ON SHARING THE BENEFITS OF COMMUNICATION
EXTENDED ABSTRACT

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Abstract. Agents derive benefit from communicating with each other. In order to communicate they need to have a language in common. Learning languages is costly. In this setting we discuss Groves mechanisms with the additional feature that participation is voluntary. We characterize the least wasteful among them.

JEL classification: D63; C72

Introduction

The typical hindrance to the process of broadening communication among people is the presence of a multitude of different languages. As a matter of fact, the paradigm extends, beyond individuals, to a wider class of entities. Examples are abundant. Historically in the Iberian Peninsula trains are running on tracks of a narrow gauge. Travelers from France to Spain (and vice versa) had to switch trains. Up until quite recently (and to a lesser extent still), academics would publish the output of their research in the native language of the institute they were affiliated with. In the entertainment industry, content is distributed through platforms that are often incompatible with each other. An HD-DVD player will not play Blu-Ray discs. A track bought on iTunes will not play on Windows Media Player. A Sony Playstation game will not run on Microsoft's Xbox.

We propose a new model with the aim of investigating how policy can help a group of agents attain the Pareto efficient amount of communication. The basic motivation is that in the absence of outside intervention, as the model predicts, the efficient outcome does generically come about. Roughly speaking agents may converge to the "wrong" platform. A celebrated example is the QWERTY keyboard on which these very words are typed. It has emerged as a dominant industry standard, yet studies indicate that it does not represent the optimal configuration of keys: other layouts would facilitate typing better.

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Hence the question arises: Can a centralized solution do better? In reality, a central Planner does not have all the information he needs in order to determine the efficient outcome. We embrace this restriction and hence we pose the problem as an implementation exercise. We seek for solutions that are efficient, induce all individuals to reveal their private information and respect voluntary participation.

Unfortunately, any solution that shares these properties, formally Assignment Efficiency, Strategy Proofness and Individual Rationality, will require the Planner to bring money from the outside. The main result of the paper is to characterize the least wasteful among these solutions.

The model

The finite set of individuals is denoted $N \subseteq \mathbb{N}$, with $|N| = n$. The set of languages is $\Lambda = \big\{1, 2, \ldots, \lambda\big\}$. For each $i \in N$ the λ-dimensional vector $l_i \in \{0,1\}^\lambda$ is the comprehensive description of that individual's linguistic achievement. For instance, if $\Lambda = \big\{1, 2, 3\big\}$ and for some $i \in N$ we have $l_i = (1,0,1)$ we infer that i speaks languages 1 and 3. Initially, each individual speaks one language, his native one. We denote $\bar{l}_i \in \{0,1\}^\lambda$ the initial language endowment of each $i \in N$. Thus, in the previous example, if agent i's native language is 1 then $\bar{l}_i = (1,0,0)$. Let $N(\bar{l}_i)$ be the set of individuals who have the same native language as i,

$$N(\bar{l}_i) = \{j \in N | \bar{l}_i = \bar{l}_j\}.$$

The amount of effort that one needs to exert in order to learn a foreign language depends on his native tongue. The $\lambda \times \lambda$ matrix C with typical element $c_{jk} \in \mathbb{R}_+$ provides this information. In particular, c_{jk} is the cost of learning language k if one speaks j. Our only assumption is that $c_{jk} = 0$, whenever $j = k$.

The benefit one derives from learning foreign languages is simply a linear function of the number of individuals one can communicate with as a result of her linguistic achievement. The marginal willingness to communicate is measured, for each individual, by the parameter $\theta_i \in \mathbb{R}_+$. Hence, for individual i, the expression

$$\theta_i \Big(\sum_{j \in N/N(\bar{l}_i)} min\{1, l_i l_j^T\} \Big),$$

specifies his gross benefit from communication. For instance, let $N =$

$\{1,2,3\}$, $\Lambda = \{English, French, Italian\}$ and suppose that each individual has a different native language. Then, for any $i, j \in N$,

$l_i l_j^T \in \{0,1,2,3\}$, that is i and j may have as many as three languages in common. By contrast, $min\{1, l_i l_j^T\} \in \{0,1\}$. Utility is generated by the amount of communication alone. The means by which this is achieved have no bearing on the end result. Agents do not care neither with whom they communicates, nor in what language they do so.

On the other hand, the disutility pertaining to action l_i, given $\overline{l_i}$ and C, is $\overline{l_i}C(l_i - \overline{l_i})^T$. Hence, for any $i \in N$, the gross benefit associated with $l = \{l_i\}_{i\in N}$ is

$$v\big(l, \overline{l_i}; \theta_i; C\big) = \theta_i\big(\sum_{j\in N-N(\bar{l}_i)} min\{1, l_i l_j^T\}\big) - \overline{l_i}C(l_i - \overline{l_i})^T.$$

For each $(l, \theta_i) \in \{0,1\}^\lambda \times \mathbb{R}_+$, we use the following notational shortcut. For $\overline{l_i} \in \{0,1\}^\lambda$ and given the cost matrix C, $v_i(l;\theta_i) = v\big(l, \overline{l_i}; \theta_i; C\big)$.

Each individual may also consume a positive or negative transfer $t_i \in \mathbb{R}$. The final utility of each individual is then

$$u_i(l, t_i; \theta_i) = v_i(l;\theta_i) + t_i$$

that is, preferences are quasi-linear.

Let $\bar{l} \equiv \{\bar{l}_i\}_{i\in N}$, $\theta \equiv \{\theta_i\}_{i\in N}$. An economy is denoted $e = (\theta, \bar{l}, C) \in \mathcal{E}$, where $\mathcal{E}$ is the set of economies complying with our assumptions.

An allocation for N is a list $\{l_i, t_i\}_{i\in N}$ where l_i is a linguistic assignment for individual i and t_i is a transfer she receives. Let Z be the set of all allocations.

A mechanism is a function φ defined over $\mathcal{E}$ that associates with each economy an allocation $(l,t) \in Z$. Abusing notation, we will write, for each $e \in \mathcal{E}$, $\varphi(\theta) = \varphi(e)$. The Planner knows the parameters $\bar{l}, C$, but he can only rely on individual announcement regarding the parameter θ_i. Along these lines, $\varphi_i(\theta) = (l_i(\theta), t_i(\theta)) \in Z_i$. This notational choice serves the purpose of exemplifying that even once an allocation rule has been elected and announced, agents behaving strategically have the power to influence the actual bundle they receive by misreporting their private information.

Properties of rules

Efficiency is a standard requirement, there should be no allocation that each agent finds at least as desirable as the selected allocation and at least one agent prefers. Since individual utility is increasing in the transfer she receives then any allocation is Pareto-inferior to any other allocation with higher transfers. We begin by giving a notion of efficiency which strictly concerns the allocation of the linguistic skills among the agents. Given the profile of individual preferences θ and given quasi-linearity of preferences, an allocation that maximizes the sum of individual net benefits is Pareto-efficient among all allocations with the same or smaller total transfer. For all $\theta \in \mathbb{R}^n_+$ let

$$\Sigma(\theta) = \{l \in \{0,1\}^{\lambda \times N} \mid l \in argmax \sum_{i \in N} v_i(l;\theta_i)\}$$

be the set of all the linguistic assignments that maximize the sum of individual's net benefits.

Assignement − Efficiency. For each $\theta \in \mathbb{R}^n_+$, $l(\theta) \in \Sigma(\theta)$.

The next axiom is motivated by the fact that the social planner does not necessarily know each agent's willingness to communicate. Some agents might then find convenient do behave strategically and misreport it determining a loss of efficiency. We require that, for each agent $i \in N$, revealing her real willingness to communicate be at least as good as misrepresenting it.

Strategy − Proofness. For each $\theta \in \mathbb{R}^n_+$, $\theta'_i \in \mathbb{R}_+$, $i \in N$, $u_i(\varphi_i(\theta), \theta_i) \geq u_i(\varphi_i(\theta'_i, \theta_{-i}), \theta_i)$.

Since the domain of preference profiles is convex (and hence smoothly connected) we know from Holmstrom (1979) that an allocation rule satisfies Assignment Efficiency and Strategy Proofness *if and only if* it belongs to the family of Groves rules.

Such rules determine a transfer composed of two parts. First, each agent pays the total net benefit obtained by all other agents at the assignment chosen by the mechanism. Second, each agent receives a sum of money that does not depend on her own (announced) willingness to communicate. Let h_i be a real-valued function defined on $\mathbb{R}^n_+$ such that for each $i \in N$ and each $\theta \in \mathbb{R}^n_+$, h_i depends only on θ_{-i}.

The Groves Mechanism. Let $G^h = (l(\theta), t^h(\theta))$ be such that for each $\theta \in \mathbb{R}^n_+$ and each $i \in N$

$$l(\theta) \in \Sigma(\theta)$$

$$t^h_i(\theta) = \sum_{j \neq i} v_j(l(\theta), \theta_i) + h_i(\theta_{-i}).$$

In our model, there is no a priori restriction on the size of the total transfer. Transfers are essentially meant to achieve strategy-proofness and eventually fairness. In particular, transfers are not meant to provide income to the center. Ideally, the budget should be balanced.

Balancedness. For each $\theta \in \mathbb{R}^n_+$, $\sum_{i \in N} t_i(\theta) = 0$.

Finally, as a minimal fairness property, we will require voluntary participation of individuals to the proposed scheme. In other words, we consider as unappealing, from an ethical point of view, rules that have to rely on an authority coercing agents to interact.

Individual Rationality. For each $\theta \in \mathbb{R}^{\ltimes}_+$ and each $i \in N$, $u_i(\varphi_i(\theta), \theta_i) \geq 0$.

The Result

Let G^{ir} be the sub class of Groves Mechanisms that satisfy *Assignment Efficiency*, *Strategy Proofness* **and** *Individual Rationality.* We show that, for all allocation rules belonging to this subclass and all $\theta \in \mathbb{R}^n_+$ there will be a deficit, namely $\sum_{i \in N} t_i^{ir}(\theta) \geq 0$.(*the proof is to be completed*).

The rule we propose has the property of minimizing such a deficit for all $\theta \in \mathbb{R}^n_+$.

For each $i \in N$, let $\tilde{t}(0, \theta_i)$ be some element of $\Sigma(0, \theta_{-i})$.

The Minimal Deficit Rule. Let $G^{md} = (l(\theta), t^{md}(\theta))$ be such that for each $\theta \in \mathbb{R}^n_+$ and each $i \in N$

$$l(\theta) \in \Sigma(\theta)$$

$$t_i^{md}(\theta) = \sum_{j \neq i} v_j(l(\theta), \theta_i) - \sum_{j \in N} v_j(\tilde{l}(0, \theta_{-i}), \theta_j)$$

In order to calculate the transfers the Planner assesses the impact of each agent by setting his willingness to communicate equal to zero and then recalculating the optimal amount of communication. To gain some intuition the reader should note that this process produces a smaller deficit than the Clarke rule(which also belongs to G^{ir}), as in our framework the mere presence of an agent in the economy is a potential source of value for the rest, even if that given agent cares not to communicate.