Is Selling Immigration Rights Politically Sustainable ?

Revised Version

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Abstract

This paper relies on Benhabib (1996)' s immigration model to analyze the political sustainability of selling immigration permits, an idea proposed by Gary Becker. In order to simplify the analysis, we focus on the effects of immigrations flows on input prices. We first study how the choice of an immigration permit's price or a system of quotas affects the capital-labor ratio. We compare the maximal and minimal values of the capital-labor ratios obtained with the two systems. We find that immigration quotas generate the highest capital-labor ratio. We also provide an example in which immigration permits generate the lowest value of the capital-labor ratio. We show that if the wealth of the median voter is low enough, immigration quotas will be chosen over immigration permits. If the median voter's wealth is high, then the issue of majority voting will be the system which delivers the lowest capital-labor ratio. These results are then discussed, in particular with respect to our assumption that immigration rights are not rebated to native agents. We show that redistributing immigration

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fees to native agents can make them favor immigration permits over quotas. This happens when the difference in the maximal wage rates corresponding to both systems is low compared to the per capita value of immigration fees.

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1 Introduction

Rich nations face huge pressures from workers living in the rest of the world for opening their borders and increasing the number of immigrants.

Why do rich nations do not open borders ? One of the main reason is that it is impossible to prevent immigrants from receiving social welfare benefits and accordingly, it is feared that illimited immigration would put public finance in jeopardy (implicitly, a lot of immigrants would come in order to get social benefits, and would not work at all). Moreover, free immigration could result in undesirable changes in factor prices (for instance, either a decrease in wage income or in capital income).

From a pure economic viewpoint, these concerns has led several nations to set immigration quotas (i.e. The United-States, Canada, Germany etc...). The latter are used to regulate the flows of foreign workers, allowing an easy entry for those whose skills are must needed.

These quotas have been criticized by Gary Becker (1997)-(2005) because there are better tools to regulate inflows of foreign workers. These tools should rely more on market forces and less on bureaucracy. Becker proposes that countries should sell the right to immigrate. Under his proposal, a country would set a price for the right to immigrate and would allow entry to all applicants willing to pay the price.

There are several other possible ways to implement this idea. For instance, a country could auction the right to immigrate (see Ochel (2001)); it could also auction employment permits (by allocating work permits to the cheapest immigrant who apply for a certain period of time, see Felbermayr (2003))[1].

[1]De la Croix and Gosseries (2006) discusses tradable emigration and immigration quotas (respectively of skilled and unskilled workers) in relation to the procreation quotas advocated by Boulding (1964).

Why would such system favor entry of immigrants with desired characteristics ? First of all, applicants would be younger (since a relatively long period of time would be needed to earn enough to finance the immigration right) and then healthier (they would not rely on social welfare programs for their living). Naturally, it would be easier to immigrate for skilled persons or ambitious individuals (this is because these agents earn the highest incomes and are in better position to finance the immigration right). Moreover, only those individuals who want to stay in a country for a rather long period of time would be interested in paying the right to immigrate.

Ochel (2001) discusses several disadvantages of what he calls the auction model. There is no reason that immigration permits would select the "right immigrants" (those whose skills are the most needed). It is also possible that there would exist an information deficit about the receiving country from the part of potential immigrants. Finally, one could raise ethical objections to the sale of immigration permits.

Becker (2005) suggests that "Economics analysis proves that there certainly exists a positive price (and I believe a significant one) that would have a larger number of immigrants than under the present quota system". But this assumes that immigration permits would be politically sustainable, i.e. compatible with voters' preferences.

The present paper takes up this issue by focusing on the political process underlying the choice of the permits' price. It analyzes the conditions under which voters would prefer immigration permits over immigration quotas and which immigration price would be chosen.

This paper can be considered as a contribution to the literature that analyzes immigration from a political economy view point. The seminal article of this literature seems to be that of Benhabib (1996) where quotas are determined by a majority voting (and where agents are differentiated according to their wealth-human capital). Magris and Russo (2004) have extended the Benhabib model in endogenizing migration decisions as well as in introducing border enforcement costs and imperfect screening of immigrants. Voting on immigration policy is also studied by Grether et al. (2001) and Bilal et al (2003) in versions of the Ricardo-Viner model of international trade. Atsu Amegashie (2004) examines a model in which the number of immigrants allowed into a country is the outcome of a costly political lobbying contest between a firm and a union (the lobbying contest is an all-pay auction). Epstein and Nitzan (2006) analyze the endogenous determination of a migration quota viewing it as an outcome of a two-stage political struggle between two interest groups: those in favor and those against the proposed migration quota. Bellettini and

Berti Ceroni (2005) study the determinants of immigration policy in an economy with entrepreneurs and workers where a trade union has monopoly power over wages. Facchini, Razin and Willmann (2004) study the determination of immigration policy as the outcome of a lobbying game between domestic interest groups and the government when there is welfare leakage. Ortega (2005) studies the determination of immigration policy when there are heterogeneously skilled agents who anticipate that immigrants will have the right to vote and, hence, may affect future policies. Finally, Dulla, Kahana and Lecker (2006) have studied the political economy of the interactions between sources and receiving countries (they suggest that under certain conditions, the receiving country should direct some of the resources earmarked for coping with the problem of the illegal flow of workers to financially supporting the source countries, allowing them to compete among themselves for such aid).

In this paper, we rely on the framework proposed by Benhabib (1996). In order to simplify the analysis, we shall focus on the effects of immigration flows on input prices (hence we shall disregard the effects of immigration on welfare expenditures or receipts[2]). We shall also retain a useful stylisation of the political process, in which policies are set according to the preferences of the majority.

The main results of the paper as well as its organization are as follows. After presenting the model in section 2, we first study how the choice of a price for the immigration permit affects the capital-labor ratio of the economy (section 3). We provide conditions under which there exist finite prices that yield a maximal or a minimal capital labor ratio (in doing so, we assume that the hazard rate of the wealth distribution of potential migrants is monotonic). A similar study is also presented for immigration quotas (it is shown that there exist unique values of quotas that realize maximal and minimal capital-labor ratios). These two sets of results are important since agents always prefer extreme values of the capital-labor ratio. As a consequence, the native population is polarized between those who would like an immigration policy which maximizes the capital-labor ratio and those who would like to minimize it. We next compare in section 4 the maximal and minimal values of the capital-labor ratios obtained with immigration permits and quotas. We show that immigration quotas generate the highest value of the capital-labor ratio (this is because with immigration permits, a part of immigrants' wealth is used to pay the permit and is not invested in the economy). The comparison of the minimal capital-labor ratios with the two immigration schemes is not easy. We provide

[2]The issue of the redistribution of immigration fees is taken up however in section 6.

however an example in which immigration permits generate the lowest value of the capital-labor ratio. In section 5, the choice between immigration permits and quotas is analyzed using a median voter model (agents first choose an immigration scheme, and then the way it is implemented (i.e. if immigrations permits (resp. quotas) are favored, the value of the permit (resp. of the quotas) is chosen in a second vote)). If the wealth of the median voter is low enough, immigration quotas will be chosen over immigration permits since they realize the highest capital-labor ratio (and then the highest wage rate). If the median voter's wealth is high, then the issue of majority voting will be the system which delivers the lowest capital-labor ratio. This suggest that political sustainability is an important issue when implementing immigration permits. These results are then discussed in section 6, in particular with respect to our assumption that immigration permits are not rebated to native agents. We show that redistributing immigration fees to native agents can make them favor immigration permits over quotas. This happens when the difference in the maximal wage rates corresponding to both systems is low compared to the per capita value of immigration fees and when the fees are all consumed (when the fees are re-invested, the two immigration schemes generate the same capital-labor ratio). Section 7 contains some concluding remarks.

2 The Model

Following Benhabib (1996) we consider an economy where each agent is described by his wealth z (which is equal to a quantity of capital). The probability density function describing the wealth distribution is denoted $N(z)$ and is defined in $[0, +\infty)$. That is, the number of agents whose wealth is no higher that x is $\int_0^x N(z)dz$. The capital stock K_0 in the economy writes:

$$K_0 = \int_0^{+\infty} N(z)zdz \tag{1}$$

The size of the population in the economy (before immigration) is:

$$N_0 = \int_0^{+\infty} N(z)dz \tag{2}$$

The probability density function describing the wealth distribution of potential migrants is denoted by $I(z)$. It is defined in $[\underline{z}, +\infty)$, where $\underline{z} > 0$, and it is differentiable. Hence, the number of immigrants whose wealth is no higher that x is $P(x) \equiv \int_{\underline{z}}^{x} I(z)dz$. The number of potential migrants is $I = P(\infty) < +\infty$.

Production is realized in a single firm whose technology displays constant returns to scale. There are two inputs, capital (K) and labor (L). Let $F : \mathbb{R}_+^2 \to \mathbb{R}_+$, $(K, L) \mapsto F(K, L)$ denote the production function. $F(.,.)$ is assumed to be increasing, concave (and strictly concave with respect to each input). Moreover, $F(.,.)$ is twice continuously differentiable.

It is easy to compute the equilibrium value of factor prices since the supplies of these factors are always given. If the capital labor ratio is $k = K/L$, then, denoting R the capital price and w the labor wage rate, one has $R = F'_K(K/L, 1)$ and $w = F'_L(K/L, 1)$. We let $f(k)$ denotes $F(K/L, 1)$ so that: $R = f'(k)$ and $w = f(k) - kf'(k)$.

We shall assume that agents' preferences are an increasing function of their incomes. Thus, for simplicity, we disregard the possibility that these preferences depend on the unemployment rate, ethnicity etc[3]... An agent with wealth z has an income equal to $O_z(k) = w(k) + R(k)z$. Note that $O'_z(k) = (z - k)f''(k)$. This function reaches a minimum at $k = z$. An increase in k brings about an increase in the wage rate as well as a decrease in the return to capital. When agents own a little amount of capital, an increase in k yields an increase in their income (since the increase in the wage rate more than compensate the decrease in the capital income). The reverse effect obtains when agents are wealthy. These effects compensate exactly when $k = z$.

Immigration policies affects agents incomes because they affect the capital-labor ratio. The first policy that will be considered consists in selling immigration rights (or permits).

The permits are sold to immigrants (and not to firms in the host country). For the time being, we shall assume that the price of an immigration permit is fixed at a level p. This price must be paid before coming in the host economy. We also assume that every migrant with wealth at least equal to p chooses to migrate. The number of migrants is then equal to:

$$\overline{P}(p) \equiv 1 - P(p) = \int_{p}^{+\infty} I(z)dz, \tag{3}$$

[3]For a study of the issues on which the preferences of the local population depend, see Boeri, Hanson and McCormick (2002).

We set the post-immigration capital-labor ratio in the economy equal to:

$$\tilde{k}(p) = \frac{K_0 + \displaystyle\int_p^{+\infty} (z-p)I(z)dz}{N_0 + \overline{P}(p)} \tag{4}$$

Note that the net capital supplied by an immigrant with wealth z is just equal to $z-p$. The expression above obtains if several assumptions are satisfied (all of which will be generally standing throughout the paper). First of all, it is assumed that migrants cannot borrow from agents in the host country. This assumption is made for simplifying the analysis (its main implication is that savings in the host country is not diverted from capital accumulation). Second, it is assumed that the gross wealth z that a migrant brings in the host country does not depend on p[4]. Third, it is assumed that immigration fees are not re-invested but finance public expenditures (or a foreign aid given to developing countries[5]). Fourth, we assume that either the increase in public expenditures or the decrease in other taxes allowed by the sales of permits, have no significant impact on agents' welfare. I.e. the effects of the sale of permits on factor prices are assumed to be bigger than their effects on public expenditures or taxes (like if the proceeds of the taxes were just wasted in financing improductive expenditures). Admittedly, this last assumption is a strong one[6]. But is enables us to concentrate on the effects that work through the changes in the capital-labor ratio. Finally, we assume that immigration does not generate significant costs per se. We shall discuss these last three assumptions in section 6.

The second policy analyzed consists in choosing immigration quotas. A specification of quotas is a pair (s, q), where s is a positive real

[4]The gross wealth may depend on p when migrants borrow a part of their capital as well as the immigration fee. In such a situation, the gross wealth carried by a migrant could be a decreasing function of p. To see this, assume that the amount b borrowed by a migrant solves the next problem: $\max_b V(h+b-p) - C(b)$, where $V(.)$ is an increasing smooth concave function of the net wealth $w = h+b-p$ carried in the host country (h is the wealth of an agent who does not borrow), while $C(.)$ is an increasing convex smooth function. The optimal choice of the migrant with regard to b satisfies $V'(h+b-p) = C'(b)$. It is easy to see that $db/dp = V''(h+b-p)/(V''(h+b-p) - C''(b)) > 0$. However, $dw(p)/dp = db/dp - 1 < 0$. Our assumption can be understood as supposing that db/dp is small.

[5]This could be a way to respond politically to the objection that "citizenship should not be for trade" (see Becker (1997)). Moreover, such a scheme would have the flavor of a Bhagwati tax (see Bhagwati and Parkington (1976)).

[6]As was suggested by a referee, one could interpret the effect of introducing permit on factor prices as a long-run one (whereas the effects of the permits' value on the budget as short-one). Thus voters care about the long-run and less about the short-run.

number, $q \in [s, \infty]$, which determines the types of agents that are allowed to enter in the country. That is, the number of immigrants is equal to $\int_s^q I(z)dz = P(q) - P(s)$ and the capital-labor ratio writes:

$$k(s,q) \equiv \frac{K_0 + \displaystyle\int_s^q zI(z)dz}{N_0 + P(q) - P(s)} \tag{5}$$

In order to analyze the impacts of immigration policies on welfare, we have to study how they affect the capital-labor ratio. We address this issue in the next section.

3 The capital-labor ratio, immigration permits and immigration quotas

This section is devoted to a technical study of the effects on the capital-labor ratio of either selling immigration rights or setting immigration quotas. It seems not easy to give general results concerning the effects of the immigration permits. So, we shall only give results for the special class of wealth distributions with a monotone hazard rate (but this class encompasses several usual ones). It is possible to derive more general results with immigration quotas. We prove the existence (and uniqueness) of values of quotas which minimize or maximize the capital-labor ratio. This topic was already taken up in Benhabib (1996) for the case $\underline{z} = 0$. Here, we restate his result in the case $\underline{z} > 0$ and we indicate where lie the quotas maximizing or minimizing the capital-labor ratio with respect to K_0/N_0. The proofs of the results are gathered in Appendix 1.

3.1 The capital-labor ratio and the price of immigration permits

We first study the capital-labor ratio as a function of the price of immigration permits, $\tilde{k} : [\underline{z}, +\infty) \to \mathbb{R}_{++}$. Notice that: $\tilde{k}(\infty) \equiv \lim_{p \to +\infty} \tilde{k}(p) = K_0/N_0$.

Let us study the extrema of $\tilde{k}(p)$. At each interior extremum, one has:

$$\frac{d\tilde{k}(p)}{dp} = \frac{I(p)\tilde{k}(p) - \overline{P}(p)}{N_0 + \overline{P}(p)} = 0 \tag{6}$$

Two compensating effects are at work. First, there is a negative effect (which is equal to $-\overline{P}(p)$) since the net capital transfer by each potential migrant decreases marginally. Second, there is a positive effect (proportional to $I(p)$) which stems from an anti-dilution effect: as there as less migrants, hence less workers, ceteris paribus, the capital-labor ratio increases.

The second-order condition writes:

$$\frac{d^2\tilde{k}(p)}{dp^2} = I'(p)\frac{\frac{d\tilde{k}(p)}{dp}}{I(p)} + I(p)\{\frac{\left(\frac{d\tilde{k}(p)}{dp} - \frac{d}{dp}(\frac{\overline{P}(p)}{I(p)})\right)(N_0 + \overline{P}(p))\big)}{(N_0 + \overline{P}(p))^2} + \frac{I(p)\big(\tilde{k}(p) - \frac{\overline{P}(p)}{I(p)}\big)}{(N_0 + \overline{P}(p))^2}\}$$

At an extremum, the preceding expression reduces to:

$$\frac{d^2\tilde{k}(p)}{dp^2} = -I(p)\frac{\frac{d}{dp}(\frac{\overline{P}(p)}{I(p)})}{N_0 + \overline{P}(p)} \tag{7}$$

Hence, the existence of maxima or minima of the capital-labor ratio as a function of p hinges on the sign of $\frac{d}{dp}(\frac{\overline{P}(p)}{I(p)})$ ($\frac{\overline{P}(p)}{I(p)}$) is the inverse of the hazard rate).

For some distribution functions, the sign of this expression turns out to be constant. For instance, it is positive with a Pareto distribution, negative with a uniform distribution, either positive or negative with a exponential distribution. For some other distributions, like the log-normal law, the sign is not constant.

In the remainder of this paper, we shall assume that one of the two following assumptions (H1) and (H2) holds true.

Assumption H1 The hazard rate of $P(.)$ is decreasing, i.e. $\phi(p) = \frac{\overline{P}(p)}{I(p)}$ is increasing with respect to p.

Assumption H2 The hazard rate of $P(.)$ is increasing, i.e. $\phi(p) = \frac{\overline{P}(p)}{I(p)}$ is decreasing with respect to p.

Using assumption (H1) we can assert that there is at most one real value of p for which the capital-labor ratio is maximized. Indeed, if there were two values $p_2 > p_1$ which realize the maximum capital-labor ratio k we would have:

$$\frac{d\tilde{k}(p_1)}{dp} \leq \frac{d\tilde{k}(p_2)}{dp} = 0 \tag{8}$$

After a little algebra, the above condition and equation (6) imply that:

$$\tilde{k}(p_1) - \phi(p_1) \leq \tilde{k}(p_2) - \phi(p_2) \tag{9}$$

Hence, $\phi(p_2) \leq \phi(p_1)$ which is impossible when assumption (H1) is satisfied[7].

Also, under Assumption (H1), there are no local interior minimal capital-labor ratios (this is so since every interior extremum is a local maximum). Hence, if there is a minimum value of the capital-labor ratio which is realized at a finite price, this price must be $\underline{z}$.

The reasoning used with assumption (H1) applies with assumption (H2). There is at most one real value of p for which the capital-labor ratio is minimized[8].

It is easy to provide a necessary and sufficient condition for $\underline{z}$ to be a local minimizer of $\tilde{k}(.)$ (resp. a local maximizer of $\tilde{k}(.)$) if assumption $(H1)$ (resp. $(H2)$) holds. This condition writes:

$$\frac{d\tilde{k}(\underline{z})}{dp} = I(\underline{z})\frac{\tilde{k}(\underline{z}) - \phi(\underline{z})}{N_0 + \overline{P}(\underline{z})} > 0 \; (resp. \; < 0) \tag{10}$$

or:

$$\tilde{k}(\underline{z}) > \; (resp. <) \; \phi(\underline{z}) \tag{$C_{\underline{z}}$}$$

In the case where (H1) holds true, it is clear that the condition is sufficient. Let us show that it is necessary. A necessary condition for a minimum of $\tilde{k}(.)$ at $\underline{z}$ writes $\frac{d\tilde{k}(\underline{z})}{dp} \geq 0$. However, if $\frac{d\tilde{k}(\underline{z})}{dp} = 0$, as $\frac{d^2\tilde{k}(\underline{z})}{dp^2} < 0$, the function $\tilde{k}(p)$ is locally concave and a local maximum is realized at $\underline{z}$. This contradicts the assumption that a minimal capital-labor ratio is realized at $\underline{z}$. The argument is similar when (H2) is satisfied.

We can now present our results on the existence and uniqueness of the extrema of $\tilde{k}(p)$.

[7] We can show similarly that if a maximal capital-labor ratio is realized at a finite price, then there are no other local maxima.

[8] We can show similarly that if a minimal capital-labor ratio is realized at a finite price, then there are no other local minima. Moreover there are no interior local maximal capital-labor ratios. If a finite price maximizes $\tilde{k}(p)$, this price must be $\underline{z}$.

Proposition 1 *Assume (H1). Furthermore:*

a) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ and $\underline{z}$ is a local minimizer of $\tilde{k}(p)$. Then, there exists a unique finite immigration permit's price which maximizes the capital-labor and the minimal capital-labor ratio is K_0/N_0.

b) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ and $\underline{z}$ is a local maximizer of $\tilde{k}(p)$. Then, $\underline{z}$ maximizes the capital-labor ratio and K_0/N_0 is its minimal value.

c) Assume that $\tilde{k}(\underline{z}) \leq K_0/N_0$ and that $\underline{z}$ is a local minimizer of $\tilde{k}(p)$. Then the minimal capital-labor ratio is realized at $\underline{z}$. If $\tilde{k}(\underline{z}) = K_0/N_0$, there exists a finite p that maximizes the capital labor-ratio. If, on the other hand, $\tilde{k}(\underline{z}) < K_0/N_0$, either there is a maximal value of the capital-labor ratio which is realized at a finite price p or K_0/N_0 is the maximal value of the capital-labor ratio (and $\tilde{k}(p)$ is increasing).

Proof. See Appendix 1.

The intuition of this Proposition is as follows. We have seen that a marginal increase in p yields two opposite effects on the capital-labor ratio. On the one hand, it generates a decrease in the net entry of foreign capital - there are fewer migrants who can afford the immigration fee and each of them brings a lower net capital. This decrease has a negative effect on the capital-labor ratio. On the other hand, since there are few migrants, the labor supply is lower and this has a positive effect on the capital-labor ratio.

In case a), there exists a unique finite price at which the two marginal effects compensate exactly and a maximal capital-labor ratio is realized at this price (such price may also exist in case c). In case b) the first effect always dominates the second. Hence the maximal capital-labor ratio is achieved at $\underline{z}$. In case c), it may happen that the second effect dominates the first: so, to realize a maximal capital-labor ratio, it is optimal to set an infinite price (that is, entry is forbidden).

Remark. The case where $\tilde{k}(\underline{z}) \leq K_0/N_0$ and $\underline{z}$ is not a local minimizer of $\tilde{k}(p)$ is not possible. Indeed, by assumption (H1), this would imply that $\tilde{k}(p)$ realizes a local maximum at $\underline{z}$, which would necessarily be a global maximum. So, the inequality: $\tilde{k}(\underline{z}) < K_0/N_0$ is impossible. If $\tilde{k}(\underline{z}) = K_0/N_0$, the function $\tilde{k}$ must be constant (otherwise, there would exist an "interior" minimum, which is impossible with assumption (H1)). But $\tilde{k}$ is not constant, so this is impossible.

The preceding results are interesting not only because they provide us with informations about the existence and uniqueness of extrema of $\tilde{k}(p)$ but also with informations on the *location* of these extrema.

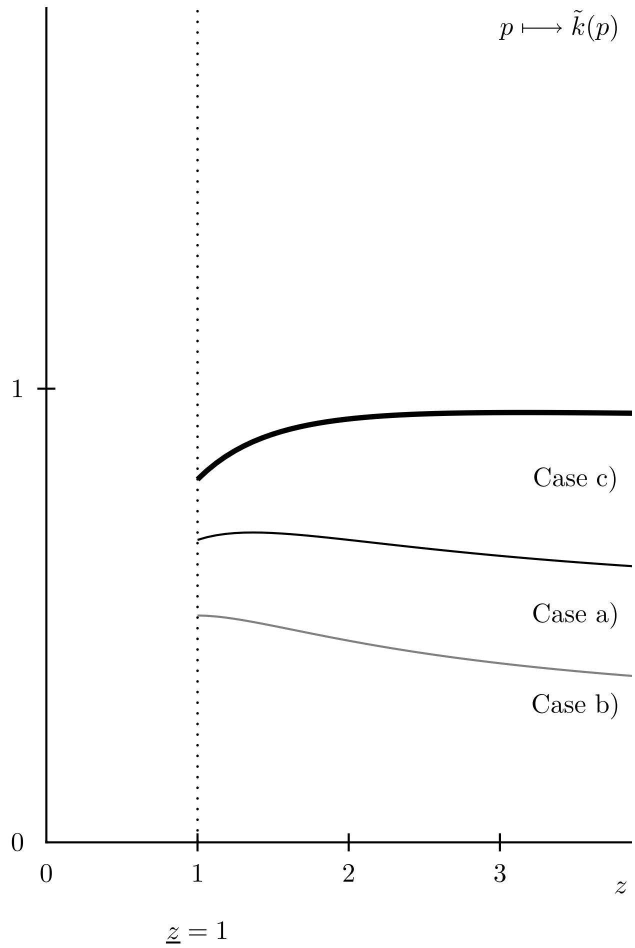

Figure 1: Graphs of $\tilde{k}(p)$ with various values of K_0/N_0.

Proposition 1 is illustrated in figure 1. The intermediate curve corresponds to case a), the grey one to case b, and the bold one to case c).

The curves are drawn using a Pareto distribution for which one has:

$$\tilde{k}(p) = \frac{K_0 + I\frac{\underline{z}^2}{p}}{N_0 + I\frac{\underline{z}^2}{p^2}} \tag{11}$$

We have set $\underline{z} = 1$, $I = 1$, $N_0 = 2$. For case a), we have set $K_0 = 1$, for case b) $K_0 = 1/2$, and for case c) $K_0 = 3$.

Proposition 2 *Assume (H2). Furthermore:*

a) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ and that K_0/N_0 is not the minimum value of $\tilde{k}(p)$. Then $\tilde{k}(\underline{z})$ is the maximal value of $\tilde{k}(p)$ and the minimum of $\tilde{k}(p)$ is realized at a unique finite price.

b) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ and that the minimal value of $\tilde{k}(p)$ is realized at $p = +\infty$. Then, $\underline{z}$ maximizes the capital-labor ratio and $\tilde{k}(p)$ is decreasing.

c) Assume that $\tilde{k}(\underline{z}) \leq K_0/N_0$. Then if $\tilde{k}(\underline{z})$ is a local maximum of $\tilde{k}(p)$ there exists a unique finite price higher than $\underline{z}$ that minimizes $\tilde{k}(p)$ and the maximal value of $\tilde{k}(p)$ is K_0/N_0. If $\tilde{k}(\underline{z})$ is a local minimizer of $\tilde{k}(p)$ then $\underline{z}$ is the unique value of p that minimizes the capital-labor ratio, the maximal value of $\tilde{k}(p)$ is K_0/N_0 and $\tilde{k}(p)$ is increasing.

PROOF. See Appendix 1.

The intuition that drives the result has the same flavor to that of Proposition 1. In case a), there is a unique finite price at which the marginal negative effect of an increase in p - the decrease in the net inflows of capital - is compensated by the marginal positive effect (the anti-dilution effect). When p either decreases or increases, the positive effect dominates the negative one. In case b) the negative effect always dominates the positive one. Case c) is interpreted as in cases a) and b).

3.2 The capital-labor ratio and immigration quotas

We now turn to a brief study of how immigration quotas affect the capital-labor ratio. This topic was already taken up in Benhabib (1996) for the case $\underline{z} = 0$. Here, we restate his result in the case $\underline{z} > 0$ and we indicate where lie the quotas maximizing or minimizing the capital-labor ratio with respect to K_0/N_0.

Recall that a specification of quotas is a pair (s, q), where s is a non-negative real number, which determines the types of agents that are allowed to enter in the country[9]. That is, the number of immigrants is equal to $\int_s^q I(z)dz$ and the capital-labor ratio writes:

$$k(s,q) \equiv \frac{K_0 + \displaystyle\int_s^q zI(z)dz}{N_0 + P(q) - P(s)}$$

[9]Notice that, strictly speaking, there are no quotas for agents whose wealth is between s and q.

We assume that: $\underline{z} < K_0/N_0$. This is a reasonable assumption since $\underline{z}$ could be thought of as being close to zero (in fact, the only reason why we assumed that $\underline{z}$ is positive is that it allows us to consider a Pareto distribution for the immigrants' wealth).

Proposition 3 *a) There exists a unique real number v, $\underline{z} < v < K_0/N_0$, such that with immigration quotas $(s, q) = (\underline{z}, v)$, $k(\underline{z}, v)$ is the minimal value of the capital-labor ratio.*

b) There exists a unique real number $\underline{s}$, $\underline{s} > K_0/N_0$, such that with immigration quotas $(s, q) = (\underline{s}, +\infty)$, $k(\underline{s}, +\infty)$ is the maximal value of the capital-labor ratio.

PROOF. See Appendix 1.

The gist of this Proposition is as follows. A marginal increase in q generates two opposite effects on the capital-labor ratio. On the one hand, an increase in q allows wealthier migrants to enter and this is conducive to an inflow of capital. On the other hand, the entry of new migrants increases the labor supply. The marginal effects of an increase in s can be analyzed in a similar way (but they work in opposite directions).

From point a) one sees that to achieve a minimal capital-labor ratio, one should not allow wealthy migrants to enter. Only the poorest migrants should enter in the country. The reason for this is that poor migrants bring with them small amounts of capital. Hence, the effect of their entry on the supply of capital is positive but small whereas the effect on the labor supply is relatively high.

Symmetrically, as shown in point b), to realize a maximal capital-labor ratio, one should not allow the poorest migrants to enter.

4 Comparing capital-labor ratios with immigration quotas and immigration permits

In the previous section we have provided a detailed analysis of the feasible capital-labor ratios. Recall that the capital-labor ratio is the key variable that affects agents' incomes. We also know that agents' incomes reach a minimum when the capital-labor ratio is precisely equal to their wealths. So, in order to maximize their preferences, agents should favor extremal capital-labor ratios. Depending on their wealth levels, they may prefer either a minimal or a maximal capital-labor ratio. In this respect, the choice between a system of immigration quotas or immigrations permits boils down to compare the extremal values of the capital-ratios that are feasible with these two systems.

As shown in the next result, it is always possible to compare the maximal capital-labor ratios obtained with both systems.

Proposition 4 *Assume either (H1) or (H2). Then the maximal capital-labor ratio with a system of quotas is strictly higher than the maximal capital-labor ratio with immigration permits.*

PROOF. Let us notice that for all $p \geq \underline{z}$, one has:

$$\tilde{k}(p) = \frac{K_0 + \displaystyle\int_p^{+\infty} (z-p)I(z)dz}{N_0 + \overline{P}(p)} < k(p,\infty) \equiv \frac{K_0 + \displaystyle\int_p^{\infty} zI(z)dz}{N_0 + \overline{P}(p)} \tag{12}$$

So:

$$\tilde{k}(p) < \sup_{p \geq \underline{z}} k(p,\infty) = \max_{p \geq \underline{z}} k(p,\infty) = k(\underline{s},\infty) \tag{13}$$

where $\underline{s}$ is the value found in the preceding section. Then:

$$\sup_{p \geq \underline{z}} \tilde{k}(p) \leq k(\underline{s},\infty) \tag{14}$$

In particular, this inequality is strictly satisfied when $\tilde{k}(p)$ realizes its maximum at a finite price (see equation (13)). If this is not the case, then $\sup_{p \geq \underline{z}} \tilde{k}(p) = K_0/N_0$. But as was seen in the previous section, $k(\underline{s},\infty) > K_0/N_0$. Hence, we always have $\sup_{p \geq \underline{z}} \tilde{k}(p) < k(\underline{s},\infty)$. $\square$

This result is intuitive. Imagine indeed that the permit's price p maximizing the capital-labor ratio is equal to $\underline{s}$. Then, necessarily, one would have $\tilde{k}(p) < k(\underline{s},\infty)$ since with a system of permits, immigrants must pay an immigration fee and, as a result, came with a lower net capital than if there were a system of quotas. Of course, there is no reason why p would be equal to $\underline{s}$. But whatever may be the value of p, it is impossible that $\tilde{k}(p) > k(\underline{s},\infty)$. If this were the case, a system of quotas with $s = p$ would be feasible and, due to the immigration fee, would generate more capital inflows than the system of permits, contradicting the inequality[10].

We now turn to the comparison of the minimal capital-labor ratios obtained with permits and quotas.

[10]When (H2) is satisfied, as was noticed by an associate editor, the reasoning is even more direct. Indeed, under a permit system the capital-labor ratio is maximized by letting everybody or nobody in (the fee being either $\underline{z}$ or $+\infty$). Clearly either arrangements is dominated by a suitable quotas system.

With a system of quotas, the minimal capital labor-ratio is achieved by preventing migrants with wealth higher than a level v to enter. This is in contrast with a system of permits: all agents with wealth higher than the value of the fee can enter.

When (H1) is satisfied, Propositions 1 c) and 3 a) show that the only case where a system of permits can yield a capital-labor ratio lower than with quotas is when the immigration fee is equal to its minimum value, i.e. $\underline{z}$. In all other cases, $\underline{z} < k(\underline{z}, v) < K_0/N_0 = \inf_{p \geq \underline{z}} \tilde{k}(p) = \tilde{k}(+\infty)$. That is, the minimal value of the capital-ratio with permits is realized when there is no entry at all (with an infinite immigration fee).

Propositions 2 a) and c) and 3 q) show that similar results obtain with assumption (H2) (except that the price minimizing the capital-labor ratio is not necessarily equal to $\underline{z}$).

Hence, when the lowest capital-labor ratio is achieved by a system of permits, this is because there exists a dilution effect (there are more agents who enter than capital). Of course, the existence of the immigration fee contributes to this effect.

The next example illustrates the possibility that $\tilde{k}(\underline{z}) < k(\underline{z}, v)$ (in this example (H1) is satisfied).

Example. We assume that P is a Pareto distribution. Then, one has:

$$\tilde{k}(p) = \frac{K_0 + I\frac{\underline{z}^2}{p}}{N_0 + I\frac{\underline{z}^2}{p^2}} \tag{15}$$

and:

$$k(\underline{z}, q) = \frac{K_0 + 2I\underline{z}^2(\frac{1}{\underline{z}} - \frac{1}{q})}{N_0 + I(1 - \frac{\underline{z}^2}{q^2})} \tag{16}$$

We assume furthermore that $K_0 = 2$, $\underline{z} = 1/2$, $N_0 = 1$, $I = 1$. The graphs of $\tilde{k}(.)$ and $k(\underline{z}, .)$ obtained with these values are depicted in figure 2. This picture shows that $\tilde{k}(\underline{z}) < k(\underline{z}, q)$ for all $q \geq \underline{z}$.

In appendix 2, we show that this example is robust (i.e. the same conclusion is reached whenever $K_0 \geq 1$).

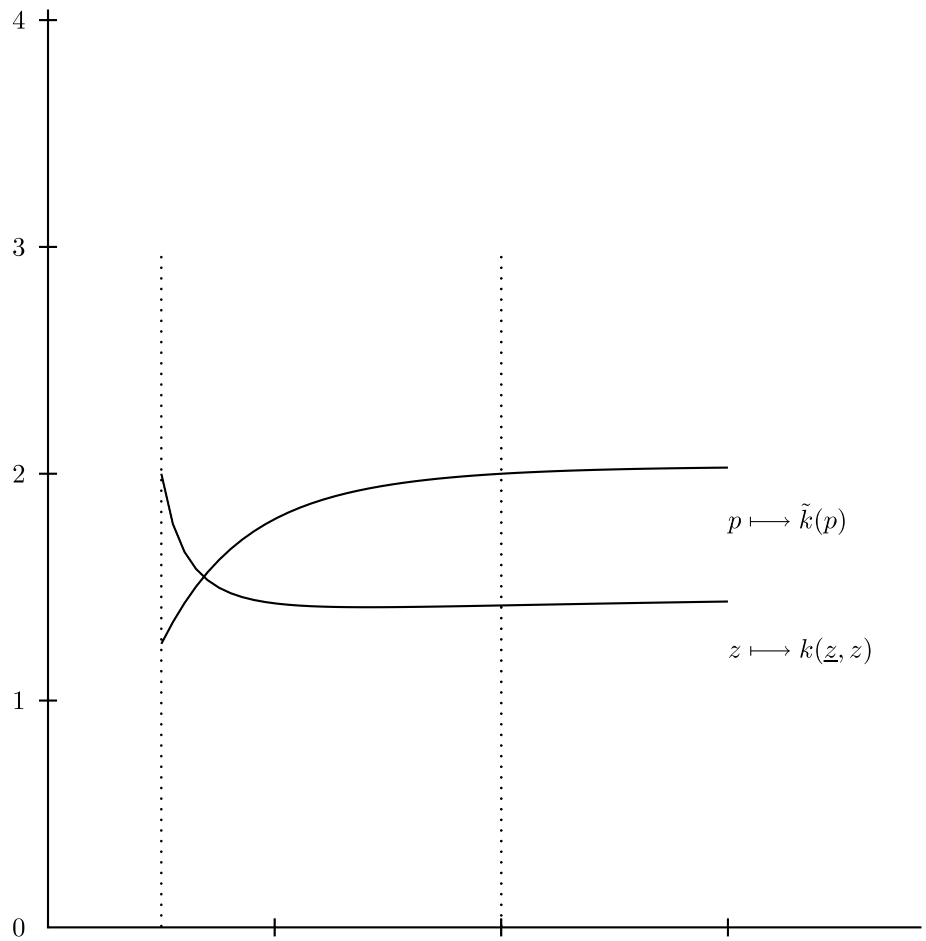

Figure 2: A case where $\min \tilde{k}(p) < k(\underline{z}, v)$.

5 Majority voting and the political sustainability of immigration permits

We are now in position to analyze the political sustainability of the two immigration policies considered in this paper. These policies affect directly the capital labor-ratio and thus the income of every agents (recall that the income of agent s writes $O_s(k) = w(k) + R(k)s$).

To analyze the votes, we need the next notion. We shall say that an agent with wealth s is *indifferent* between two capital-labor ratios k and z if:

$$w(k) + R(k)s = w(z) + R(z)s \tag{17}$$

This agent always exists, is unique and such that:

$$s = \frac{w(k) - w(z)}{R(z) - R(k)} \tag{18}$$

The following Lemma, which is due to Benhabib (1996), is instrumental in studying the agent indifferent between two capital-labor ratios.

Lemma 1 (Benhabib) *Let two positive capital-labor ratios z and k be given, with $z < k$. Let $\triangle(z,k)$ denotes the capital stock of the agent which is indifferent between z and k. Then, $z < \triangle(z,k) < k$.*

We also have:

Lemma 2 *a) Every agent with wealth $s > \triangle(z,k)$ (resp. $s < \triangle(z,k)$) prefers z (resp. k) to k (resp. z): $O_s(z) > (<)\ O_s(k) \iff s > (<)\ \triangle(z,k)$.*
b) Let a capital stock u be in $]z,k[$. Then for all s, $\max\{O_s(z), O_s(k)\} > O_s(u)$.

Proof. a) The function $\phi(s) = w(k) - w(z) + \big(R(k) - R(z)\big)s$ is decreasing with s. Since it vanishes at $s = \triangle(z,k)$, one has $\phi(s) < 0 \iff s > \triangle(z,k)$. If follows that $O_s(z) > (<)\ O_s(k) \iff s > (<)\ \triangle(z,k)$.

b) Let u be in $]z,k[$. Since $O_s(.)$ reaches its minimum at s, one has: if $s < u$, then $O_s(u) < O_s(k) \leq \max\{O_s(k), O_s(z)\}$ and if $s > u$, then $O_s(u) < O_s(z) \leq \max\{O_s(k), O_s(z)\}$. $\square$

Depending on their levels of wealth, agents will prefer either the smallest possible capital-labor ratio, or the highest. In the first case, they will choose to maximize the return to capital; in the second, they will look for the highest possible wage.

Let us now consider a vote whose issue is decided according to the majority principle. In our setting, the issue of the vote is decided by the median voter, i.e. the agent whose wealth k_m is the solution to:

$$\frac{\int_0^{k_m} N(z)dz}{N_0} = 0.5 \tag{19}$$

We consider that the choice between immigration quotas and immigration permits is done in two steps. In the first step, voters have to choose between the two alternative systems; in the second one, an alternative having been chosen, they choose either the values of the quotas, or an immigration price.

The analysis presented in the preceding sections leads us to consider two cases. Indeed, either[11]:

$$k(\underline{z}, v) < \inf_{p \geq \underline{z}} \tilde{k}(p) < \sup_{p \geq \underline{z}} \tilde{k}(p) < k(\underline{s}, \infty) \tag{20}$$

or[12]

$$\min_{p \geq \underline{z}} \tilde{k}(p) < k(\underline{z}, v) < \sup_{p \geq \underline{z}} \tilde{k}(p) < k(s, \infty) \tag{21}$$

where v is such that $(v, +\infty)$ minimizes $k(s, q)$ (see Proposition 3).

In the first case, we can see that in a vote with immigration quotas and immigration permits as alternatives, no agent will choose permits over quotas. Indeed, let us consider the indifferent agent $\triangle(\tilde{k}(\underline{z}, v), k(\underline{s}, \infty))$.

If an agent's wealth i is such that $i > \triangle(\tilde{k}(\underline{z}, v), k(\underline{s}, \infty))$ this agent will favor immigration quotas $(\underline{z}, v)$ (Lemma 2 a)). These quotas generate the lowest possible capital-labor ratio and the agent prefers this ratio over $k(\underline{s}, \infty)$. From Lemma 2 b), we also know that this agent will favor quotas over immigration permits.

If an agent's wealth i satisfies $i < \triangle(\tilde{k}(\underline{z}, q), k(s, \infty))$, this agent will most prefer immigration quotas (s, ∞). Again, immigration permits are not a better alternative.

[11]Notice that since $\sup_{p \geq \underline{z}} \tilde{k}(p) \geq K_0/N_0$, we always have: $k(\underline{z}, v) < \sup_{p \geq \underline{z}} \tilde{k}(p)$.

[12]Due to Lemma 3 in the appendix and the fact that $k(\underline{z}, v) < K_0/N_0$, the infimum is realized.

Depending on whether the median agent has a wealth higher or lower than $\triangle(\tilde{k}(\underline{z},v),k(\underline{z},\infty))$, the vote will favor immigration quotas $(\underline{z},v)$ or $(\underline{s},\infty)$. But in the first place, immigration quotas will be chosen over immigration permits.

The conclusion turns out to be different in the second case. Indeed, in this case, the lowest capital-labor ratio is realized with immigration permits. The issue of the vote can be analyzed using the indifferent agent $\triangle(\min_{p\geq\underline{z}}\tilde{k}(p),k(\underline{s},\infty))$. If the median agent has a wealth lower than $\triangle(\min_{p\geq\underline{z}}\tilde{k}(p),k(s,\infty))$, then immigrations quotas will be preferred to immigration permits (Lemma 2 a)). Conversely, immigration permits will be chosen over immigration quotas whenever the median agent's wealth is higher than $\triangle(\min_{p\geq\underline{z}}\tilde{k}(p),k(\underline{s},\infty))$.

We may now summarize the preceding reasoning which is the main result of this paper:

Proposition 5 *a) If, $k(\underline{z},v)<\inf_{p\geq\underline{z}}\tilde{k}(\underline{z})<\sup_{p\geq\underline{z}}\tilde{k}(p)<k(\underline{s},\infty)$, immigration quotas will always be chosen over immigration permits by a majority of voters. If the median agent's wealth is higher (resp. lower) than $\triangle(\tilde{k}(\underline{z},v),k(\underline{s},\infty))$, the vote will favor immigration quotas $(\underline{z},v)$ (resp. $(\underline{s},\infty)$).*
b) If, on the other hand, $\min_{p\geq\underline{z}}\tilde{k}(\underline{z})<k(\underline{z},v)<\sup_{p\geq\underline{z}}\tilde{k}(p)<k(\underline{s},\infty)$, immigration permits (resp. immigration quotas (s,∞)) will be preferred to immigration quotas (resp. immigration permits) when the median agent's wealth is higher (reps. lower) than $\triangle(\min_{p\geq\underline{z}}\tilde{k}(\underline{z}),k(\underline{s},\infty))$.

We have seen that when immigration permits are chosen by a majority of agents, it is because they generate the lowest capital-labor ratio. The capital-labor ratio is reduced more by charging a suitable fee and letting people come in who can pay the fee than by targeting immigration quotas toward those who have the lowest levels of capital[13].

This has striking implications when the price minimizing the capital-labor ratio is $\underline{z}$?[14]. This is the lowest possible price for immigration permits. In this case, when permits are chosen over quotas, every potential migrant is free to enter (whenever he pays the immigration fee).

But if $\underline{z}=0$ (as could be the case with an exponential distribution), the lowest capital-labor ratio would be realized with a price equal to

[13] I thank an associate editor for this remark.

[14] Recall that this is always the case when (H1) is satisfied (see Proposition 1 and footnote 2). This may also happen when (H2) is satisfied (see Proposition 2 c)).

zero. This would amount to allow free entry of immigrants. However, in such a situation, it is evident that immigration permits are useless since it suffices to open the borders.

This conclusion is however no longer true when assumption (H1) is not satisfied. In particular, when (H2) is satisfied, Proposition 2 a) and c) shows that the minimum value of the capital-labor ratio can be realized with a finite value of p greater than $\underline{z}$.

6 Discussions

We must now qualify the conclusions of the preceding section with regard to the usefulness of permits since they rely on the assumption that agents do not value the turnover of the permits sales. Recall also that it was assumed that immigration do not generate specific costs.

6.1 Redistribution of immigration fees

If agents were to value permits sales, it is not a priori evident that they would favor a zero price for permits. Even our conclusion that, if the median agent has a relatively small wealth, quotas will be preferred over permits must be qualified (especially when immigration quotas generate a small increase in the capital-labor ratio in comparison to permits). Indeed, if immigration permit sales are rebated to agents, permits could be preferred over quotas[15]. Assuming that these receipts are equally shared among agents, the following Proposition formalizes this intuition.

Proposition 6 *Let p be the price maximizing the capital-labor ratio with immigration permits. Assume that:*

$$F'_L(k(\underline{s}, \infty), 1) - F'_L(\tilde{k}(p), 1) \leq \frac{p\overline{P}(p)}{N_0}, \tag{22}$$

then every agent prefers immigration permits (sold at price p) over the quotas $(\underline{s}, \infty)$.

[15] In a model of international trade with endogenous growth *à la Grossman-Helpman*, Lundborg and Segerstrom (2002) show that mass immigrations can be welfare decreasing (both for laborers as well as capital owners). They also show that an immigration tax can compensate native workers. Such an immigration tax would be very similar to having to buy an immigration permit.

PROOF. The preceding equation may be rewritten as:

$$\frac{1}{N_0} p\overline{P}(p) \geq w(k(\underline{s}, \infty)) - w(\tilde{k}(p)) \tag{23}$$

Hence,

$$w(\tilde{k}(p)) + \frac{1}{N_0} p\overline{P}(p) \geq w(k(\underline{s}, \infty)) \tag{24}$$

Consider an agent with wealth i. We have:

$$w(\tilde{k}(p)) + \frac{1}{N_0} p\overline{P}(p) + iR(\tilde{k}(p)) \geq w(k(\underline{s}, \infty)) + iR(\tilde{k}(p)) \tag{25}$$

Since $k(\underline{s}, \infty) > \tilde{k}(p)$ and the return to capital is a decreasing function, it follows that:

$$w(\tilde{k}(p)) + \frac{1}{N_0} p\overline{P}(p) + iR(\tilde{k}(p)) \geq w(k(\underline{s}, \infty)) + iR(k(\underline{s}, \infty)) \tag{26}$$

This proves that every agent prefers permits over quotas. □

The Proposition above shows that if the per-capita value of immigration permits sales is greater than the difference of wages, then permits are preferred by all agents over quotas.

In the Proposition above, we have assumed that all agents consume the transfers they received. But these transfers could also be re-invested[16]. This alternative assumption is particularly relevant if migrants bring capital goods in the economy (this distinction is not so relevant in our framework which is a one-produced good economy but it would matter in a more complex setting). An immediate consequence of this assumption is that the details of the immigration schemes do not matter. More formally:

Proposition 7 *Assume that immigrations fees are turned over to native agents and are used by them in the form of capital. Then, a system of permits is equivalent to a system of quotas.*

PROOF. This is trivial. If immigrations fees - $p\overline{P}(p)dz$ - are rebated to native agents, the capital ratio equal:

[16] I am grateful to an associate editor who indicated this alternative and the result of the next Proposition.

$$\begin{aligned}\tilde{k}(p) = \frac{K_0 + p\overline{P}(p)dz + \int_p (z-p)I(z)dz}{N_0 + \overline{P}(p)} \\ = \frac{K_0 + \overline{P}(p)}{N_0 + \overline{P}(p)} \\ = k(p, \infty)\end{aligned}$$

The result follows. □

The Proposition rests nevertheless on two implicit assumptions. First, immigration permits do not affect the gross amount of capital transferred by migrants in the immigration country. Indeed, as was discussed in footnote 4, this amount, $z(p)$ could be a decreasing function of the permit's price p. Second, due to a wealth effect, native agents may not invest the total amount of immigration fees that they received as lump-sum transfers. So, the neutrality result of the above Proposition is unlikely to be true in full generality.

Beyond the cases considered in the two last Propositions, it is not evident to analyze what permit price would be chosen by a majority of agents with redistribution of permits sales. This is so since there is no clear relation between an agent's wealth i and his preferred price, i.e. that which maximizes:

$$w(\tilde{k}(p)) + iR(\tilde{k}(p)) + \frac{1}{N_0}p\overline{P}(p) \tag{27}$$

Let us now turn to our assumption that immigration is not costly per se.

6.2 Immigration costs

Up to now, we have not taken into account the fact that immigration may be costly.

There are at least three kinds of economic costs generated by immigration. First, migrants received social benefits (and perhaps more than the average native). Second, the inflows of migrants yield a dilution of capital (an increase in savings may be necessary to build new schools, hospitals...). Third, immigration may have negative effects on certain incomes (as there is an increase in competition on the labor market).

Of course, immigration yields economic benefits as well (through the increase in production and in the capital inflows). As a consequence, the net costs are not easy to know.

Whatever the net costs may be, immigration permits are a scheme which aims to induce entry of migrants at low social costs. First, with permits, younger, more skilled and wealthier migrants would come. This would decrease the two first costs. Moreover, the revenues of the permits can be used to finance the remaining cost and to compensate the native agents (the extra revenues can finance public expenditures as well). However, though this last advantage would not be negligible, it is the first advantage that seems to be more important for proponents of permits like Becker (see Becker (1997) and (2005)). The use of permits as an immigration is essentially seen as a way to increase the number of migrants with the desired characteristics.

In the model used in this paper, taking into account the first kind of cost is not easy (redistribution is not explicitly modeled). The two other costs are more or less explicitly taken into account. But as far as the first cost is concerned, it must be noticed that in our framework, quotas can be used in the same way as permits to choose migrants with desired characteristics (i.e. agents which do not rely a lot on social benefits). Hence, quotas can decrease immigration costs like permits.

The consequence of the above remarks is that immigration costs may not be a major point in the comparison of our immigration schemes (especially in the long-run). For sure, the revenues of the permits could be used to finance immigration costs. But with permits, these costs would be small - and so will they be with quotas. So the revenues would mostly finance other expenditures and we are back to the cases discussed above.

7 Conclusion

In this paper, we have analyzed and compared immigration permits and immigration quotas by focusing on their effects on the capital-labor ratio. Two main conclusions can be drawn from the analysis.

First, the highest possible capital-labor ratio is always achieved with immigration quotas. This is because with immigration permits, immigrants' wealth is reduced by the amount of the permit price. We have also seen that it is not always the case that immigration quotas generate the lowest capital-labor ratio.

Second, the political process may be of considerable importance when designing a market for immigration permits. Immigration permits could not be politically sustainable in the sense that a majority of agents would prefer immigration quotas. This is because agents prefer extreme values of the capital-labor ratio and immigration permits do not always yield these extreme values.

These conclusions rely on several assumptions, some of which have been discussed in the preceding section. We shall now address some assumptions that have not yet been discussed.

Recall that we have assumed that borrowing in the destination country is infeasible. If this last assumption were relaxed, immigrants could enter in the country with their gross wealth and paying the immigration fee would not reduce the inflow of capital. However, the effects of this operation on the capital-labor ratio would remain the same since immigration fees must be paid and this would reduce the amount of the capital stock in the destination country (provided that the fees are not re-invested). The same conclusion would be reached if firms in the destination country were allowed to buy immigration permits.

We have also generally assumed that immigration fees are not rebated to native agents. However, immigration fees could decrease the tax burden or help finance more public expenditures. Each of these two possibilities would make easier for agent to support immigration permits[17]. Still, it is not clear how easy it would be to use mean-voter arguments to further analyze these issues.

Finally, potential migrants pay the same price to enter irrespective of their wealth levels. We could have also relied on more complex pricing schemes. We could imagine to discriminate and charge different fees to people with different wealths levels[18]. Similarly, we could have introduced more complex system of quotas.

Relaxing the above assumptions is a natural topic for further research. But several other issues could be considered. For instance, it would be interesting to extend the study of immigration permits to models differing from that of Benhabib. This would allow us to take into account some agents like lobbies or trade-unions and to address dynamic issues linked to migrations.

[17]These results could be proved in a way similar to that presented in the preceding section (when immigration fees are rebated to native agents).

[18]I thank an assistant editor for suggesting this possibility. This would probably imply to refine the study of the decision to entry made by migrants.

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APPENDIX 1

Before proving Propositions 1 and 2, we need the next Lemma:

Lemma 3 *Assume that* $\sup_{p?\geq \underline{z}} \tilde{k}(p) > K_0/N_0$ *(resp.* $\inf_{p?\geq \underline{z}} \tilde{k}(p) < K_0/N_0$*). Then, there exists* $\hat{p}$ *such that:* $\sup_{p?\geq \underline{z}} \tilde{k}(p) = \sup_{p\in[\underline{z},\hat{p}]} \tilde{k}(p)$ *(resp.* $\inf_{p?\geq \underline{z}} \tilde{k}(p) = \inf_{p\in[\underline{z},\hat{p}]} \tilde{k}(p)$*) and the maximum (resp. minimum) of* $\tilde{k}(p)$ *is realized in* $[\underline{z}, \hat{p}]$*.*

Proof. We shall only consider the existence of a maximum of $\tilde{k}(p)$ (the argument is similar for the realization of the minimum). Suppose that the first part of the Lemma is false. Then for all $\hat{p}$, there exists $p'(\hat{p}) > \hat{p}$ such that $\sup_p \tilde{k}(p) > \tilde{k}(p'(\hat{p})) > \sup_{p\in[\underline{z},\hat{p}]} \tilde{k}(p)$. Letting $\hat{p}$ goes to infinity, one gets:

$$\sup_p \tilde{k}(p) \geq \lim_{\hat{p}\to+\infty} \tilde{k}(p'(\hat{p})) \geq \sup_p \tilde{k}(p) \tag{28}$$

Hence, $\sup_p \tilde{k}(p) = K_0/N_0 = \sup_p \tilde{k}(p)$ which is a contradiction. As for the last part of the Lemma, since $\tilde{k}$ is a continuous function on $[\underline{z}, \hat{p}]$, Weierstrass Theorem ensures that it realizes its maximum. □

The next condition will also be useful for the study of $\tilde{k}(p)$:

$$\tilde{k}(\underline{z}) > K_0/N_0 \iff \frac{\int_{\underline{z}}^{\infty} zI(z)dz}{\int_{\underline{z}}^{\infty} I(z)dz} > \underline{z} + K_0/N_0 \tag{C_∞}$$

Proposition 1 *Assume (H1).* Furthermore:
a) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ *and* $\underline{z}$ *is a local minimizer of* $\tilde{k}(p)$*. Then, there exists a unique finite immigration permit's price which maximizes the capital-labor and the minimal capital-labor ratio is* K_0/N_0*.*
b) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ *and* $\underline{z}$ *is a local maximizer of* $\tilde{k}(p)$*. Then,* $\underline{z}$ *maximizes the capital-labor ratio and* K_0/N_0 *is its minimal value.*
c) Assume that $\tilde{k}(\underline{z}) \leq K_0/N_0$ *and that* $\underline{z}$ *is a local minimizer of* $\tilde{k}(p)$*. Then the minimal capital-labor ratio is realized at* $\underline{z}$*. If* $\tilde{k}(\underline{z}) = K_0/N_0$*, there exists a finite* p *that maximizes the capital labor-ratio. If, on the other hand,* $\tilde{k}(\underline{z}) < K_0/N_0$*, either there is a maximal value of the capital-labor ratio which is realized at a finite price* p *or* K_0/N_0 *is the maximal value of the capital-labor ratio (and* $\tilde{k}(p)$ *is increasing).*

Proof.

a) Under our assumptions, K_0/N_0 is not the maximal capital-labor ratio nor is $\tilde{k}(\underline{z})$. From Lemma 3, there exists a finite immigration permits price that realized the maximum capital-labor ratio. From condition (H), this price is unique. Also, from assumption (H) and condition C_∞, there are no finite prices minimizing the capital-labor ratio. Hence $\tilde{k}(\infty) = K_0/N_0$ is the minimal capital-labor ratio. Indeed, if $\inf_p \tilde{k}(p) < K_0/N_0$, by Lemma 3 there exists a finite value of p at which the minimal capital-labor ratio is realized. But we have just seen that this is impossible. Hence $\tilde{k}(\infty) = K_0/N_0 = \inf_{p\geq\underline{z}} \tilde{k}(p)$.

b) First of all, in virtue of Lemma 3, there exists a finite price which maximizes the capital-labor ratio. Assume that this price is different from $\underline{z}$. Then $\underline{z}$ is a local maximum. It follows that there are two prices p_1 and p_2 such that $\underline{z} \leq p_1 < p_2 < p$, and such that $\frac{d\tilde{k}}{dp}(p_1) < 0$ and $\frac{d\tilde{k}}{dp}(p_2) > 0$. By continuity, there then exists p' such that $p_1 < p' < p_2$ and $\frac{d\tilde{k}}{dp}(p') = 0$. By assumption (H), this implies that $\tilde{k}(p)$ realizes a local maximum at p' but, under assumption (H) again, this is impossible. The proof that $K_0/N_0 = \tilde{k}(\infty) = \inf_{p\geq\underline{z}} \tilde{k}(p)$ is similar to that used in point a).

c) By assumption, $\inf_{p\geq\underline{z}} \tilde{k}(p) \leq \tilde{k}(\underline{z}) \leq K_0/N_0$. If $\inf_{p\geq\underline{z}} \tilde{k}(p) < \tilde{k}(\underline{z})$ by Lemma 3, there exists a finite price which realizes the minimal capital-labor ratio. Under assumption (H) this prices must be $\underline{z}$ since there is no finite price greater that $\underline{z}$ at which a minimal capital-labor ratio is realized. This is a contradiction. Hence $\tilde{k}(\underline{z}) = \inf_{p\geq\underline{z}} \tilde{k}(p)$.

If $\tilde{k}(\underline{z}) = K_0/N_0$, $\sup_{p\geq\underline{z}} \tilde{k}(p) > K_0/N_0$ (since there is a minimum at $p = \underline{z}$ and the function $\tilde{k}(.)$ is not constant). Hence Lemma 3 applies and $\tilde{k}(.)$ realizes a maximum at a finite price. If $\tilde{k}(\underline{z}) < K_0/N_0$, then either $\sup_{p\geq\underline{z}} \tilde{k}(p) > K_0/N_0$ and we may apply Lemma 3 once again, or $\sup_{p\geq\underline{z}} \tilde{k}(p) = \tilde{k}(\infty) = K_0/N_0$. In that case, it is easy to see that $\tilde{k}(p)$ is increasing (otherwise there would exist a local minima at a price $p > \underline{z}$ which is impossible). $\square$

Proposition 2 *Assume (H2).* Furthermore:

a) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ and that K_0/N_0 is not the minimum value of $\tilde{k}(p)$. Then $\tilde{k}(\underline{z})$ is the maximal value of $\tilde{k}(p)$ and the minimum of $\tilde{k}(p)$ is realized at a unique finite price.

b) Assume that $\tilde{k}(\underline{z}) > K_0/N_0$ and and that the minimal value of $\tilde{k}(p)$ is realized at $p = +\infty$. Then, $\underline{z}$ maximizes the capital-labor ratio and $\tilde{k}(p)$ is decreasing.

c) Assume that $\tilde{k}(\underline{z}) \leq K_0/N_0$. Then if $\tilde{k}(\underline{z})$ is a local maximum of $\tilde{k}(p)$, there exists a unique finite price higher than $\underline{z}$ that minimizes $\tilde{k}(p)$, and the maximal value of $\tilde{k}(p)$ is K_0/N_0. If $\tilde{k}(\underline{z})$ is a local *minimizer of $\tilde{k}(p)$ then, $\underline{z}$ is the unique value of p that minimizes the capital-labor ratio, the maximal value of $\tilde{k}(p)$ is K_0/N_0 and $\tilde{k}(p)$ is increasing.*

PROOF.

a) We know that the maximal value of $\tilde{k}(p)$ is realized either at $p = \underline{z}$ or $p = +\infty$. Under our assumptions, it follows that $\tilde{k}(\underline{z})$ is the maximal value of $\tilde{k}(p)$. From Lemma 3, there exists a finite immigration permits price that realizes the minimal value of the capital-labor ratio. From condition (H2), this price is unique.

b) Again, the maximal value of the capital-labor ratio is realized at price $\underline{z}$. Let us show that $p = \infty$ is the unique price that minimizes $\tilde{k}(p)$. If not, there would exist a finite price p which also realizes the minimal value of $\tilde{k}(p)$. Since $\tilde{k}(p)$ is not constant, there exists a value $p' > p$ such that: $\tilde{k}(p') > \tilde{k}(p)$. If $\tilde{k}(p')$ is not a local maximum in $[p, p']$, by continuity of $\tilde{k}(p)$ there exists a price in $[p, p']$ at which there is a local maximum. But under $(H2)$ this is impossible. Suppose now that $\tilde{k}(p')$ maximizes $\tilde{k}(p)$ in $[p, p']$. Necessarily, there exists a price p'' such that, $p'' > p'$ and $\tilde{k}(p'') < \tilde{k}(p')$. But there then exists a local maximum of $\tilde{k}(p)$ in $[p, p'']$ and we get again a contradiction.

c) It is clear that if $\tilde{k}(\underline{z})$ is a local maximum of $\tilde{k}(p)$ there exists a unique value of p that minimizes the capital-labor ratio. If not, by using the same argument as in b), the unique value at which the minimal value of $\tilde{k}(p)$ is realized is $\underline{z}$. In both, cases, K_0/N_0 is the maximal value of the capital-labor ratio. □

Remark. All other cases are impossible.

Proposition 3

a) There exists a unique real number v, $\underline{z} < v < K_0/N_0$, such that with immigration quotas $(s, q) = (\underline{z}, v)$, $k(\underline{z}, v)$ is the minimal value of the capital-labor ratio.

b) There exists a unique real number $\underline{s}$, $\underline{s} > K_0/N_0$, such that with immigration quotas $(s, q) = (\underline{s}, +\infty)$, $k(\underline{s}, +\infty)$ is the maximal value of the capital-labor ratio.

PROOF.

a) A simple computation yields:

$$\frac{\partial k(s,q)}{\partial s} = \frac{I(s)(k(s,q) - s)}{N_0 + \displaystyle\int_s^q I(z)dz} \tag{29}$$

Hence,

$$\frac{\partial k(s,q)}{\partial s} > 0 \iff k(s,q) > s \iff \frac{K_0}{N_0} + \frac{1}{N_0}\int_s^q (z-s)I(z)dz - s > 0 \tag{30}$$

Inspecting (30) reveals that:

- If $q \in [\underline{z}, K_0/N_0)$, then $k(s,q) > s$ for all s in $[\underline{z}, q]$. Then, $k(s,q)$ realizes its minimum at $\underline{z}$, i.e., $k(\underline{z}, q)$.

- If $q \geq K_0/N_0$, then $k(s,q)$ realizes its maximum at a point $s(q) \geq K_0/N_0$. The minimizing value of s is realized either at $\underline{z}$ or q (in which case, $k(s,q)$ is equal to $k(q,q) = K_0/N_0$).

In order to determine the minimum value of the capital-labor ratio, all we need to see is how $k(\underline{z}, q)$ changes with q. Notice that:

$$\frac{\partial k(\underline{z},q)}{\partial q} = I(q)\frac{q - k(\underline{z},q)}{N_0 + \displaystyle\int_{\underline{z}}^q I(z)dz} \tag{31}$$

One has:

$$\frac{\partial k(\underline{z},q)}{\partial q} > 0 \iff q > k(\underline{z},q) \iff \frac{K_0}{N_0} + \frac{1}{N_0}\int_{\underline{z}}^q (z-q)I(z)dz - q < 0 \tag{32}$$

Inspecting (32), one may see that there exists v, $\underline{z} < v < K_0/N_0$ (because $\displaystyle\int_{\underline{z}}^v (z-v)I(z)dz \leq 0$), such that for all $q \leq v$, $\frac{\partial k(\underline{z},q)}{\partial q} \leq 0$, and for all $q \geq v$, $\frac{\partial k(\underline{z},q)}{\partial q} \geq 0$. Hence, $k(\underline{z}, q)$ realizes its minimum at $q = v$.
We are now in position to determine the minimal capital-labor ratio. This minimal value is realized at $(s,q) = (\underline{z}, v)$ since $k(\underline{z}, v) < k(\underline{z}, q)$ for all q, so that, in particular, $k(\underline{z}, v) < k(\underline{z}, \underline{z}) = K_0/N_0$.

b) The proof proceeds along similar lines to that of point a). Let $s \geq \underline{z}$ be fixed. We have:

$$\frac{\partial k(s,q)}{\partial q} = I(q)\frac{q - k(s,q)}{N_0 + \displaystyle\int_s^q I(z)dz} \tag{33}$$

So,

$$\frac{\partial k(s,q)}{\partial q} > 0 \iff q > k(s,q) \iff \frac{K_0}{N_0} + \frac{1}{N_0}\int_s^q (z-q)I(z)dz - q < 0 \tag{34}$$

Notice that when $s > K_0/N_0$, one has always $q > k(s,q)$ for all $q \geq s$. Then, the ratio $k(s,q)$ is maximized by choosing $q = \infty$.

If not, as was seen in point a), the capital labor ratio reaches a minimum at a value $q(s)$. So, there are two potential maximizing choices for q, namely $q = s$ (and the ratio $k(s,s) = K_0/N_0$) or $q = +\infty$.

To determine a maximizing choice for q, we have to study the ratio $k(s,\infty)$. One has:

$$\frac{\partial k(s,+\infty)}{\partial s} = \frac{I(s)(k(s,\infty) - s)}{N_0 + \displaystyle\int_s^{\infty} I(z)dz} \tag{35}$$

We have:

$$\frac{\partial k(s,+\infty)}{\partial s} > 0 \iff k(s,\infty) > s \iff \frac{K_0}{N_0} + \frac{1}{N_0}\int_s^{\infty}(z-s)I(z)dz - s > 0 \tag{36}$$

One can see that there exists $\underline{s} > K_0/N_0$ such that $k(s,\infty)$ reaches a maximum at $s = \underline{s}$. $\square$

APPENDIX 2

In this appendix, we analyze more formally the example given in the text.

Recall that we have assumed that P is a Pareto distribution so that:

$$\tilde{k}(p) = \frac{K_0 + I\frac{\underline{z}^2}{p}}{N_0 + I\frac{\underline{z}^2}{p^2}} \tag{37}$$

It is easy to see that $\tilde{k}(\underline{z}) < K_0/N_0$ if and only if $\underline{z} < K_0/N_0$ which holds true by assumption. Hence condition C_∞ (of appendix 1) is never satisfied.
If $\tilde{k}(.)$ realizes a local minimum at $\underline{z}$, this will be in fact a global minimum[19].
We know that if:

$$\tilde{k}(\underline{z}) > \frac{\int_{\underline{z}}^{\infty} I(z)dz}{I(\underline{z})} \tag{38}$$

there is a local minimum at $p = \underline{z}$ (condition $C_{\underline{z}}$ is satisfied). After a little algebra, this condition reduces to:

$$\frac{K_0 + I\underline{z}}{N_0 + I} > \frac{\underline{z}}{2} \tag{39}$$

or:

$$K_0 > \underline{z}(\underline{z}\frac{(N_0 + I)}{2} - I) \tag{40}$$

We now consider the expression $k(\underline{z}, q)$ obtained with a system of quotas. After a few computations, one gets:

$$k(\underline{z}, q) = \frac{K_0 + 2I\underline{z}^2(\frac{1}{\underline{z}} - \frac{1}{q})}{N_0 + I(1 - \frac{\underline{z}^2}{q^2})} \tag{41}$$

The value of q that minimizes the capital-labor ratio satisfies $q = k(\underline{z}, q)$ which reduces to:

$$L(q) = (N_0 + I)q^2 - q(K_0 + 2I\underline{z}) + I\underline{z}^2 = 0 \tag{42}$$

This equation has always two reals roots[20].

[19] To see this, suppose that contrary to the assumption there exists $\hat{p}$ such that $\hat{p} > \underline{z}$ and $\tilde{k}(\hat{p}) < \tilde{k}(\underline{z})$. Then there is a local extremum and from condition (H), this extremum is a local maximum. This is impossible and we get a contradiction.

[20] To see this, notice that its discrimnant $\triangle$ is such that:

$$\triangle = (K_0 + 2I\underline{z})^2 - 4(N_0 + I)I\underline{z}^2$$

One can see that the highest root q is such that: $\underline{z} < q < K_0/N_0$[21]. Hence, the value of q that we are looking for is the greatest root of the above equation, i.e.

$$q = v = \frac{K_0 + 2I\underline{z} + \sqrt{\triangle}}{2(N_0 + I)} \tag{43}$$

where:

$$\triangle = (K_0 + 2I\underline{z})^2 - 4(N_0 + I)\underline{z}^2 I \tag{44}$$

We can now compare $v = k(\underline{z}, v)$ and $\tilde{k}(\underline{z})$:

$$v - \tilde{k}(\underline{z}) = \frac{1}{2(N_0 + I)}(\sqrt{\triangle} - K_0) \tag{45}$$

The condition $v > \tilde{k}(\underline{z})$ reduces to:

$$K_0^2 + 4IN_0\underline{z}(\frac{K_0}{N_0} - \underline{z}) > K_0 \tag{46}$$

This inequality is satisfied - for instance - whenever $K_0 > 1$.

$$> \quad (\underline{z}N_0 + 2I\underline{z})^2 - 4(N_0 + I)I\underline{z}^2 = \underline{z}^2 N_0^2 > 0.$$

[21]Indeed, $L(\underline{z}) = N_0\underline{z}(\underline{z} - (K_0/N_0)) < 0$. Moreover, $L(K_0/N_0) = I((K_0/N_0)^2 - 2\underline{z}K_0/N_0 + \underline{z}^2)$. But considering the function $\psi(u) = u^2 - 2u\underline{z} + \underline{z}^2$, one sees that $\psi(\underline{z}) = 0$. Since, $\psi'(u) = 2(u - \underline{z})$, this proves that $L(K_0/N_0) > 0$.