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Skills, Immigration and Selective Policies

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Skills, immigration and selective policies

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Abstract

This paper examines the decision process that leads destination countries to introduce selective immigration policies based on skill requirements. We show that in absence of policy implementation costs, destination countries' preferences are polarized between complete openness and complete closure; however, this result changes if we take into account for policy implementation costs. In presence of enforcement costs, selective immigration policies consist in positive quotas both for unskilled and skilled workers; this result realistically fits the current scenario. We also show that the resulting policy depends on the capital endowment of the median voter: the richer, the less restrictive the immigration policy.

1 Immigration and the new environment

The increasing global dimension of economic and financial transactions creates new challenges for national borders and human capital mobility. In the last decades, capital markets have been extensively liberalized and free-trade areas have facilitated and stimulated international trade. As a reflection of the increased dimension of transactions, labour markets have experienced a significant enlargement. The attention of policy makers and international organizations has been initially directed towards the elimination of trade barriers and the gradual liberalization of financial markets; however, policy considerations on factors mobility have then been crucial. The approval of NAFTA was in fact the result of a long debate on its possible repercussions on employment and factors mobility. Also, in Europe, free factor mobility is the outcome of a process that was started in order to facilitate trade. Nonetheless, the enlargement of the European Union constitutes nowadays a new challenge for European immigration policies.

In the last decades, national borders have been challenged also by events of geopolitical nature. The collapse of the Soviet Union triggered consistent migration flows towards the industrial world; the end of mobility restrictions and its dramatic impact on welfare in Eastern Europe became in fact an incentive for moving towards richer countries. Analogous considerations are valid for the breakdown of Yugoslavia and the conflicts in the Balkans. While violent turmoil seems nowadays to be over, the same cannot be said for the lasting welfare impact on the area; flows of clandestine workers are still an issue of big concern for neighbor European countries.

2 Immigration policies

Migration flows are the natural outcome of world income inequalities, geopolitical events and world economic interdependence. Having said that, migration flows need to be regulated.

From the perspective of destination countries, immigration flows represent both a precious resource and a cost. Immigrants often satisfy the needs of destination countries: they provide part of the unskilled labour force, especially in light of the old aging of the population in many industrial countries. In fact, according to IMF (2005, ch. 2), elderly dependency ratios in the advanced countries will nearly double by 2050. In addition, highly qualified immigrants can offer skills which are both scarce and critical. Finally, cultural diversity is at the root of skill complementarity and scientific progress. However, cultural diversity is also associated with significant social costs due to the need of adapting institutions to an heterogeneous population; immigration inflows also imply an increase in public expenditure (public services and public security in particular).

For the purpose of optimizing costs and benefits, immigration policies need to be selective. Selection criteria are nowadays an issue of great priority in the agenda of policy makers.

3 The new brain drain literature

There is a growing attention towards the interaction between human capital accumulation, income distribution and migration. The attention is generally directed towards welfare effects of migration on source countries; contrary to the fears of brain drain (see, among the others, Bhagwati and Hamada, 1974; Carrington and Detragiache, 1998; Reichlin and Rustichini, 1999; Wong and Yip, 1999), the new brain-drain literature shows how migration does not necessarily imply a loss of human capital in developing countries. Mountford (1997) proves that whenever wage differentials between the developed and the developing countries are high enough, it is always possible to find a positive migration policy that assures the optimal productivity level in the source economy. Analogously, Stark and Wang (2001) argue that when productivity is fostered by both individuals' own human capital and economy-wide average of human capital, agents tend to under-invest in education. However, a strictly positive (but restrictive) probability to migrate to a richer country can lead to a welfare optimum. Finally, they show also that a restrictive immigration policy has positive welfare effects both for migrants and for the part of the population who eventually does not migrate.[1]

While these analyses provide useful workhorses for analyzing the impact of migration on education and welfare, some important caveats are found. As Shiff (2005) remarks, the optimal migration policies that are suggested by the analysis are the outcome of an optimization problem that only takes into account for the source country. This assumption follows the fact that the welfare analysis of the new brain drain literature is focused on source countries; however, the assumption does not realistically fit the empirical evidence. Since the collapse of the Soviet Union, only few countries restrict their citizen the possibility to migrate (*i.e.* Cuba, Myanmar and North Korea). A part from these exceptions, migration restrictions are decided by destination countries.

Finally, the new brain drain literature does not explain how selective policies are set.

4 Settings

In this paper, we focus on the decision process that leads destination countries to introduce selective immigration policies based on skill requirements. In a static framework, destination-country citizens choose an immigration policy that maximizes their utility. Each immigration policy is defined as a couple of probabilities to enter the country, (π_1, π_2), which refer respectively to unskilled and skilled potential immigrants. Since any border closure implies entry rationing, a restrictive policy is simply a low probability of entering.

The destination-country inhabitants choose their optimal immigration policy according to the effect of immigration flows on their income. Destination-country citizens are endowed by different level of physical capital[2] but offer inelastically one unit of labour[3]; potential immigrants do not own physical capital. The arrival of new labour force affects the capital-labour ratio of the destination country and has significant implications for income distribution; given the initial endowments, immigration inflows have a positive effect on capital income and a dampening effect on wages. The entrance of human-capital-intensive labour

[1] See also Stark *et al.* (1997) and Beine *et al.* (2003) for further analyses about the effects on education and welfare.

[2] In this paper we focus on human capital flows and we do not take into account for physical capital flows. This simplification allow us to focus on human capital flows. Also, according to IMF (2005, ch. 2), "it is possible that movements of labour from regions with rising working-age populations to those with rising elderly dependency ratios (as predictions suggest) are a possible alternative to capital flows".

[3] We assume for simplicity that destination-country natives' human capital is normalized to 1. The endowment in human capital of skilled S-country individuals can be larger or smaller than 1.

(*i.e.* skilled individuals) has thus a stronger negative effect on wages and a stronger positive effect on capital income.

Immigration policies are not costless. According to Ortega (2004), destination countries inhabitants choose the immigration policy taking into account for its welfare effects on their descendants. His articulated analysis is based on an inter-generational dynamic framework where agents behave altruistically; it shows that when skills are positively correlated between parents and children, the choice of quotas for unskilled and skilled immigrants has welfare effects on future generations. Capital does not enter the production function and wages are positively affected by the increase of the complementary-skill labour. However, the increase of complementary-skill labour affects future political decisions (which reflect the majority of the population). The latter constitutes a political cost and it is an inverse function of the degree of openness of the regulation.

In this paper, the implementation of immigration restrictions implies economic costs that need to be financed by the inhabitants of the destination country. To have a concrete idea of these costs, one can reasonably think about the current discussion on US southern frontiers and the recent (costly) proposals to reinforce the borders. The choice of the optimal immigration policy for each individual is thus subject to the costs of implementing the restrictions; the stricter the restrictions, the higher the costs to implement it (free factor mobility implies zero costs). We assume that implementation costs are financed through a flat tax on capital income. In addition, policy implementation costs enter the utility function additively. We show that even if skilled labour has a stronger effect both on wages (negative effect) and on capital returns (positive effect), additive separate costs for the policies relative to skilled and unskilled individuals imply a positive quota for both categories. This result fits reality: selective policies are generally based on strictly positive quotas both for skilled and unskilled workers. Having said that, this result may seem contra-intuitive at a first glance; given the stronger weight of intensive labour (*i.e.* skilled workers) on the capital-labour ratio, physical-capital endowed individuals would intuitively prefer positive quotas only for skilled immigrants; on the other hand, human-capital-endowed individuals would vote for positive quotas for unskilled labour only. Our model explains why in reality this does not happen. The reason is that additive costs weight on income such that all individuals prefer to increase marginally both quotas, (π_1, π_2). Also, the existence of implementation costs assures that under certain conditions, the optimal selective immigration policy is not necessarily a corner solution. Magris and Russo (2005), as in our case, show that the presence of enforcement costs can lead to a degree of frontier openness which is interior to $[0, 1]$. However, they do not take into account for immigrants' heterogeneity in terms of skills. Therefore, their model does not completely fit reality. As well known, selective immigration policies are indeed based on skill requirements.

Finally, the individual optimal decision is incorporated in policy-making through the political decision process. The resulting policy depends on the medium voter's capital endowment: the richer, the less restrictive immigration regulations.

5 The model

Consider now two small open economies in a static framework: the source country and the destination country (that we denote from now on, respectively S and D). Country D is characterized by a strictly positive aggregate level both of physical and human capital; country S is characterized by a strictly positive level of human capital. The world one good is produced under constant returns to scale: in country D, by two factors, capital and efficient units of labour; in country S, only by labour. We assume that wages per capita in country D are strictly larger than wages in country S. Thus, since all agents optimize their income, they are always willing to migrate from country S to country D. First, D-country inhabitants choose the optimal immigration policy; the immigration policy takes into account for the implications of the policy for capital and labour income. Then, a fraction of S-country inhabitants successfully migrate to country D. Immigration policies are an endogenous outcome of the interactions between D-country and S-country inhabitants.

5.1 Destination country

Let country D include a given population of natives that earn their income from labour and capital. As in Benhabib (1996), they are indexed by the level of capital they are endowed with, that we denote by k[4]. Each native is endowed with a unit of labour which is supplied inelastically in a perfectly competitive labour market. An homogeneous consumption good is produced according to a CRS aggregate production function $F(K, L)$, where K and L are respectively aggregate capital and efficient units of labour. The intensive production can be expressed in the form $f(\kappa)$ where $\kappa \equiv K/L$ is the capital labour-ratio which exhibits the usual neoclassical features.

Assumption 1. *$f : R_+ \to R_+$ is smooth (i.e. C^2), strictly increasing and strictly concave.*

The density of natives is given by a continuous function $n(k)$ defined over $[0, \infty)$. Thus, the aggregate capital in D, K, is given by:

$$K = \int_0^\infty n(k)\, k dk$$

and the total population is:

$$N = \int_0^\infty n(k)\, dk$$

The median voter in the native population is endowed with an amount of capital

[4] Capital endowment is the only source of heterogeneity across natives.

k_m solving:

$$\int_0^{k_m} n(k)\, k dk = \frac{N}{2}$$

The competitive interest rate, r, and the competitive wage, w, are, respectively:

$$\begin{aligned} r &= f'(\kappa) \\ w &= w(\kappa) = f(\kappa) - f'(\kappa)\,\kappa \end{aligned}$$

Without immigration, w and r are respectively: $r = f'(\kappa_0)$ and $w = w(\kappa_0)$, where $\kappa_0 \equiv K/N$, is the pre-immigration capital-labour ratio. The total pre-immigration income, ρ_k, of individual k depends upon κ_0 and k:

$$\rho_k = w(\kappa_0) + f'(\kappa_0)\, k \tag{1}$$

Given the static nature of the model, agents consume their whole income. Therefore, for each native, utility coincides with her/his total income and pre-immigration utility can be ranked with respect to capital endowment, according to (1).

5.2 Source country

Natives of country S do not own physical capital, but are characterized by two different levels of human capital, respectively h_1 and h_2.[5] Human capital endowments are exogenously given and satisfy $h_1 < h_2$. We will refer to agents with human capital h_1 as unskilled workers, whereas those with human capital h_2 as to skilled workers. The human capital of S before migration is given by $n_1h_1 + n_2h_2$, where n_2 refers to the number of skilled individuals and n_1 refers to the number of the unskilled ones.

In absence of migration, natives of the S-country dispose of a linear technology converting one unit of human capital in one unit of consumption. We will assume in the following that even under complete migration the wage in country D is higher than that earned in country S, as follows.

Assumption 2.

$$w\left(\frac{K}{N + n_1h_1 + n_2h_2}\right) > 1 \tag{2}$$

Since utility of S-country inhabitants coincides with their individual labor income, Assumption 2 simply implies that they will try to migrate to D, whatever the number of successful migrants is.[6] Contrary to Dustmann (2001), we

[5] This assumption does not alter our results as long as it is true that, on average, newcomers are endowed with less physical capital than natives.

[6] More precisely, all the natives of the S-country will try to migrate, if the individual income in the D-country after migration is higher than the income in the S-country: $wh_i > h_i$, $i = 1, 2$. Since the wage after migration depends positively on the new capital-labor ratio and the lowest possible ratio is $K/(N + n_1h_1 + n_2h_2)$ (when all the natives of the S-country migrate), we obtain (2) as sufficient condition.

assume that immigrants' utility of home consumption is equal to the utility of consumption in the D-country. Introducing different degrees of utility would not affect our main results. The reason is that here we focus on a two-step process of immigration policy-making where we do take into account for the possibility that in the long term immigrants could return to source countries.

6 Immigration policy

In Australia, immigration inflows are regulated by a well defined legislation which is articulated in 72 cases. Permanent visas are grouped in three different chapters: Permanent Skilled Immigration Visas, Permanent Business Immigration Visas and Permanent Family Immigration Visas. The latter chapter regulates all candidates which are linked to the country by parental links (Australia welcomes also refugees under the Humanitarian Program). The second chapter is mainly addressed to candidates that already own a business at the time they apply for the visa. Finally, the first chapter of the list is based on a point system that is aimed at assessing the skill level of the potential immigrant: the higher the score, the higher the chances to enter the country. The assessment is also affected by market and demographic considerations; if the applicant has skills or experience in the professions which are listed on the MODL (Migration Occupation in Demand List) she or he will gain extra points; analogous considerations can apply if she or he has a job offer. Finally, lower requirements are asked for those who are willing to migrate to low-populated regions.

Canada is one of the world main destination countries with about 200 000 immigrants coming every year subject to the rules of its immigration system. The Canadian immigration system is structured analogously to Australian one and it is articulated in a skilled-work category and a business-immigration category; also, 40% of annual Canada immigration is under the family reunion and refugees programs. While the business-immigration category is designed to attract experienced business people, the high skilled category is intended for people with high qualifications and skills. The skills assessment depends on six main factors: the level of education of the candidate; his/her French or English ability; his/her work experience; age (the younger, the more the points one can gain); the arranged employment (you gain extra points if you have a job offer); adaptability.

US immigration policies are based on a complicated system of visas which is articulated in more than 60 temporary visas and some permanent ones. A part from Family Relations Visas, permanent visas are issued only as last step of a long process that starts with a job offer. A job offer allows the potential immigrant to apply for H1B visas (Speciality Occupation Visas), L1A, L1B visas (Intra-Company Transferee), E1 and E2 visas (respectively Treaty Trader and Treaty Investor) and B1 visas (Business Visitor). Aliens with extraordinary ability in business, sciences, arts, education, or athletes, outstanding researchers and professors, international executive managers, registered physical therapists and registered professional nurses can apply for the permanent residence permit (the Green Card). Other categories of workers need to obtain first a "Labour Certification". This certification is needed to prove that there are not sufficient US workers who are willing, qualified and available for that position at the time of application for the visa. If this and other requirements are met, it is then possible to apply for the Green Card. The obtainment of the Green Card is subject to a national lottery and the result cannot be known *a priori*; where the labour certification has demonstrated any particular type of skills shortages in US, it is possible to be granted a Green Card. However, where the workers are not officially deemed to be skilled, the process may take several years.

While the above countries have been historically mass destination countries, mass immigration flows towards Europe are a relatively recent phenomenon; in Europe, immigration policies are currently a big concern for policy makers and the enlargement of the European Union represents an additional challenge for coordinated policy-making. In May 2004, ten new countries joined the European Union and 12 of the existing EU members imposed transitional restrictions to the right of movement freedom inside the Union. Britain and Ireland opened their markets to all newcomers; on the opposite position, Germany and Austria imposed strict restrictions. These transitional arrangements are nowadays under discussion and can only be extended for a maximum of five years.

While the Schengen agreement allows foreigners in Europe to freely circulate amongst the members, permanent residency is generally regulated by national policies. As a general rule, the concession of a permit of residency is associated with a work permit and it is not generally subject to rigidly structured selective criteria. Having said that, the debate on selective immigration policies is currently an issue of great concern and several countries are trying to introduce selection rules based on skills and labour shortages considerations.

The UK has recently introduced a number of new immigration visas and work category visas; the Highly Skilled Migrant Program aims at selecting immigrants with high skills and work experience. There is also a new low-skilled UK work permit category for the sectors-based visas. Immigration policies are currently under discussion; it is likely that the Highly Skilled Migrant Program will be extended in future and based on an annual quota. A temporary work permit will probably be used for low skilled categories.

In France, selective immigration policies are currently under debate. The focus of the discussion is on the introduction of policy regulations that would allow France to choose its immigrants according to foreigners' skills and the needs of its economy. According to the policy program, high skills and experience in sectors with scarce labour force will be the selection criteria.

In Germany, there are currently no structured selective policies; however, the worrisome scarcity of skilled labour in IT sectors has prompted the necessity to facilitate the arrival of skilled immigrants.

The above considerations suggest that in several countries immigration policies are based on skill criteria. Potential immigrants are generally allowed to enter destination countries according to immigration quotas (that are based on skill levels). Immigration quotas are not static rules and can vary over time in order to take into account for the needs of destination countries; in fact, they also reflect the evolution of the population, the trends of the public opinion and destination economies labour shortages.

In practice, the effectiveness of immigration restrictions is weakened by the existence of illegal immigration. For simplicity, we assume that both legal and illegal immigrants earn the same wage. Thus, both legal and illegal immigrants affect the capital-labour ratio in the same way. Having said that, in reality illegal immigration can have significant and peculiar effects on wages; the phenomenon carries in fact manifold implications. However, in our paper we focus the attention on how selective policies are determined. We express quotas as a probability to enter successfully the destination country; this accounts for the possibility that individuals may entry illegally.

We thus define the immigration policy chosen in the D-country as a vector $\pi \equiv (\pi_1, \pi_2)$ belonging to $[0,1] \times [0,1]$ which for every $i = 1, 2$ fixes the probability π_i of a successful migration for a candidate migrant with human capital endowment h_i.

We can describe the model as a two-step process with the following timing: (1) natives chose an immigration policy π, (2) nature randomly chooses a fraction π_i, $i = 1, 2$ of successful migrants of type h_i.

Aggregate labour supply and the capital-labour ratio after migration in the D-country become:

$$\begin{aligned} L &= N + \pi_1 n_1 h_1 + \pi_2 n_2 h_2 \\ \kappa &\equiv \frac{K}{L} = \frac{K}{N + \pi_1 n_1 h_1 + \pi_2 n_2 h_2} \end{aligned} \tag{3}$$

When the fundamentals are given (exogenous distributions of capital and human capital in both the countries) the capital per unit of labour will depend only on the immigration policy π: $\kappa = \kappa(\pi)$.

One immediately verifies that $\kappa(\pi)$ is decreasing in both its arguments. The main effect of immigration is therefore a decrease in the capital-labour ratio; this implies an increase in capital income and a decrease in real wages. We notice, eventually, that $\kappa_0 = \kappa(0)$.

Notice that technologies differ amongst the two-countries. In fact, in the S-country, natives dispose of a linear technology that converts one unit of human capital in one unit of consumption. We will assume in the following that even under complete migration the wage in the D-country is higher than that earned in the source one (see Assumption 2).

6.1 Immigration policy without enforcement costs

Assume that there are no enforcement costs to implement any policy π. It follows that for a given immigration policy π, the income of an individual endowed with an amount of capital k is given by:

$$\rho_k(\pi) \equiv w(\kappa(\pi)) + kf'(\kappa(\pi)) \tag{4}$$

An individual endowed with k maximizes (4) with respect to π. Let

$$\tilde{k} \equiv \frac{w(\kappa(0,0)) - w(\kappa(1,1))}{f'(\kappa(1,1)) - f'(\kappa(0,0))} \tag{5}$$

Proposition 1 *With no enforcement costs, the Condorcet winner is $\pi^* = (0,0)$ if $k_m < \tilde{k}$, and $\pi^* = (1,1)$ if $k_m > \tilde{k}$, where k_m denotes the capital endowment of the median voter.*

Proof. See the Appendix.

Notice that such a result reproduces the findings in Benhabib (1996) although obtained in a different framework.

6.2 Immigration policy with enforcement costs

According to Ortega (2004) individuals choose their optimal immigration policy in an infinite-time horizon taking into account for future generations. Their optimization problem also considers the political costs related to the entrance of complementary-skill immigrants: the higher their number, the higher are costs.

We will instead assume that mitigating the flows of immigrants is costly: the stricter the restrictions, the higher the costs. Stricter restrictions imply more controls, and thus, more public expenditure. One can have an idea of these costs thinking of tighter controls at the frontiers, or more infrastructures to delimit borders.

We also suppose costs are additive in the two components of the migration policy. It is in fact reasonable to think that the suitability of unskilled workers cannot be evaluated according to the same criteria used for skilled immigrants; applications for different visas are in fact evaluated according to different protocols and, generally, by different directorates. We assume that enforcement costs are determined as follows.

$$C(\pi) \equiv C_1(\pi_1) + C_2(\pi_2)$$

For each $i = 1, 2$, the function $C_i(\pi_i)$, satisfies the following properties.

Assumption 3.

$$\begin{aligned} C_i(0) &> 0 && (6)\\ C_i(1) &= 0 && (7)\\ C_i'(0) &= -\infty && (8)\\ C_i'(1) &= 0 && (9)\\ C_i''(\pi_i) &> 0 && (10) \end{aligned}$$

for every $\pi_i \in [0,1]$, $i = 1, 2$

Condition (6) states that the costs of a complete closure are positive, while (7) says that no restrictions for a given type of immigrant yields zero costs.

Condition (8) ensures that the enforcement cost is decreasing in each of its arguments. Condition (10) states the convexity of the cost, *i.e.* the progressive closure of the frontier is more and more costly.

The immigration policy is financed by a flat tax on capital income:[7] $C(\pi) = \tau f'(\kappa) K$, where κ is given by (3) and τ is the constant tax rate. The amount of tax paid by an individual owing an amount of capital equal to k is therefore: $c_k(\pi) = \tau f'(\kappa) k = C(\pi) k/K$.

It is obvious that on aggregate individuals will earn a sufficient amount of capital income to finance the equilibrium policy. Under the above assumption, the income of the native in the D-country endowed with k is:

$$\sigma_k(\pi) \equiv \rho_k(\pi) - c_k(\pi) = w(\kappa(\pi)) + kf'(\kappa(\pi)) - C(\pi) k/K \qquad (11)$$

Let now

$$\hat{k} \equiv \max_i \left\{ \max_{\pi_j} \frac{n_i h_i f''(\kappa_i) \kappa_i^3}{C_i'(0) + n_i h_i f''(\kappa_i) \kappa_i^2} \right\}, \text{ where } \kappa_i(\pi_j) \equiv \frac{K}{N + \pi_j n_j h_j}$$

and

$$\check{k} \equiv \min_i \left\{ \min_{\pi_j} \frac{n_i h_i f''(\kappa_i) \kappa_i^3}{C_i'(1) + n_i h_i f''(\kappa_i) \kappa_i^2} \right\}, \text{ where } \kappa_i(\pi_j) \equiv \frac{K}{N + n_i h_i + \pi_j n_j h_j}$$

Assumption 4. $\hat{k} < \check{k}$.[8]

The following proposition gives conditions in order to obtain an interior solution for the maximization program (11).

Proposition 2 *Under the Assumption 1, 3 and 4, the optimal immigration policy* $\arg\max_\pi \sigma_k(\pi)$ *for the individual* $k \in \left(\hat{k}, \check{k}\right)$ *is an interior solution* $\pi_k^* \in (0,1) \times (0,1)$.

Proof. See the Appendix.

$\hat{k} < \check{k}$ is satisfied only in presence of the entry cost and whenever the marginal cost of policy implementation of the type of immigrant, such that (24) is more restrictive, evaluated in zero is sufficiently larger than the marginal cost evaluated in one, relative to the type of immigrant for which (26) is also more restrictive. The reason is intuitive; focusing the attention on agents with small capital endowments whose optimal policy in the absence of costs was $(0,0)$, one can note that their optimal immigration policy may change in presence of high marginal implementation costs. They will in fact choose to depart from the initial optimal policy in order to avoid part of the costs. However, if the marginal cost in zero is very high, a very small departure from the policy $(0,0)$ will dramatically increase their revenues; the higher the marginal cost, the more significant the increase. This explains why the lower bound of capital of the

[7] Taxing also wages would not affect the main results as long as D-country inhabitants own significant amounts of capital.

[8] Notice that $\hat{k} = 0$, if $C_1'(0) = C_2'(0) = -\infty$.

interval including interior solutions will be lower as soon as the marginal cost in zero is higher.

On the other hand, the number of those who will choose the optimal policy $(1,1)$ will be lower, enlarging the upper band; in fact, the marginal cost of a more restrictive policy is offset by higher labour income.

6.2.1 Numerical simulation

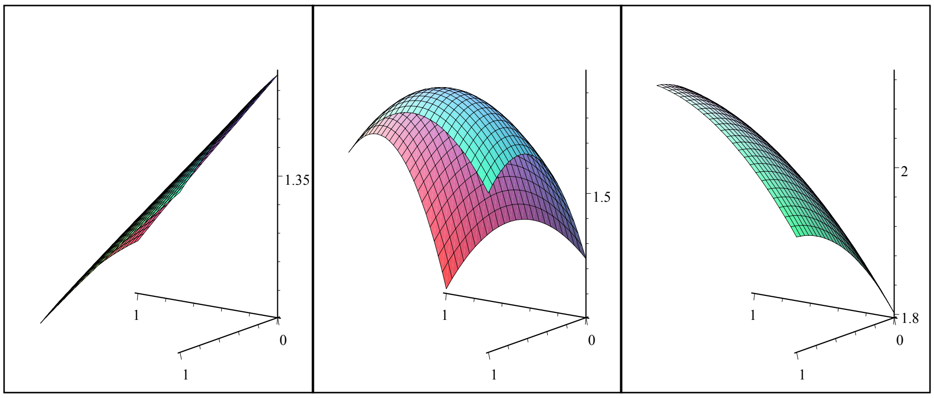
In order to illustrate the implications of the above considerations, we now provide a clarifying example. We show that for a given value of π_2, conditions (24) and (26) imply an optimal interior solution for π_1. For simplicity, we assume that output is determined according to a Cobb-Douglas CRS technology whose reduced form is of the type

$$f(\kappa) = \kappa^{\alpha} \tag{12}$$

It follows that $r = \alpha\kappa^{\alpha-1}$, $w = (1-\alpha)\kappa^{\alpha}$. Assuming also that $C_i(\pi_i) \equiv \pi_i^2/2 - \pi_i + 1/2$, $i = 1, 2$, we obtain

$$\begin{aligned}\sigma_k(\pi) \quad = \quad & (1-\alpha)\left(\frac{K}{N+\pi_1 n_1 h_1 + \pi_2 n_2 h_2}\right)^{\alpha} + \alpha k \left(\frac{K}{N+\pi_1 n_1 h_1 + \pi_2 n_2 h_2}\right)^{\alpha-1} \\ & -\frac{k}{K}\left(\frac{1}{2}\left(\pi_1^2+\pi_2^2\right) - \pi_1 - \pi_2 + 1\right)\end{aligned}$$

Setting $\alpha = 1/3$, $K = 32$, $N = 4$, $n_1 = n_2 = 1$, $h_1 = 1/2$, $h_2 = 1$, we plot the income function:



Corner solution: $k = 1$ Interior solution: $k = 3$ Corner solution: $k = 9$

We observe that poorest individuals choose complete closure, the middle class prefers an interior solution, while richer agents choose complete openness.

7 The policy decision making: the Condorcet winner

The above considerations prove useful to show that for certain levels of capital endowments the individual's income optimization process implies interior solutions for both immigration quotas, π_1 and π_2. This result fits realistically the empirical evidence and contributes to explain why selective policies generally imply positive quotas both for skilled and unskilled workers. The above results suggest also that the individual's optimal degree of frontier openness depends on her or his capital endowments. However, individuals' capital endowments are heterogeneous and destination countries natives are thus subject to different incentives. We proceed now analyzing the process of preferences aggregation. We first prove the existence of a ranking of preferences which depends upon capital. Then, we incorporate preferences in the political process of policy making.

7.1 The impact of capital on the optimal immigration policy

In order to find useful conditions to analyze the capital's impact on immigration quotas , we introduce the following fundamental elasticities and ratios:

$$\varepsilon_i \equiv \frac{d\pi_i}{\pi_i} / \frac{dk}{k} \tag{13}$$

$$\varphi \equiv \frac{f'''(\kappa)\,\kappa}{f''(\kappa)} \tag{14}$$

$$\gamma_i \equiv \frac{C_i''(\pi_i)\,\pi_i}{C_i'(\pi_i)} < 0 \tag{15}$$

$$\nu_i \equiv \frac{\pi_i n_i h_i}{N + \pi_1 n_1 h_1 + \pi_2 n_2 h_2} \in [0,1) \tag{16}$$

$$\xi \equiv \frac{\kappa}{k-\kappa} \tag{17}$$

We observe that under Assumption 3 (costs are decreasing and convex according to inequalities (8) and (10)), we have $\gamma_i < 0$ Moreover, in the Cobb-Douglas case (12): $\varphi = \alpha - 2 \in (-2,-1)$.

Consider now the inhabitants of country D. As previously set, the only source of heterogeneity is given by their endowment of physical capital; we also know that D-country natives are those who set the immigration policy. We thus proceed by characterizing D-country inhabitants' immigration preferences according to their endowment of physical capital. For simplicity, we introduce the following notation: $\pi < \pi'$ iff $\pi_i < \pi_i'$, $i = 1, 2$.

It is possible to prove that the best immigration policy is non-decreasing in the capital endowment of each native. We know that π_k^* (where π_k^* denotes an optimal policy for the individual k) exists and, under the conditions of Proposition 2, it is interior. We need to prove that individuals endowed with more capital prefer to open more the frontiers, that is to attire more the complementary factor. The first step is to prove the following lemma.

Lemma 3 *Under Assumptions 1 and 3,* $signum\partial\pi_{1k}^*/\partial k = signum\partial\pi_{2k}^*/\partial k.$

Moreover, if $\bar{\xi} < \xi < 0$ *or* $0 < \xi < \bar{\xi}$*, where*[9]

$$\bar{\xi} \equiv 2 + \varphi + \left(\frac{\nu_1}{\gamma_1} + \frac{\nu_2}{\gamma_2} \right)^{-1} \tag{18}$$

then

$$\partial \pi_{ik}^* / \partial k > 0 \tag{19}$$

$i = 1, 2$.

A stationary point such that $\partial \pi_{ik} / \partial k = 0$ *for* $i = 1, 2$ *is a saddle point if* $\xi < \bar{\xi}$ *and a local maximum* π_{ik}^* *if* $\bar{\xi} < \xi$.

Proof. See the Appendix.

Lemma 3 allows us to individuate a set of optimal choices, which is an upward-sloped curve in the π-plane; π_{2k}^* is in fact a strictly increasing function of π_{1k}^*. Moreover, this curve points at $\pi = (1, 1)$. In addition, if the conditions for ξ in the Lemma are satisfied, the position of the individual's preferred policy moves to $(1, 1)$ as k increases.

We now need to analyze the behavior of the individual agent with regard to her or his entire set of optimal choices. Lemma 4 proves the existence of an unique direction of the relation that links the individual optimal policy with capital endowments.

Lemma 4 *Let* $\pi < \pi'$ *and* $k_1 < k_2$*. Then*

$$\sigma_{k_2}(\pi) > \sigma_{k_2}(\pi') \Rightarrow \sigma_{k_1}(\pi) > \sigma_{k_1}(\pi') \tag{20}$$

$$\sigma_{k_1}(\pi') > \sigma_{k_1}(\pi) \Rightarrow \sigma_{k_2}(\pi') > \sigma_{k_2}(\pi) \tag{21}$$

Proof. See the Appendix.

Lemma 4 implies a non-decreasing relation between the degree of frontier openness and physical capital endowments. In other words, richer individuals do not prefer strict regulations. The reason is that the increase in labour dumps the capital-labour ratio and has a positive effect on capital incomes.

The next step is to extend the results of Lemma 3 to the entire set of individual optimal preferences; we need in fact to find the conditions under which the positive relation between capital and frontier openness exists for the whole set of individual optimal choices.

Assumption 5. The costs are isoelasic and sufficiently convex, that is

$$\gamma_i < -\nu_i (2 + \varphi - \xi)$$

and constant, with $i = 1, 2$.

[9] We observe that, in the Cobb-Douglas case,

$$\bar{\xi} \equiv \alpha + \left(\frac{\nu_1}{\gamma_1} + \frac{\nu_2}{\gamma_2} \right)^{-1}$$

Proposition 5 *Under Assumptions 1, 3 and 5 and isoelastic costs (constant γ_i's), the individual solution increases with the capital endowment: $k_2 > k_1 \Rightarrow \pi^*_{ik_2} > \pi^*_{ik_1}$ with $i = 1, 2$.*

Proof. See the Appendix.

7.2 Aggregate preferences

Let us now consider the process that leads destination countries to the concrete determination of immigration policies. Immigration policies are an issue of great debate in most of industrial countries. The reason why the public opinion is intensively involved in the discussion is that their effect is immediate and visible. Individuals' preferences on immigration are significant for the determination of immigration policies.

The previous findings allow us to prove the following Proposition:

Proposition 6 *Under the Assumptions 1, 3, 5, the median voter's choice is the Condorcet winner.*

Proof. Consider now the median voter's optimal immigration policy, $\pi^*_{k_m}$, and compare it with any $\pi_a > \pi^*_{k_m}$. Consider all the voters on the left of the median voter: since the median voter is the richest among them, case (20) holds and $\pi^*_{k_m}$ is voted by majority. Consider now the choice between $\pi^*_{k_m}$ and any $\pi_b < \pi^*_{k_m}$. The median voter is poorer than all voters on her right. In this case, the hypothesis of case (21) is verified and $\pi^*_{k_m}$ is voted by majority. Therefore, $\pi^*_{k_m}$ is the Condorcet winner. ■

Proposition 7 *Assume (19) holds and $\gamma_1 < \gamma_2$.*[10] *If a given individual $\bar{k}$ chooses at optimum $\pi^*_{\bar{k}}$, where $\pi^*_{1\bar{k}} < \pi^*_{2\bar{k}}$, then all individuals with $k > \bar{k}$ will choose $\pi^*_{1k} < \pi^*_{2k}$. Symmetrically, if individual $\bar{k}$ chooses at optimum $\pi^*_{\bar{k}}$, where $\pi^*_{1\bar{k}} > \pi^*_{2\bar{k}}$, then all individuals with $k < \bar{k}$ will choose $\pi^*_{1k} > \pi^*_{2k}$.*

Proof. $\gamma_1 < \gamma_2$ implies $1/\gamma_1 > 1/\gamma_2$ and, under the conditions ensuring (19), $\varepsilon_1 < \varepsilon_2$ or, equivalently,

$$\varepsilon_2 - \varepsilon_1 = \frac{\frac{d(\pi_2/\pi_1)}{\pi_2/\pi_1}}{\frac{dk}{k}} > 0$$

If $\pi^*_1 < \pi^*_2$, then a higher capital endowment increases the gap $\pi^*_2 - \pi^*_1$. ■

8 Concluding remarks

This paper aims at explaining why selective immigration policies are based on positive quotas both for skilled and unskilled workers. We have shown that if

[10] This means that a progressive more restrictive regulation for the unskilled immigrants becomes relatively more and more costly.

immigration restrictions do not imply implementation costs, individuals' preferences will be polarized between complete frontier openness and complete closure. The policy decision will depend on the collocation of the median voter: complete openness, if endowed with large amounts of capital; complete closure, if endowed with little capital. By contrast, if we account for implementation costs, there is a large range of agents whose best policies are interior: the larger the marginal costs of restrictions, the larger such interval. We have also shown that the relative amplitude of the quotas persists all along the individuals.

We are not able to study the outcome of a referendum. Since we can only compare individuals' optimal policies, we left such an issue for future research.

9 Appendix

Proof of Proposition 1. In order to characterize the solution, it is useful to compute the partial derivatives of $\rho_k(\pi)$. Since $w'(\kappa) = -\kappa f''(\kappa)$, we obtain $\rho_{ki} = (k-\kappa) f''(\kappa)\,\partial\kappa/\partial\pi_i$. Noticing that $f''(\kappa) < 0$ and that $\partial\kappa/\partial\pi_i = -n_i h_i \kappa/L < 0$, we immediately verify that $\partial\rho_k/\partial\pi_i > 0$ if and only if $k > \kappa$ and both the derivatives vanish at $k = \kappa$.

The implicit inequality $k \geq \kappa(\pi)$ allow us to determine from (3) a one-dimensional line in the (π_1, π_2)-plane:

$$\begin{aligned} \pi_2 &\geq a_k - b\pi_1 && (22)\\ a_k &\equiv \frac{K}{n_2 h_2}\left(\frac{1}{k} - \frac{1}{\kappa_0}\right)\\ b &\equiv \frac{n_1 h_1}{n_2 h_2} \end{aligned}$$

Then $\partial\rho_k/\partial\pi_i > 0$ if and only if $\pi_2 > a_k - b\pi_1$, $i = 1, 2$. Given that $b > 0$, the sign of the derivative crucially depends upon the value of a_k.

Assume first $a_k \in [0, 1+b]$. This implies that ρ_k is minimal along the line (22) passing through $(0,0)$ and $(1,1)$. Below this line both the derivatives $\partial\rho_k/\partial\pi_i$ are negative; since the function ρ_k inherits the property C^1 from the assumption $f \in C^2$, then $\pi = (0,0)$ is the $\arg\max \rho_k$. Similarly, above the line (22) both the derivatives are positive; also, since the function ρ_k is C^1, then $\pi = (1,1)$ is the $\arg\max \rho_k$ The global maximum in the unit square $[0,1]\times[0,1]$ is the maximum of these two maxima, but the optimal choice remains one of the corner solutions, $(0,0)$ or $(1,1)$: $\pi_k^* = \arg\max\{\rho_k(0,0), \rho_k(1,1)\}$.

If $a_k < 0$, then $\pi_k^* = (1,1)$. Finally, if $a_k > 1+b$, then $\pi_k^* = (0,0)$.

We now need to prove that the population is polarized between those preferring $\pi = (0,0)$, and those preferring $\pi = (1,1)$. Consider type $\tilde{k}$, who is indifferent between these polar choices, *i.e.* the type that solves $\rho_k(0,0) = \rho_k(1,1)$ or, more explicitly, expression (5).

We observe that $\tilde{k} > 0$ because $\kappa(0,0) > \kappa(1,1)$, that is $w(\kappa(0,0)) > w(\kappa(1,1))$ and $f'(\kappa(0,0)) < f'(\kappa(1,1))$. Such a type exists and is unique, provided that there is at least a native with a sufficiently low capital endowment $(k < \tilde{k})$ and another with a sufficiently large capital endowment $(k > \tilde{k})$.

First notice that $k < \tilde{k}$ iff $\rho_k(0,0) > \rho_k(1,1)$. In other terms, low capital types $k < \tilde{k}$ will prefer $\pi = (0,0)$, while high capital types $k > \tilde{k}$ will prefer $\pi = (1,1)$. Therefore if $k_m < \tilde{k}$ ($k_m > \tilde{k}$), the policy $\pi = (0,0)$ ($\pi = (1,1)$) is a Condorcet winner. ■

Proof of Proposition 2. In order to find the optimal immigration policy for individual k, we compute now the partial derivatives of (11):

$$\frac{\partial \sigma_k}{\partial \pi_i} = -\frac{k}{K}\left[n_i h_i \kappa^2 f''(\kappa)\left(1-\frac{\kappa}{k}\right) + C_i'(\pi_i)\right] \tag{23}$$

for $i = 1,2$. It is then possible to find the conditions under which σ_k has an interior optimum for π_i, given the value of π_j, $i \neq j$. For this purpose, notice that $\lim_{\pi_i \to 0} \partial\sigma_k/\partial\pi_i > 0$, when

$$k > \hat{k}_i(\pi_j) \equiv \kappa_i \frac{n_i h_i \kappa_i^2 f''(\kappa_i)}{n_i h_i \kappa_i^2 f''(\kappa_i) + C_i'(0)} \ (\geq 0) \tag{24}$$

where $\kappa_i(\pi_j) \equiv K/\left(N + \pi_j n_j h_j\right)$.

Consider $\hat{k}_i$ as a function $\hat{k}_i = \hat{\lambda}_i(\kappa_i)$ and observe that, since

$$\kappa_i([0,1]) = \left[\frac{K}{N + n_j h_j}, \frac{K}{N}\right]$$

is a compact set and $\hat{\lambda}_i$ is continuous in $\kappa_i([0,1])$, then $\hat{k}_i$ attains a maximum value $\max_{\pi_j} \hat{k}_i(\pi_j)$. Thus, if $k > \max_{\pi_j} \hat{k}_i(\pi_j)$, then $\lim_{\pi_i \to 0} \partial\sigma_k/\partial\pi_i > 0$, for each $\pi_j \in [0,1]$.

Let now

$$\hat{k} \equiv \max\left\{\max_{\pi_2} \hat{k}_1(\pi_2), \max_{\pi_1} \hat{k}_2(\pi_1)\right\} (\geq 0) \tag{25}$$

It follows that $\lim_{\pi_i \to 0} \partial\sigma_k/\partial\pi_i > 0$, for $i = 1,2$ and for all $k > \hat{k}$.

Similarly, we need to find the condition under which $\lim_{\pi_i \to 1} \partial\sigma_k/\partial\pi_i < 0$ for $i = 1,2$. According to expression (23), this is true when

$$k < \check{k}_i(\pi_j) \equiv \kappa_i \frac{n_i h_i \kappa_i^2 f''(\kappa_i)}{n_i h_i \kappa_i^2 f''(\kappa_i) + C_i'(1)} \ (\geq 0) \tag{26}$$

where $\kappa_i(\pi_j) \equiv K/\left(N + n_i h_i + \pi_j n_j h_j\right)$.

As above, consider $\check{k}_i$ as a function $\check{k}_i = \check{\lambda}_i(\kappa_i)$ and observe that, since

$$\kappa_i([0,1]) = \left[\frac{K}{N + n_1 h_1 + n_2 h_2}, \frac{K}{N + n_i h_i}\right]$$

is a compact set and $\check{\lambda}_i$ is continuous in $\kappa_i([0,1])$, then $\check{k}_i$ attains a minimum value $\min_{\pi_j} \check{k}_i(\pi_j)$. Thus, if $k < \min_{\pi_j} \check{k}_i(\pi_j)$, we have $\lim_{\pi_i \to 1} \partial\sigma_k/\partial\pi_i < 0$ for every $\pi_j \in [0,1]$.

Let now

$$\check{k} \equiv \min\left\{\min_{\pi_2} \check{k}_1(\pi_2), \min_{\pi_1} \check{k}_2(\pi_1)\right\} (\geq 0) \tag{27}$$

It follows that $\lim_{\pi_i \to 1} \partial\sigma_k/\partial\pi_i < 0$ for $i = 1, 2$ for all $k < \check{k}$.

Then, if $\hat{k} < \check{k}$ and $k \in \left(\hat{k}, \check{k}\right)$, for each point located on the frontier of the unit square $[0,1] \times [0,1]$, there exists at least one strictly preferred point in the interior $(0,1) \times (0,1)$ of the unit square. Moreover, the objective function σ_k, (11), is bounded from above and, under Assumptions 1 and 3, it is C^1 on $[0,1] \times [0,1]$. Therefore the function attains a maximum in the interior $(0,1) \times (0,1)$. ■

Proof of Lemma 3. The individual k's optimal solution, π_k^*, is solution of the two-dimensional system $\partial\sigma_k/\partial\pi_i = 0$, $i = 1, 2$. Using (23), we obtain a set of two equations

$$n_i h_i \kappa^2 f''(\kappa)\left(1 - \frac{\kappa}{k}\right) + C_i'(\pi_i) = 0 \tag{28}$$

$i = 1, 2$. We are interested in the impact of k on π_k^*. In order to compute the derivatives $\partial\pi_{ik}^*/\partial k$, we apply the implicit function theorem to system (28). More explicitly, we compute the total differential of system (28) with respect to k, π_1, π_2. Using (3) and still (28), we get

$$\begin{aligned} &\left(\left[2 + \frac{f'''(\kappa)\kappa}{f''(\kappa)} - \frac{\kappa}{k-\kappa}\right]\frac{\pi_i n_i h_i}{N + \pi_i n_i h_i + \pi_j n_j h_j} + \frac{C_i''(\pi_i)\pi_i}{C_i'(\pi_i)}\right)\frac{d\pi_i}{\pi_i} \\ &+ \left[2 + \frac{f'''(\kappa)\kappa}{f''(\kappa)} - \frac{\kappa}{k-\kappa}\right]\frac{\pi_j n_j h_j}{N + \pi_i n_i h_i + \pi_j n_j h_j}\frac{d\pi_j}{\pi_j} \\ = \ &\frac{\kappa}{k-\kappa}\frac{dk}{k} \end{aligned} \tag{29}$$

$i = 1, 2$, $i \neq j$.

Introducing elasticities and ratios (13) into (17), system (29) simplifies to

$$[(2 + \varphi - \xi)\nu_i + \gamma_i]\varepsilon_i + (2 + \varphi - \xi)\nu_j\varepsilon_j = \xi$$

where $i = 1, 2$, $i \neq j$.

By solving the system, we obtain the impact of k on π_k^* in terms of elasticities

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} = \frac{\xi}{1 - \frac{2+\varphi-\xi}{2+\varphi-\bar{\xi}}}\begin{bmatrix} 1/\gamma_1 \\ 1/\gamma_2 \end{bmatrix} \tag{30}$$

where $\bar{\xi}$ is given by (18).

Notice first that $signum\varepsilon_1 = signum\varepsilon_2$. This implies that the impact of capital on π_{1k}^* is positive iff the impact on π_{2k}^* is positive. Form 30 it is also possible to individuate the conditions under which capital has a positive impact on π^*, i.e.: (1) If $k < \kappa$, that is $\xi < 0$, we require $\bar{\xi} < \xi < 0$. (2) If $k > \kappa$, that is $\xi > 0$, we require $0 < \xi < \bar{\xi}$. In equivalent terms, we have two possible cases for a positive impact of k on π_k^*: (1) if $\bar{\xi} < 0$, we require $\bar{\xi} < \xi < 0$; (2) if $\bar{\xi} > 0$, we require $0 < \xi < \bar{\xi}$.

We now proceed by characterizing locally the concavity of $\sigma_k(\pi)$. We compute the Hessian matrix of 11 evaluated at the stationary point. From (23), the first order conditions (28) and $\partial\kappa/\partial\pi_i = -n_i h_i \kappa/L$, we obtain:

$$\begin{aligned}
&\begin{bmatrix} \frac{\partial^2\sigma_k}{\partial\pi_1^2} & \frac{\partial^2\sigma_k}{\partial\pi_1\partial\pi_2} \\ \frac{\partial^2\sigma_k}{\partial\pi_2\partial\pi_1} & \frac{\partial^2\sigma_k}{\partial\pi_2^2} \end{bmatrix}_{\pi_k=\pi_k^*} \\
= &\begin{bmatrix} -\left(\gamma_1+\nu_1\left(2+\varphi-\xi\right)\right)\frac{k}{K}\frac{C_1'(\pi_1)}{\pi_1} & -\left(2+\varphi-\xi\right)\frac{k}{\kappa}\frac{n_2h_2C_1'(\pi_1)}{L^2} \\ -\left(2+\varphi-\xi\right)\frac{k}{\kappa}\frac{n_1h_1C_2'(\pi_2)}{L^2} & -\left(\gamma_2+\nu_2\left(2+\varphi-\xi\right)\right)\frac{k}{K}\frac{C_2'(\pi_2)}{\pi_2} \end{bmatrix}
\end{aligned}$$

where φ, γ_i, ν_i, and ξ are given by (14), (15), (16) and (17).

Under the Assumptions 1 and 3, $\partial^2\sigma_k/\partial\pi_1^2$ is positive if and only if $\xi < 2+\varphi+\gamma_1/\nu_1$, while the determinant of the Hessian matrix is positive if and only if $\xi > \bar{\xi}$, where $\bar{\xi}$ is given by (18). We observe that $2+\varphi+\gamma_1/\nu_1 < \bar{\xi}$. Then $\xi > \bar{\xi}$ implies the negative definition, while $\xi < \bar{\xi}$ entails a negative determinant. In other words, the stationary point is a saddle point if $\xi < \bar{\xi}$ and a local maximum if $\xi > \bar{\xi}$. ■

Proof of Lemma 4. Suppose the hypothesis in (20) is true. More explicitly:

$$\begin{aligned}
& w\left(\kappa\left(\pi\right)\right)+f'\left(\kappa\left(\pi\right)\right)k_2-\left[C_1\left(\pi_1\right)+C_2\left(\pi_2\right)\right]\frac{k_2}{K} \\
> \;& w\left(\kappa\left(\pi'\right)\right)+f'\left(\kappa\left(\pi'\right)\right)k_2-\left[C_1\left(\pi_1'\right)+C_2\left(\pi_2'\right)\right]\frac{k_2}{K}
\end{aligned}$$

or, equivalently,

$$\begin{aligned}
& w\left(\kappa\left(\pi\right)\right)-w\left(\kappa\left(\pi'\right)\right)+\left[f'\left(\kappa\left(\pi\right)\right)-f'\left(\kappa\left(\pi'\right)\right)\right]k_2 \\
& +\left[C_1\left(\pi_1'\right)-C_1\left(\pi_1\right)+C_2\left(\pi_2'\right)-C_2\left(\pi_2\right)\right]\frac{k_2}{K} \\
> \;& 0
\end{aligned}$$

We notice that:

$$\begin{aligned}
w\left(\kappa\left(\pi\right)\right)-w\left(\kappa\left(\pi'\right)\right) &> 0 \\
f'\left(\kappa\left(\pi\right)\right)-f'\left(\kappa\left(\pi'\right)\right) &< 0 \\
C_1\left(\pi_1'\right)-C_1\left(\pi_1\right)+C_2\left(\pi_2'\right)-C_2\left(\pi_2\right) &< 0
\end{aligned}$$

Then, since $k_1 < k_2$, it must be:

$$\begin{aligned}
& w\left(\kappa\left(\pi\right)\right)-w\left(\kappa\left(\pi'\right)\right)+\left[f'\left(\kappa\left(\pi\right)\right)-f'\left(\kappa\left(\pi'\right)\right)\right]k_1 \\
& +\left[C_1\left(\pi_1'\right)-C_1\left(\pi_1\right)+C_2\left(\pi_2'\right)-C_2\left(\pi_2\right)\right]\frac{k_1}{K} \\
> \;& 0
\end{aligned}$$

which implies the RHS in (20):

$$\begin{aligned}
& w\left(\kappa\left(\pi\right)\right)+f'\left(\kappa\left(\pi\right)\right)k_1-\left[C_1\left(\pi_1\right)+C_2\left(\pi_2\right)\right]\frac{k_1}{K} \\
> \;& w\left(\kappa\left(\pi'\right)\right)+f'\left(\kappa\left(\pi'\right)\right)k_1-\left[C_1\left(\pi_1'\right)+C_2\left(\pi_2'\right)\right]\frac{k_1}{K}
\end{aligned}$$

Suppose, now, the hypothesis in (21) is true. Then we have:

$$\begin{aligned} & w(\kappa(\pi')) + f'(\kappa(\pi')) k_1 - [C_1(\pi_1') + C_2(\pi_2')] \frac{k_1}{K} \\ > \; & w(\kappa(\pi)) + f'(\kappa(\pi)) k_1 - [C_1(\pi_1) + C_2(\pi_2)] \frac{k_1}{K} \end{aligned}$$

or, equivalently,

$$\begin{aligned} & w(\kappa(\pi')) - w(\kappa(\pi)) + [f'(\kappa(\pi')) - f'(\kappa(\pi))] k_1 \\ & + [C_1(\pi_1) - C_1(\pi_1') + C_2(\pi_2) - C_2(\pi_2')] \frac{k_1}{K} \\ > \; & 0 \end{aligned}$$

Notice that

$$\begin{aligned} w(\kappa(\pi')) - w(\kappa(\pi)) &< 0 \\ f'(\kappa(\pi')) - f'(\kappa(\pi)) &> 0 \\ C_1(\pi_1) - C_1(\pi_1') + C_2(\pi_2) - C_2(\pi_2') &> 0 \end{aligned}$$

Then, since $k_1 < k_2$, it must be:

$$\begin{aligned} & w(\kappa(\pi')) - w(\kappa(\pi)) + [f'(\kappa(\pi')) - f'(\kappa(\pi))] k_2 \\ & + [C_1(\pi_1) - C_1(\pi_1') + C_2(\pi_2) - C_2(\pi_2')] \frac{k_2}{K} \\ > \; & 0 \end{aligned}$$

which means:

$$\begin{aligned} & w(\kappa(\pi')) + f'(\kappa(\pi')) k_2 - [C_1(\pi_1') + C_2(\pi_2')] \frac{k_2}{K} \\ > \; & w(\kappa(\pi)) + f'(\kappa(\pi)) k_2 - [C_1(\pi_1) + C_2(\pi_2)] \frac{k_2}{K} \end{aligned}$$

that is the RHS of (21). ■

Proof of Proposition 5. The optimal solution is in the unit square $(0,1) \times (0,1)$ or belongs to the frontier: $\pi_{ik}^* = 0$ or $\pi_{ik}^* = 1$ for some i.

We want to prove that either is interior or is equal to $\pi_k^* = (1,1)$.

We first rule out the possibility that $\pi_{ik}^* = 0$. Indeed, according to equation (23), $\lim_{\pi_i \to 0^+} \partial\sigma_k / \partial\pi_i = +\infty$ and σ_k increases with π_i for $i = 1,2$. Assume now $\pi_{ik}^* = 1$ for some i. If the solution exists and it is neither $\pi_{jk}^* = 0$ nor $\pi_{jk}^* = 1$, then $\pi_{jk}^* \in (0,1)$, for which $\partial\sigma_k / \partial\pi_j = 0$. Notice that σ_k is smooth. Evaluating the second partial derivative in such a solution under Assumption 5, we have:

$$\frac{\partial^2 \sigma_k}{\partial \pi_j^2} = -\frac{C_j'(\pi_j)}{\pi_j} \frac{k}{K} \left(\gamma_j + \nu_j (2 + \varphi - \xi)\right) < 0$$

Then, there are no local partial minima; also, and since $C_j'(1) = 0$ (Assumption 3, equation (9)), σ_k is increasing in π_j and, under the restriction $\pi_i = 1$, it generically has a local maximum at $(1,1)$. Then the set of optimal solutions is included in a positive-sloped (maybe discontinuous) locus in the π-plane; according to Lemma 3:

$$\{\pi_k^*\} \subseteq \{\pi_k : \partial\sigma_k/\partial\pi_i = 0, i = 1, 2\} \cup \{(1,1)\}$$

Finally, we need to prove that $k_2 > k_1 \Rightarrow \pi_{k_2}^* > \pi_{k_1}^*$. Assume at the contrary that k_1 and k_2 are such that $k_1 < k_2$ and $\pi_{k_2}^* < \pi_{k_1}^*$. Then, according to Lemma 4 and implication (20), $\sigma_{k_2}\left(\pi_{k_2}^*\right) > \sigma_{k_2}\left(\pi_{k_1}^*\right)$ entails that $\sigma_{k_1}\left(\pi_{k_2}^*\right) > \sigma_{k_1}\left(\pi_{k_1}^*\right)$; this cannot be true because it contradicts the fact that $\pi_{k_1}^*$ is the best choice for the individual endowed with k_1. ■

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Ramiro SOSA NAVARRO

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