratification generates several languages in equilibrium, with a negative feedback effect on productivity. At a most metaphorical level, people may speak the same language but use it so differently than communication is difficult. People from different social and regional backgrounds may have trouble communicating with each other even though they use the same language.

In the paper we identify two forces which lead to a "unified" language : social mobility, by which I mean that people from different "groups" or "communities" have frequent interactions with each other outside the workplace; and technological standardization, which favors the development of a specialized jargon at the workplace. Technological standardization avoids

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the adverse effects on productivity of linguistic stratification, and increases the tendency towards a homogeneous communication system. It is shown that an increase in "flexibility", meaning a less specialized, less standardized technology, will have adverse effects on productivity if society is too socially stratified.

While the points made in this paper are to my knowledge quite novel, this is not the first paper to deal with the language from an economic point of view[1]. In particular, our results are congruent with Lazear (1999), who studies the link between cultural and linguistic assimilation, and the relative size of communities, concluding that it is in the interests of native citizens to encourage diverse cultural immigration over concentrated one (a related analysis can be found in Grin (1992), Saint-Paul (1995), and Bisin and Verdier (2001)). The endogeneity of language which is a characteristic of the present paper is also shared by Blume (2000), while its costs and benefits play a role in Sussman's (1998) analysis, where he discusses implications for contract theory. An empirical literature studies how language skills are related to earnings; it is beyond the scope of this paper to review it[2], but the model can provide theoretical foundations for these regularities. Especially, the link between social stratification and linguistic stratification analysed here, with its adverse implications for productivity, is empirically documented in Chiswick and Miller (1996).

The paper is organized as follows: we first discuss the welfare economics of the language. We then set up a general model and apply it to examples which allows to analyze whether or not there will be linguistic stratification in equilibrium, and to perform the welfare analysis of these equilibria.

2 Welfare aspects of the language

There are two reasons to believe that communication is not being carried efficiently. First, the language is associated with a *thin market externality*. Second, there is a *network externality*.

The thin market externality is due to the fact that when learning, say, the meaning of a word, I do not take into account the fact that the welfare of all people who know it and with whom I will communicate increases. This argument is also valid, incidentally, for all objects that can be considered as inputs into the communication process, such as culture, education, etc. The thin market externality implies that in equilibrium, people will be undereducated; literacy is suboptimally low because an individual has no incentive to use a word that nobody else uses, no matter how useful, concise and potent may the word be.

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[1] Earlier work goes back to Neale (1982), Abrams (1983), and Lang (1986)

[2] Examples include Bellante and Kogut (1998) and Grin and Sfreddo (1998).

The thin market externality refers to how intensively a pre-existing language is used. Which language is used is in turn subject to a network externality (the well known economics of QWERTY, as analyzed by David (1985)). The language is a particular mapping from signs to meanings which must be accepted by all the members of a given linguistic community. No single individual can unilaterally shift to another set of conventions. Because of this coordination failure, inefficiencies in the language may persist (as do inefficient conventions such as QWERTY). For example the French use *soixante-dix, quatre-vingt* and *quatre-vingt dix* for *seventy, eighty* and *ninety* (literally *sixty-ten, four-twenty* and *four-twenty-ten*) instead of the much more logical and easy to learn *septante, octante* and *nonante* (the strict equivalents of *seventy*, etc.) that are typically used by the French speaking Belgians, Swiss and Canadians. Thus there is a potential role for centralized institutions aimed at clarifying and standardizing the language, as is the role of the *Académie Française*, for example (although we are disappointed that it has not yet imposed the use of *septante, octante* and *nonante).*

Also, these externalities explain why too many languages may coexist in equilibrium, thus reducing communication possibilities (this does not imply that a single language is optimal; it depends on people's culture and physical characteristics).

To highlight the role of the network externality, let us set up a model which will then be extended to embody sociological aspects. As will be clear, this model is similar in many respect to the Diamond (1982) model of thin market externalities.

People live two periods. In the first period of their life, they rationally learn the language. Then they match randomly and comunicate. Communication is formalized as the exchange of a message m between the two individuals. This message is drawn randomly from the set of possible messages with probability $\phi(m)$. Communication is successful if both parties know how to exchange this message; that is, if they both have learned the "sign" s which conveys the message. In this case each individual derives a utility $y(m)$ from communication. If one of the two individuals does not know s, then communication is unsuccessful and utility is 0 for both parties. The language is then defined as a mapping from the set of signs to the set of messages which gives a meaning to each sign. In the first period, individuals decide how many signs they learn. The cost of learning a sign, in terms of utility, is $c(s) + \varepsilon$, where ε is an individual specific cost. We assume ε is distributed among individuals with density f. This implies that (i) the ranking of signs in terms of difficulty to learn is the same across individuals, and (ii) the cost of learning a sign is specific to the sign, irrespective of its meaning. This is a simplification which is meant to highlight the conventional aspect of the language. More generally we could assume that the cost depends on both the sign and the meaning, and try to formalize the intermediary notion of a "concept", which is probably more relevant. To analyze the thin market externality, this assumption does not matter since we start postulating a mapping from s to m (we will call $h(m)$ the sign whose meaning is m).

Accordingly we can ignore the distinction between a sign and its meaning; given the language, learning a sign is like learning its meaning.

How is optimal learning determined? Let $\pi(m)$ be the proportion of people who know m. Then expected utility from knowing m is clearly equal to $\pi(m)y(m)\phi(m)$, while the individual cost is $c(h(m))+\varepsilon$. Thus, the individual will learn $h(m)$ if and only if:

$$\pi(m)y(m)\phi(m) - c(h(m)) = \varepsilon^* > \varepsilon \tag{1}$$

We can already see the thin market externality in the fact that expected utility depends on the probability of matching with a person who also knows m. The equilibrium value of $\pi(m)$ must then satisfy the following equation:

$$F[\phi(m)y(m)\pi(m) - c(h(m))] = \pi(m) \tag{2}$$

Readers familiar with search theory already have recognized the standard analysis of a thin market externality (Diamond, 1982). Equation (2) may have multiple solutions: high-literacy equilibria may co-exist with low-literacy equilibria. One equilibrium is one where message m is never exchanged. Equilibria are Pareto-rankable, with the high literacy ones dominating the low literacy ones (as in Cooper and John (1988)). Even the highest equilibrium has a suboptimally low literacy level. To see this, consider the decision rule of a social planner who would maximize aggregate welfare. The corresponding problem is:

$$\max \int_0^{\varepsilon^*} \left[F(\varepsilon^*)y(m)\phi(m) - c(h(m)) - \varepsilon\right] f(\varepsilon)d\varepsilon$$

The social planner is arbitrarily determining the cut-off level ε^* of the individual cost below which people learn m. The first order condition is:

$$\left[F(\varepsilon^*)y(m)\phi(m) - c(h(m)) - \varepsilon^*\right] f(\varepsilon^*) + \int_0^{\varepsilon^*} f(\varepsilon^*)y(m)\phi(m)f(\varepsilon)d\varepsilon = 0$$

The first term represents the net private returns for the cut-off individual ε^*. It is equal to zero at any decentralized equilibrium (equation (1)). The last term is the contribution of the externality to the net social marginal return of increasing ε^*; i.e., the sum over all inframarginal people of their gain from the increased likelihood of successfully communicating. Because this term is positive, at any decentralized equilibrium there is a net social gain from increasing the number of people who know m.

Turning now to the mapping from signs to meanings, it is clear that because of the network externality, it is almost totally arbitrary. The most realistic way to get rid of this indetermination is to set up some evolutionary process which gradually eliminates the most inefficient conventions. What we do instead is assuming coordination among individuals of a sufficiently homogeneous social group in determining their language.

Before we proceed, let us note a caveat : if the welfare gains from using one's preferred language are not transferrable, then the welfare optimum may not be implementable by a set of transfers, and linguistic minorities will not be compensated for abandoning their original language[3].

3 Introducing social stratification

We now study how the role of communication in the production process generates a link from the social structure to productivity. We analyze how social groups with different cultural or ethnic background will develop different "languages" and have difficulty communicating with each other at the workplace. This mechanism can operate at various levels. First, people can simply speak different languages because they have different nationalities. More interestingly, people of the same nationality can find it costly to have to use the same language because they belong to different social groups.

To capture these ideas we extend the model as follows : we assume there are two social groups, indexed by $i \in \{1, 2\}$. First, each group collectively decides on its language. Second, each individual matches with somebody else and they interact *socially*. Third, people match with somebody else and *produce*. The distinction between social interaction and production is, as far as the model is concerned, a matter of labels. We use them because we are especially interested in this interpretation of the model. That people from the same group decide on their language in a cooperative fashion is obviously a metaphor. Ideally one would want to set up an evolutionary process.

As in the previous section, communication, which takes place in both matching processes, consists in exchanging a message m drawn from a distribution. As in the previous section, this is a distribution of *candidate* messages : communication actually takes place only if the two individuals speak the same language.

We assume the distribution to be :

- $f_1(m)$ if two individuals of type 1 have met each other in the first (social) matching process.
- $f_2(m)$ if two individuals of type 2 have matched in the social process.
- $f_{12}(m)$ if a type 1 has matched a type 2 in the social process.
- $\phi(m)$ in the production process, regardless of the individual's type.

Thus, the messages exchanged in the production process depend on the technology and are invariant to "culture", which is not the case in the social interaction process.

[3] I am indebted to an anonymous referee for this point.

Another assumption is that society is *stratified,* so that matching is not totally random. Thus, if ρ is the proportion of type 1 individuals, the social process is such that:

- Type 1 matches type 1 with probability $\rho + (1 - \rho)\psi$
- Type 1 matches type 2 with probability $(1 - \rho)(1 - \psi)$
- Type 2 matches type 2 with probability $1 - \rho + \rho\psi$
- Type 2 matches type 1 with probability $\rho(1 - \psi)$

ψ is an index of stratification. For $\psi = 0$ society is not stratified: the probability of matching any type i is, for any type j, equal to the proportion of type i in the population. For $\psi = 1$ society is totally stratified: people only match with the same type. We similarly assume that the production process is stratified, with the relevant probabilities given by the same formulae, with ψ replaced with σ. ψ is therefore an index of "social" stratification, and σ an index of "economic" stratification. In particular, if, as in Kremer (1993), we assume strong complementarities among cooperating workers, then production will be segregated in the sense that skilled workers will work with other skilled workers.

Last, we assume that sucessful communication at the social level yields each party x units of utility, while at the production level it yields y (supposed to be in material form and thereafter referred to as "output").

In the first stage, each group decides to coordinate on a given mapping from signs to messages, i.e. a language. They do so while taking the other group's language as given. Thus we have a Nash equilibrium.

Let us now turn to a particular example. We assume only two messages can be exchanged: $m \in \{m_A, m_B\}$. Only one sign can be used, s. The cost of learning s, c, is the same for everybody. We assume that in the social process message m_A is more specific of group 1 and m_B more specific of group 2:

$$f_1(m_A) = 1; f_2(m_B) = 1; f_{12}(m_A) = 1/2$$

In the production process both messages are equally used:

$$\phi(m_A) = \phi(m_B) = 1/2$$

How does the Nash equilibrium look like? Either both groups use the same language, or they don't. There are two possible languages: language A, which maps s to m_A; and language B, which maps s to m_B. Let us assume group 2 uses language B. What is it optimal to do for group 1?

Suppose first that it decides to use language B. Then the benefit from learning s is $(1 - \rho)(1 - \psi)x/2 + y/2$, so that total utility is $(1 - \rho)(1 - \psi)x/2 + y/2 - c$. If language A is learned, utility is instead equal to $(\rho + (1 - \rho)\psi)x + y/2(\rho + (1 - \rho)\sigma) - c$. Note that if a sign is not available to exchange the message which is drawn (for example if language B is adopted and message m_A pops out), then communication does not take place and the associated utility flow is zero, as reflected in the formulae just derived.

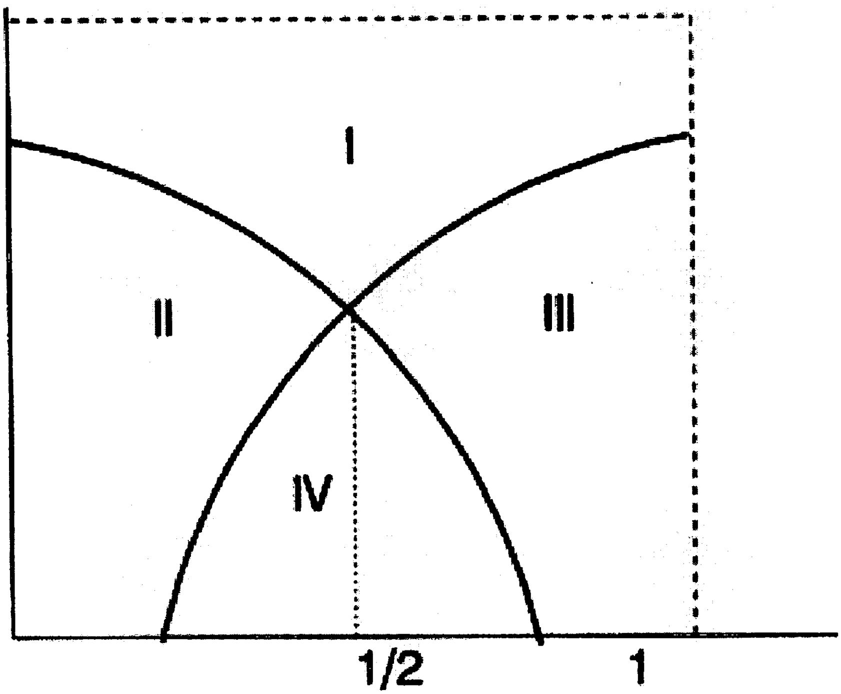

Figure 1

Thus, language A will be used if and only if:

$$(\rho + (1-\rho)\psi)x + y/2(\rho + (1-\rho)\sigma) > (1-\rho)(1-\psi)x/2 + y/2 \qquad (3)$$

This condition is equivalent to:

$$\psi > \frac{y}{x}\frac{1-\sigma}{3} - \frac{3\rho - 1}{3(1-\rho)} \qquad (4)$$

This condition is more likely to hold when stratification is greater and when type 1 people are more numerous.

Figure 1 represents equilibrium determination in the (ρ, ψ) plane. Above AA (3) holds, so that type 1 will not elect language B. The corresponding locus for type 2 not to elect language A is BB, the mirror image (by symmetry) of AA around the $\rho = 1/2$ plane. The plane is therefore partitioned in four zones. In zone 1 social stratification is large and both groups are large. Because of that the equilibrium is linguistically stratified: type 1 speaks A and type 2 speaks B. In zone III there is a unique equilibrium where both groups speak A: the dominant group (in numerical terms) imposes its preferred language; it is too costly for the minority to speak its preferred language because it matches too often with the majority. In zone

II, both groups speak B. In zone IV, there are two non stratified equilibria, with A or B equilibrium languages. Average output is y in the non stratified equilibria and $y[1-2(1-\sigma)\rho(1-\rho)]$ in the stratified ones.

Let us now turn to the welfare analysis of this economy. Because of the thin market externality, it can be shown that there is too much stratification. This is because when a social group decides to opt for a different language, it is ignoring the negative externality it is imposing on the other group which becomes unable to communicate.

To see this, we just have to compute aggregate welfare in the three possible cases.

1. If everybody speaks language A, aggregate welfare is:

$$\begin{aligned} W_A &= \rho\left[(\rho+(1-\rho)\psi)x+(1-\rho)(1-\psi)x/2+y/2\right] && (5)\\ &+(1-\rho)\left[\rho(1-\psi)x/2+y/2\right] && (6)\\ &=\rho x+y/2 \end{aligned}$$

2. If everybody speaks language B, we get:

$$\begin{aligned} W_B &= \rho\left[(1-\rho)(1-\psi)x/2+y/2\right] && (7)\\ &+(1-\rho)\left[(1-\rho+\rho\psi)x+\rho(1-\psi)x/2+y/2\right] && (8)\\ &=(1-\rho)x+y/2 \end{aligned}$$

3. If group 1 speaks A and group 2 speaks B we get:

$$\begin{aligned} W_S &= \rho\left[(\rho+(1-\rho)\psi)x+(\rho+(1-\rho)\sigma)y/2\right] && (9)\\ &+(1-\rho)\left[(1-\rho+\rho\psi)x+(1-\rho+\rho\sigma)y/2\right] && (10)\\ &=\left[1-2(1-\psi)\rho(1-\rho)\right]x+\left[1-2(1-\sigma)\rho(1-\rho)\right]y/2 \end{aligned}$$

Using these equations, it is possible to compute the optimal language depending on parameter values. This is represented in figure 2.[4] In zone A language A is optimal; in zone B language B is optimal; in zone S stratification is optimal. It is clear from figure 2 and the above equations that:

1. zone III (resp. II) is entirely contained in zone A (resp. B).
2. Zone IV is split between zones A and B, with the language preferred by the majority more desirable. Hence the part of zone IV at the right of $\rho = 0.5$ is included in A.

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[4] Mathematically, the analysis is as follows. First, it is clear that A is preferable to B iff $\rho > 1/2$. In the zone such that $\rho > 1/2$, the frontier between zone I (equilibrium segregation) and zone III (equilibrium use of A) is given by equation (4), with ρ replaced with $1-\rho$. i.e.: $\psi = \frac{y}{x}\frac{1-\sigma}{3} + \frac{3\rho-2}{3\rho}$. At the same time, confronting (5) with (9) we can see that the frontier between zone S and zone A is given by, after simplification: $\psi = \frac{y}{x}\frac{1-\sigma}{2} + \frac{2\rho-1}{2\rho}$. This is clearly above the other locus. A similar analysis runs for the $\rho < 1/2$ zone.

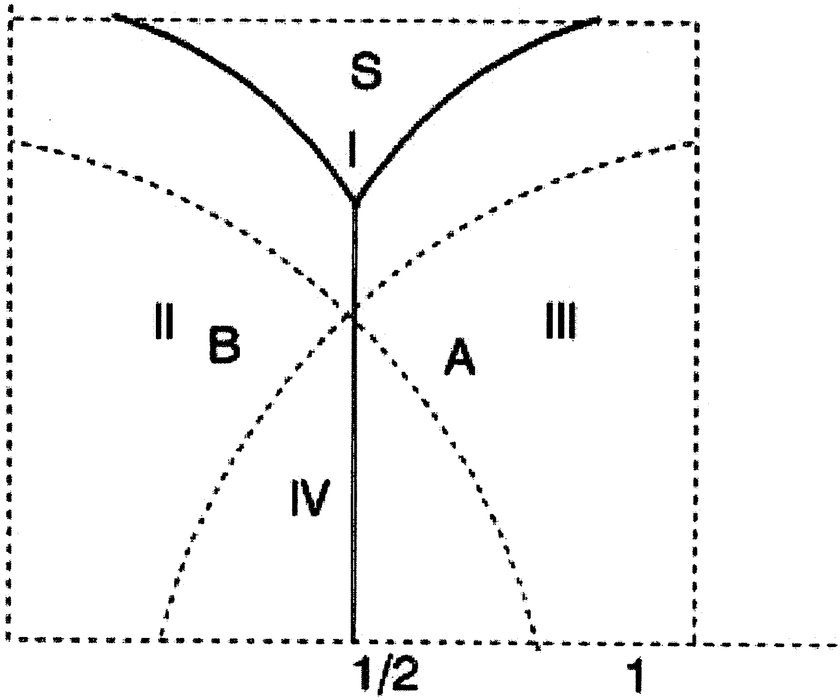

Figure 2

3. The points of zone I with low values of ψ are part of A and B; in other words S is entirely included in I; there is too much stratification in equilibrium relative to the optimum.

4 Specialized vs. flexible technologies, and the role of jargons

We now turn to another example, which allows to understand how technological change may trigger stratification. We now assume there are 3 possible messages, m_A, m_B, m_C. We assume m_A and m_B are general messages, potentially used in both social interaction and production; by contrast, m_C is a technical message, only used in production. As above, we assume that the "culture" of group 1 makes it fond of m_A, while the culture of group B makes it fond of m_B. Thus :

$$f_1(m_A) = f_2(m_B) = 1;\ f_{12}(m_A) = 1/2$$
$$\phi(m_A) = f/2 = \phi(m_B);\ \phi(m_C) = 1 - f$$

f is an index of the "flexibility" of the technology; the lower f, the more specialized the technology (the higher the division of labor), and accordingly the more specialized the messages exchanged at the workplace. We also assume no technical stratification : $\sigma = 0$. Social stratification is represented by the same matching technology with the same parameter ψ as above.

We assume there exists only 1 available sign, s, with a zero learning cost. The size of each social group is fixed at $\rho = 1/2$.

How do equilibrium languages look like ? For this we have to look at reaction functions.

1. Let us first assume that group 2 uses the "C" language, meaning that s means m_C. Then the returns to group 1 are :
   - $(1-f)y$ if it chooses C.
   - $fy/4$ if it chooses B.
   - $x(1+\psi)/2 + fy/4$ if it chooses A.

   Thus, in this case the best response is C if and only if :

   $$(1-f)y > x\frac{1+\psi}{2} + fy/4$$

   Otherwise the best response is A, which always dominates B.
2. What now if group 2 uses the "B" language ? Then the returns are :
   - $(1-f)y/2$ if 1 chooses C
   - $(1-\psi)x/4 + fy/2$ if it chooses B
   - $(1+\psi)x/2 + fy/4$ if it chooses A

   Thus the best response may either be A, B, or C. For example it is B if and only if :

   $$(1-\psi)x/4 + fy/2 > (1+\psi)x/2 + fy/4$$

   And :

   $$(1-\psi)x/4 + fy/2 > (1-f)y/2$$
3. If group 2 uses A, then the returns are :
   - $(1-f)y/2$ if 1 chooses C
   - $(1+\psi)x/2 + (1-\psi)x/4 + fy/2$ if it chooses A
   - $fy/4$ if it chooses B.

   Therefore, the best response is A iff :

   $$(1+\psi)x/2 + (1-\psi)x/4 + fy/2 > (1-f)y/2$$

   and C otherwise.

The above computations reveals that, if we label XY an equilibrium where group 1 speaks X and group 2 speaks Y, the following equilibria may

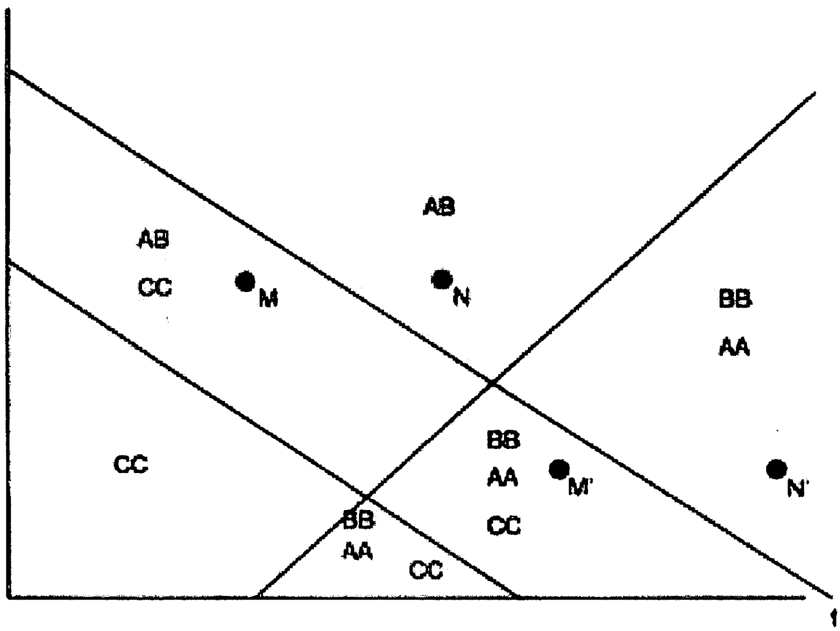

Figure 3

exist : AA, BB, CC, AB. The zones where these equilibria exist in the (f, ψ) plane are represented in figure 3.

Figure 3 suggest that technology and sociology interact in an interesting way. Technology may be a brake to social stratification by introducing a technical language common to all social groups. This is represented by the "CC" or "jargon" equilibrium. Technical change which makes specialization less valuable, as represented by an increase in f, may trigger linguistic stratification. For example if the economy starts at point M, with a very stratified society and a very specialized technology, CC is an equilibrium. An increase in technological flexibility may lead the economy to point N, where the jargon equilibrum disappears and a stratified equilibrium AB prevails. If on the other hand society is not too stratified, then the economy will move from M' to N', so that the non-stratified jargon equilibrium is replaced with a non-stratified non jargon equilibrium.

Note that it is for intermediate values of the flexibility parameter f that stratification is most likely. If flexibility is high, there is a high return to investing in the other group's language, which is valued at the workplace. If it is low, there is a high return to investing in the technical jargon. At intermediate values, one would ideally want to invest in both, but this is too costly (in the model it is in fact impossible since there is only one sign); thus the return to investing in one's own language is larger relative to the other options.

5 Summary

We have developed a model of endogenous language development which allows to study the links between social interaction and technology, and derive its consequences for productivity and welfare. Our main results are :

1. The equilibrium degree of literacy is suboptimally low because of the "thin market externality" associated with the language.
2. Social stratification generates linguistic stratification and the associated output and welfare losses due to communication failure.
3. Because of the thin market externality, there is too much stratification
4. Specialized technologies are less vulnerable to stratification than flexible ones, or, equivalently, increased flexibility may have adverse effects on output when society is stratified.

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