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Taxation, Migration, and Pollution

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Abstract

This paper analyzes optimal fiscal, environmental and immigration policy for a single jurisdiction. In the presence of immigration quotas, taxes on the output of externality-producing industries should be higher than indicated by the standard rule for Pigovian corrective taxation. Immigration quotas are not optimal if fiscal instruments can be used to control immigration, and relaxation of immigration quotas generally increases domestic welfare. If optimal taxes are imposed on immigrants, no immigration quota should be imposed, and a version of the traditional Pigovian rule characterizes optimal taxation of domestic externalities. If production in the immigrants' country of origin causes trans-boundary spillovers, domestic welfare can be improved by lighter taxation of immigrants or by further relaxation of immigration quotas.

Keywords: taxation, migration, pollution, quotas vs. tariffs

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I. Introduction

The normative theory of public finance has typically been formulated for the case of a closed economy. Theories of optimum taxation, public goods and externalities (see, e.g., Sandmo (1975)) usually abstract from the international or interregional dimension that such problems may have, or at least do not take explicit account of it. In this paper we combine two extensions of standard public finance theory in order to provide a perspective on some problems that are becoming of increasing concern to policymakers. One is the effect of tax and transfer policy on immigration and the issue of which level of immigration is in the best interest of the host country or region. Another is the effect of domestic policy on the quality of the environmental and other amenities in the presence of trans-boundary externalities such as pollution. We shall argue that these problems are related in an interesting way and that important new insights are gained by considering them in a unified framework.

We assume that immigration comes about through a divergence between the "domestic" and "foreign" levels of welfare, broadly defined to include not only gross earnings but also taking into account taxes, transfers, environmental quality, and other amenities and disamenities.[1] A country with high income, low pollution levels, and other desirable features will therefore be faced with a positive supply of immigrants, and if the immigrants are admitted, one effect of this will be to depress domestic wages and increase profits. The home country can attempt to control immigration either through quantitative restrictions (quotas) or through tax and transfer policies, and we analyze the optimal levels of quotas and taxes, respectively. Depending on the instruments available, these policies will have effects on the distribution of income between domestic residents and immigrants, and in formulating its redistribution policy the government must allow for the fact that immigration changes the size of the tax base.

In the absence of environmental problems or other market failures, the question of an optimal immigration policy would basically be a distributional issue, as discussed, *e.g.*, in Wildasin (1994). However, there are two reasons why immigration may have an important bearing on both the production and welfare costs of pollution and other amenities. If some domestic industries (or the urban areas that agglomerate around them) generate pollution and other negative externalities, increased employment will imply more pollution. One instrument by which the domestic government may attempt to control these negative externalities is through Pigovian taxes, by which production is shifted from polluting to non-polluting industries. However, such a tax will reduce the demand for labor in the externality-producing sector, affecting general labor market conditions. In particular, policies that restrict output and employment may depress the equilibrium wage rate. This will again have an effect on the supply of immigrants, so that there is indeed a connection between these two are as of policy.

Moreover, this is not the whole story of the link between immigration and environmental externalities. The effect of immigration on the immigrants' country of origin is to reduce labor supply there and to increase wages. This will reduce production in that country, including production in industries or urban areas that generate external effects. When there are trans-boundary spillovers, this means that there could be an important offsetting effect on the level of domestic (dis)amenities; although domestic generation of pollution or other externalities would increase with immigration, there would also be reduced spillovers from abroad.[2] An interesting question is therefore whether or not domestic environmental policy should be "stricter" in the presence of immigration and trans-boundary pollution or other spillovers. We discuss this question with reference to the optimal Pigovian tax under alternative assumptions about immigration and tax policy.

Throughout the paper, we consider optimal policies from the point of view of a domestic jurisdiction which takes the policies of other governments as given and which recognizes that by attracting productive resources from abroad it can influence the level of interjurisdictional spillovers. We deliberately refrain from taking a global welfare view of migration, fiscal, and environmental policy. A natural consequence of this viewpoint is that we identify social welfare with the utility of the domestic residents. Although not strictly necessary—one could, *e.g.*, imagine an immigration policy motivated by altruistic attitudes towards the immigrants—this approach allows us to cut through some difficult conceptual issues relating to the appropriate social welfare function for a country with a variable population (see Mansoorian and Myers (1993) and references therein). It also admits of an alternative interpretation of the model in terms of political economy: What kind of immigration, fiscal, and environmental policies would be pursued by a domestic government having regard only for the interests of its own citizens? Interestingly enough, as we shall see, the focus on the welfare of native citizens does *not* necessarily imply that optimal policies will ignore the benefits to immigrants of policies that enhance domestic environmental quality and other local amenities.

For the sake of concreteness and because we believe the issues involved are interesting and important, the discussion in the body of the paper focuses on the case where externalities take the form of environmental pollution and where the jurisdictions between which migration occurs are nations. The basic model is presented in Section II. While we identify the mobile resource with labor, the remarks at the end of Section II show that the model can also accommodate mobile capital. Section III analyzes optimal environmental and fiscal policy when immigration policy takes the form of an immigration quota. Section IV discusses the case where there is no (enforceable) quota and where the amount of immigration is determined by domestic fiscal policies, including environmental taxes. The concluding section summarizes some of the main conclusions, discusses alternative interpretations of the analysis, and identifies some issues for future research.

II. The Model

This section presents the simplest version of the model. As discussed at the end of the section, many of the simplifying assumptions can be relaxed without substantively changing the subsequent analysis and results.

The domestic economy contains two industries, 1 and 2, each of which employs homogeneous labor as the sole variable input in the production process. The production functions for each industry, $f(h_1)$ and $g(h_2)$, are strictly increasing and concave in the amount of labor employed, h_i. Industry 1 produces a standard private good while industry 2 creates or is associated with environmental damage, congestion effects, or other externalities. The externality produced by industry 2 is referred to as "pollution" and is harmful to domestic residents. (Other possible interpretations of the externality are discussed later.) The level of pollution caused by industry 2 is assumed to be proportional to industry output.

Both of the domestically-produced goods are traded at fixed prices on international markets, so that the domestic economy is small and open in this respect.[3] Let good 1 be taken as numeraire, and let p_2 denote the relative price of good 2. Labor is assumed to be freely mobile across sectors, earning a common wage of w in each country. Firms operate competitively both in output and input markets, choosing levels of employment and output to maximize profits. The total profit of the firms in industry 1 is given by $\pi_1 = x_1 - wh_1 = f(h_1) - wh_1$. The firms in industry 2 are assumed to be subject to a per-unit output tax at rate τ, so that their profits are equal to $\pi_2 = (p_2 - \tau)x_2 - wh_2 = (p_2 - \tau)g(h_2) - wh_2$. Profit maximization by these firms yields demand functions for labor in each industry, $h_1(w)$ and $h_2(w, \tau)$. Standard envelope-theorem arguments imply that $\partial h_i/\partial w < 0$ for both i, and that $\partial h_2/\partial \tau < 0$. Furthermore, $\partial \pi_i \partial w = -h_i$ and $\partial \pi_2/\partial \tau = -g$.

There are n identical domestic consumers, with preferences represented by a smooth, strictly quasi-concave utility function $u(c_1, c_2, y)$ defined over consumption (c_1, c_2) of each of the two commodities and the level of domestic pollution, denoted by y; we assume that u is increasing and quasi-concave in (c_1, c_2), and decreasing in y. Each consumer is endowed with one unit of labor, and earns gross wage income of w. Firms are assumed to be owned entirely by domestic residents so that each receives an equal per capita share of the profits of the firms in each industry.[4] Each domestic resident also receives a net per capita transfer of s_n, which may in principle be either positive or negative. This variable represents the net impact of government fiscal policies on the real income of domestic households, including cash benefits such as social insurance payments, family allowances, or unemployment insurance, net of taxes on consumption, earnings and other income. It should also be interpreted to include the cash equivalents of any in-kind government benefits or services, such as the value of education, health care, or transportation.

Under these assumptions, the budget constraint facing each domestic household is

$$c_1 + p_2 c_2 = w + \frac{\pi}{n} + s_n \tag{1}$$

where we define $\pi = \pi_1 + \pi_2$. Consumers choose a consumption bundle (c_1, c_2) to maximize utility subject to (1), taking all prices,policy instruments, and the level of pollution as parametrically given. This yields the indirect utility function $v(w + \pi/n + s_n, y)$, where the dependence of v on p_2 has been suppressed for convenience. The first argument of v is the net income of a representative domestic household, and the derivative of v with respect to this argument, denoted by v_I, is the marginal utility of income. The derivative with respect to y, v_y, is the marginal utility of pollution, u_y, so that v_y/v_I is the marginal rate of substitution between pollution and consumption of numeraire, *i.e.*, $-v_y/v_I > 0$ is the consumer's marginal willingness to pay for pollution reduction.

The number of immigrants is denoted by m. Each immigrant is endowed with one unit of labor, assumed to be perfectly substitutable for domestic labor. Since the analysis focuses on the effect of immigration and fiscal policy on the welfare of domestic residents, it is not necessary to specify the preferences of migrants in detail; it is sufficient to postulate that the supply of immigrants is an increasing function of the net income that they receive in the domestic country and a decreasing function of the level of pollution in the domestic country. The precise form of this functional relationship is not critical to the analysis, and it can thus accommodate such factors as attachment by immigrants to their home country or the pecuniary costs of migration; it also reflects labor market conditions, income and wealth, pollution, and other quality-of-life determinants in the country of origin.

The gross wage rate of an immigrant is w; for simplicity, it is assumed that immigrants have no ownership claims on the net incomes of domestic firms. Net income may differ from gross earnings, w, by the amount of the net fiscal benefits that they receive in the domestic country, denoted by s_m. This net fiscal benefit includes any subsidies that immigrants receive less any taxes that they pay and should be interpreted to include as well the monetized value of any in-kind benefits that they receive. The supply of immigrants to the domestic country is given by $\mu(w + s_m, y)$; letting subscripts denote partial derivatives, we assume $\mu_I > 0 > \mu_y$, where I denotes migrant net income. In particular, the domestic country does not face a perfectly elastic supply of immigrants, except possibly as a limiting case.[5]

The fiscal treatment of immigrants is a complicated matter, and the model allows for different types of policy. At the normative level, there is disagreement as to whether immigrants *should* be subject to identical fiscal treatment with domestic residents. In practice, countries sometimes impose special fiscal burdens on immigrants (e.g., Canada currently assesses a fee on immigrants, the US has recently enacted legislation restricting immigrant access to fiscal benefits). In other instances, there may be *de jure* constraints on non-discriminatory fiscal treatment of immigrants, which may or may not achieved *de facto*. For example, immigrants may be eligible for, but uninformed about, certain types of health care, family allowances, unemployment benefits, or other social benefits, and government bureaus may or may not devote much effort to information and outreach programs that would effectively extend these services to the immigrant population. On the other hand, it is sometimes impossible to exclude immigrants from enjoying certain public services, even if that were considered desirable. Fire and police protection, public health measures, many types of transportation improvements and policies that raise the supply and depress the domestic prices of health services and products, food, housing, and other goods benefit all members of relevant consuming groups on a non-exclusive basis. In view of these complexities, it is of interest to allow for different possible assumptions about the fiscal treatment of immigrants. Considering restrictions on the government's choice of s_m relative to s_n reveals the consequences of fiscal uniformity or discrimination in the treatment of immigrants.

The actual number of immigrants cannot exceed the supply of immigrants, and if there are no (enforced) immigration quotas, the number of immigrants m is equal to the supply $\mu(\cdot)$. However, the home country may impose an immigration quota of $\bar{m}$, in which case the number of immigrants is given by

$$m = min\{\mu(w + s_m, y), \bar{m}\} \tag{2}$$

where the case of no immigration quota corresponds to a level of $\bar{m}$ sufficiently high that the "quota" $\bar{m}$ is never binding.

The total level of domestic pollution y is partly the result of home production in industry 2 and partly the result of production abroad, due to trans-boundary pollution. As noted above, the level of domestically-produced pollution is proportional to the output of industry 2, with a factor of proportionality denoted by α. The level of trans-boundary pollution presumably depends on climate patterns and other geographical features. It also depends, of course, on the level of pollution-generating activities abroad. Immigration transfers productive resources from the foreign to the domestic economy, and would in general tend to decrease the level of pollution generated abroad. The exact nature of the connection between migration and foreign-source pollution presumably depends on the effect of migration on the mix of industrial output and employment abroad, on the regional structure of foreign economic activity, and a host of other factors. For present purposes, however, it is sufficient to assume that the level of trans-boundary pollution is a decreasing function of the level of immigration, $\phi(m)$; the size of the derivative $\phi'(m)$ reflects the combined effect of migration on the level of foreign polluting activities and the transmission of this pollution to the domestic economy through the operation of ecological mechanisms. Thus, the total level of pollution to which domestic residents are exposed is given by

$$y = \alpha x_2 + \phi(m). \tag{3}$$

The total domestic labor supply is given by $n + m$. We assume that the wage rate is flexible, so that there is no unemployment The market-clearing wage is thus determined by the labor market equilibrium condition

$$h_1(w) + h_2(w, \tau) = n + m. \tag{4}$$

In the case where immigration is limited by a binding quota, w is determined as a function of τ and $\bar{m}$ after substituting from (2) into (4). When there is no (binding) quota, equations (2), (3) and (4) simultaneously determine m, w, and y as functions of τ and s_m. Note that s_n does not affect the equilibrium value of w in either case, since it is a lump-sum distribution to the exogenously-fixed population of domestic workers and thus has no effect on labor supply.

The government budget constraint completes the specification of the model. In addition to the taxes and transfers already mentioned, we allow for the possibility that the government may have some other exogenously-fixed expenditure requirement (for example, for the provision of Samuelson-type public goods) in the amount z (denominated in units of numeraire), so that the government budget constraint is

$$ns_n + ms_m + z = \tau x_2. \tag{5}$$

The analysis to follow focuses on the determination of government policy in the presence of migration. Note, however, that the model can be specialized to include the case where no migration is possible. In this case, it is easily verified that the optimal policy is a standard Pigovian corrective tax on the output of industry 2, namely,

$$\tau = -n\frac{v_y}{v_I}\alpha. \tag{6}$$

Generalizations. The foregoing model can be generalized in several important respects without changing any of the analysis or results that follow. Given that outputs are traded at fixed world prices, the restriction to two production sectors is obviously inessential.[6] The model can also accommodate any number of perfectly mobile factors of production, including capital, without any change in the results, provided that these factors are not subject to distortionary taxation. In particular, we can allow for an ideal profits tax; as is well known, such a tax does not distort capital investment or other input decisions and its burden falls entirely on pure profits. As long as the proceeds of any taxes on pure profits are distributed to domestic residents on an equal per capita basis, the fact that domestic residents receive some portion of profits as owners of domestic firms and the remainder as the fiscal beneficiaries of the profits tax is immaterial. Though formally trivial, this extension does allow us to incorporate the case where profits are earned by foreign-owned firms, if those profits are taxed at 100% rate.[7]

Finally, it is worth observing that consumer prices in this model are taken as exogenously fixed, while the factor incomes that households receive are endogenously-determined and dependent on government policy. In this respect, the model reverses assumptions that are commonly imposed in models of optimal taxation.

III. Optimal Policy with Immigration Quotas

For many countries, quotas are a principal means by which immigration flows are controlled. This section examines the optimal use of an immigration quota together with the tax and transfer system to maximize the welfare of domestic residents. In order for a migration quota to be effective, it must be the case that $\mu(w+s_m) \geq \bar{m}$. Whether or not this constraint is binding depends in turn on government fiscal policy; in particular, for given values of other variables, it would always be possible to choose a value for s_m sufficiently low that the quota would not be binding. Whether the quota is binding also depends on the level of the quota itself; no matter how high the real income attainable by immigrants, there is a quota sufficiently large that it would exceed the supply of immigrants and thus would be non-binding. However, our interest at first is to understand the role of the immigration quota *per se*, since we observe such quotas in practice. We therefore begin by assuming that the government is unable to impose a tax (or subsidy) specifically targeted on immigrants, so that $s_m = 0$. This leaves s_n and τ as the only fiscal instruments at the government's disposal. Finally, it is assumed that $\bar{m}$ is initially set at a level sufficiently small that the immigration quota is binding.

The welfare evaluation of government policy must take into account the general equilibrium effects of both taxes and quotas on the economy. These general equilibrium effects can be analyzed by substituting $m = \bar{m}$ into the labor market equilibrium condition (4) and then solving implicitly for the equilibrium wage w as a function of the policy instruments $\bar{m}$ and τ. Define $H = \partial h_1/\partial w + \partial h_2/\partial w$ for notational convenience, and note that $H < 0$ by concavity of the production functions. The derivatives of the implicit function $w(\bar{m}, \tau)$ satisfy

$$\frac{\partial w}{\partial \bar{m}} = \frac{1}{H} < 0, \qquad \frac{\partial w}{\partial \tau} = -\frac{\partial h_2}{\partial \tau}\frac{1}{H} < 0. \tag{7}$$

Furthermore, by repeated substitutions into (3), $y = \alpha g(h_2[w, \tau]) + \phi(\bar{m}) = \alpha g(h_2[w(\bar{m}, \tau), \tau]) + \phi(\bar{m})$, which can be differentiated to yield

$$\frac{\partial y}{\partial \bar{m}} = \alpha g' \frac{\partial h_2}{\partial w}\frac{1}{H} + \phi'(\bar{m}), \qquad \frac{\partial y}{\partial \tau} = \alpha g' \frac{\partial h_2}{\partial \tau}\frac{\partial h_1}{\partial w}\frac{1}{H} < 0. \tag{8}$$

From (7), we see that an increase in the immigration quota depresses the wage, as does an increase in τ. From (8), an increase in the immigration quota has an ambiguous effect on the level of pollution, as domestic pollution rises but trans-boundary pollution falls. Note that in the special case where there are no trans-boundary pollution effects ($\phi' = 0$), an increase in $\bar{m}$ definitely causes an increase in y. Finally, an increase in τ leads unambiguously to a reduction in pollution.

The welfare evaluation of policy is more transparent in this model if we proceed by stages. First, suppose that the government chooses its fiscal policy instruments (s_n, τ) for some arbitrarily-given initial level of immigration. This yields an optimal pollution tax conditional on the level of immigration. Once the rule for the optimal pollution tax is derived, we proceed to the welfare evaluation of immigration policy.

Suppose, then, that the government solves the problem

$$max_{<s_n,\tau>} \quad nv\left(w + \frac{\pi}{n} + s_n, y\right) \tag{P}$$

subject to (5), remembering that $s_m = 0$ in the present case and taking $\bar{m}$ as exogenously given. Forming the Lagrangian $\mathcal{L} = nv + \lambda(\tau x_2 - ns_n - z)$, the first-order conditions for this optimization problem are:

$$\frac{\partial \mathcal{L}}{\partial s_n} = nv_I - n\lambda = 0 \tag{9.1}$$

$$\frac{\partial \mathcal{L}}{\partial \tau} = nv_I\left(\left[1 + \frac{1}{n}\frac{\partial \pi}{\partial w}\right]\frac{\partial w}{\partial \tau} + \frac{1}{n}\frac{\partial \pi}{\partial \tau}\right) + nv_y\frac{\partial y}{\partial \tau} + \lambda\left(g + \tau g'\frac{dh_2}{d\tau}\right) = 0. \tag{9.2}$$

The first of these conditions implies that

$$v_I = \lambda, \tag{10}$$

that is, the marginal utility of income for the domestic households is equal to the shadow value of government revenue. This condition follows because the instrument s_n allows the government to move resources between the public and the private sectors in a lump-sum fashion.

Using (10) and the fact that $\partial\pi/\partial w = -(h_1 + h_2) = -(n + m)$ and $\partial\pi/\partial\tau = -g$, the first-order condition for τ can be written as

$$n\frac{v_y}{v_I}\frac{\partial y}{\partial \tau} + \tau g'\frac{dh_2}{d\tau} - \bar{m}\frac{\partial w}{\partial \tau} = 0. \tag{11}$$

The first term in (11) is the (negative) shadow value, to domestic residents, of the additional pollution induced by a change in the pollution tax. The second term is the fiscal effect of the change in output of the polluting industry arising from a marginal change in policy. The first two terms taken together thus represent the portion of the marginal social cost of pollution caused by a policy change that is not internalized by the pollution tax. The third term explicitly involves the fact that the economy is open to immigration. It represents the loss of wage income to immigrants resulting from an incremental increase in the pollution tax. This loss to the immigrants is a gain to domestic residents. Although a lower wage rate reduces the earnings of domestic residents as well as that of immigrants (for a loss of domestic real income of $n\partial w/\partial\tau$), it raises the profitability of domestic firms by a larger amount by reducing the wage bill for the entire work force (namely, $(\partial\pi/\partial w)(\partial w/\partial\tau) = (n + m)\partial w/\partial\tau$). Since the profits of domestic firms are assumed to accrue to domestic owners, the net effect is to raise the real incomes of domestic residents. Note that this third factor does not appear in the special case where no migration is possible, since then $\bar{m} = 0$.

To derive more detailed implications from (11), substitute from (7) and (8) to obtain

$$\tau = -n\frac{v_y}{v_I}\alpha - \frac{\bar{m}}{g'\partial h_1/\partial w} > -n\frac{v_y}{v_I}\alpha \quad \text{if } \bar{m} > 0. \tag{6$'$}$$

When the domestic economy is closed to immigration ($\bar{m} = 0$), (6′) reduces to the standard Pigovian tax rule (6), which therefore emerges as a special case of our results. More generally, however, *the optimal pollution tax in the presence of a binding immigration quota exceeds that which would internalize the marginal cost of pollution to domestic residents*. As observed above, the reason behind this result is that the pollution tax depresses the domestic wage which effectively redistributes income in favor of domestic residents at the expense of immigrants. Note that the impact of pollution on the welfare of immigrants does *not* enter into (6′). As will be made clear in the next section, this result changes when there are no (binding) immigration quotas.

Now suppose that the government sets τ to satisfy (6′), and consider the effect on domestic welfare of a small change in the immigration quota $\bar{m}$. In general, a change in the level of immigration will change domestic employment and output in both industries as well as the level of government tax revenues. However, the government budget constraint (5) should continue to be satisfied, which means that at least one fiscal variable (*i.e.*, either s_n or τ) should adjust endogenously. To analyze the welfare effect of a change in $\bar{m}$, therefore, one could totally differentiate domestic welfare nv and the government budget constraint (5) and use the results to solve for the desired result. More simply, one can exploit the fact that the government is assumed to have optimized its fiscal instruments, so that it makes no difference, at the margin, how these instruments adjust to satisfy (5). The effect of a change in the immigration quota on domestic welfare can then simply be calculated by differentiating the Lagrangian $\mathcal{L}$ with respect to $\bar{m}$ to obtain

$$\frac{\partial \mathcal{L}}{\partial \bar{m}} = nv_I\left(1+\frac{1}{n}\frac{\partial \pi}{\partial w}\right)\frac{\partial w}{\partial \bar{m}} + nv_y\frac{\partial y}{\partial \bar{m}} + \lambda\tau g'\frac{dh_2}{d\bar{m}}.$$

Making substitutions from (7) and (8) and using (10), the change in domestic welfare with respect to $\bar{m}$, expressed in real income terms, can be written

$$\begin{aligned}\frac{n}{v_I}\frac{dv}{d\bar{m}} &= \left(n\frac{v_y}{v_I}\alpha+\tau\right)g'\frac{\partial h_2}{\partial w}\frac{1}{H} + n\frac{v_y}{v_I}\phi' - \frac{\bar{m}}{H}\\ &= -\frac{\bar{m}}{\partial h_1/\partial w} + n\frac{v_y}{v_I}\phi' > 0 \qquad (12)\end{aligned}$$

where the second equality uses (6′). The sign in (12) holds as long as $\bar{m} > 0$; it holds if there is no trans-boundary pollution (which implies $\phi' = 0$) and *a fortiori*, it still holds when trans-boundary pollution is present (so that $\phi' < 0$). Thus, *provided that pollution taxes are set optimally, an incremental relaxation of the immigration quota always increases domestic welfare*. Of course, it goes without saying that incremental relaxation of the immigration quota also raises the welfare of immigrants, by revealed preference.

What is the intuition behind this conclusion? Essentially, the result is a slightly modified version of a familiar finding from international economics. When a country imposes a quota on an imported good or factor, and when that commodity is not subject to any special taxes, so that the foreign suppliers (the immigrants, in the present case) are able to sell the commodity at the prevailing domestic price, a marginal relaxation of the quota must benefit domestic residents, assuming of course that domestic markets are competitive and that there are no other distortions in the domestic economy. The same is true here provided that the pollution tax has been optimized. In this case, the general equilibrium welfare effects of immigration that operate through the polluting sector of the economy do not overturn the traditional result from first-best analysis. To the extent that immigration can reduce the extent of trans-boundary pollution, the case for a higher level of immigration is even more favorable.

This strong conclusion is potentially important for policy. Suppose that one expects increases in immigration to increase employment and output in polluting industries. One might imagine that this provides an argument for restricting the level of immigration so as to limit the amount of damage to the domestic environment. Although this might be a valid argument when domestic environmental policy is too weak, so that there is excess output from polluting industries, the argument is definitely not valid when domestic environmental policy is optimally set.

If increases in immigration are welfare-enhancing, what is the optimal immigration policy? Evidently, it is to remove the immigration quota entirely. In a more realistic and complex model, the desirability of immigration may be limited by uninternalized externalities of various sorts, including possibly fiscal externalities associated with the provision of unpriced or under-priced services to immigrants. These are important considerations, and the fiscal treatment of immigrants is discussed further below.

Immigrant Taxes vs. Immigrant Quotas

The analysis so far has assumed that the government can make lump-sum transfers to (or impose lump-sum taxes on) domestic residents in choosing s_n, but that immigrants neither contribute to nor benefit from the domestic fiscal system. Consider instead the case where the government can make a per capita transfer s_m to each immigrant, noting that s_m may be negative if the government imposes a tax on immigrants. The level of s_m may determine whether or not an immigration quota $\bar{m}$ is actually binding; in fact, by choosing a value of s_m sufficiently small (large negative), the government could insure that the number of immigrants seeking admission to the country $(\mu(w + s_m, y))$ is less than any specified quota level $\bar{m}$. If, on the other hand, the level of $w + s_m$ is sufficiently high and $\bar{m}$ is sufficiently small that the quota is binding, a small change in s_m has no effect all on the level of immigration. In this case, what is the effect of a small change in s_m on domestic welfare?

To address this question, one can again proceed by stages, considering first how to set fiscal variables optimally for any arbitrarily-given immigration quota, and then going on to examine the effect of an incremental change in the quota itself. Formally, this involves merely adding one more fiscal instrument to the problem (P). The Lagrangian for the new problem is $\mathcal{L} = nv + \lambda(\tau x_2 - ns_n - \bar{m}s_m - z)$. Differentiating $\mathcal{L}$ with respect to s_m shows that

$$\frac{\partial \mathcal{L}}{\partial s_m} = -\lambda \bar{m}. \tag{13}$$

Since the first-order condition for s_n implies that $\lambda = v_I$, this expression is always negative, that is, *in the presence of a binding immigration quota, domestic welfare can always be increased by lowering the transfer that the immigrants receive, or by raising the taxes that they pay*. Of course, raising the taxes paid by immigrants eventually reduces the real income that they receive sufficiently that the supply of immigrants no longer exceeds the immigration quota. Thus, a further implication of (13) is that *if it is possible to subject immigrants to fiscal treatment different from that of domestic residents, it is never optimal to impose a binding immigration quota*.

This result corresponds to the standard conclusion in international trade policy that tariffs welfare-dominate quotas. Any target level of immigration that can be achieved by a quota can also be achieved by imposing a sufficiently high tax on immigrants. The only difference between these two policies is that in the latter case, immigrants must pay domestic taxes, which can only make domestic residents better off. The immigrant transfer s_m can be used to capture quota rents that would otherwise accrue to foreigners, whereupon the immigrant quota becomes a redundant instrument. Like our previous finding that incremental relaxation of immigration quotas always improves domestic welfare, this result suggests the importance of analyzing optimal policy in the absence of immigration quotas, the topic of Section IV.

Equal vs. Unequal Treatment of Immigrants

As indicated earlier, the fiscal treatment of immigrants may well differ from that of native residents, either because of explicit differentiation based on immigrant status or, more indirectly, because of the way that public service and tax systems are structured and administered. On the other hand, discriminatory fiscal treatment of immigrants is sometimes prohibited at least *de jure*, and whether or not this should be the case is debated in many countries. We therefore briefly consider how the analysis changes in this case.

Equal fiscal treatment of immigrants and natives means that $s_n = s_m = s$; subject to this condition, which affects the government budget constraint (5), one can again ask how the government would choose its fiscal instruments (now only s and τ) in order to solve (P), i.e., to maximize the welfare of native residents. Suppose first that there is some fixed and binding immigration quota in place. Formally, the key difference with the previous analysis is that the first-order conditions for (P) no longer include (10), that is, the shadow value of government revenue differs from the marginal utility of income for natives. Indeed, the first-order condition for the choice of s implies that $\lambda/v_I = n/(n+\bar{m}) < 1$, i.e., tax revenue accruing to the government is worth less than income accruing to native residents. The first-order condition for τ becomes

$$n\frac{v_y}{v_I}\frac{\partial y}{\partial \tau} + \tau g'\frac{dh_2}{d\tau} - \bar{m}\frac{\partial w}{\partial \tau} - \frac{\bar{m}}{n+\bar{m}}\frac{d\tau g(h_2)}{d\tau} = 0 \tag{11'}$$

which is identical to (11) except for the presence of the last term. To interpret this term, note that the government budget constraint implies that incremental revenues collected from the pollution tax must be used to increase s, i.e., to increase net fiscal benefit or to reduce net taxes. Since immigrants are treated identically to natives, incremental pollution tax revenues must, in effect, be shared with immigrants rather than directed entirely into incremental transfers to native residents. This "leakage" of revenue from pollution taxes into the hands of non-natives makes the pollution tax less attractive, at the margin, than otherwise. In particular, the inequality in (6′), which puts a lower limit on the optimal pollution tax, is no longer necessarily valid.

Previous literature has examined optimal immigration policy when immigrants are subject to the same fiscal treatment as natives. The basic conclusion of that literature (see, e.g., Wildasin (1994) and references therein) is that immigration benefits natives if immigrants are net fiscal contributors ($s_m < 0$) but that it harms existing residents if immigrants impose net fiscal burdens ($s_m > 0$). Essentially the same considerations come into play in the present setting. In particular, relaxation of immigration quotas need not raise the welfare of native residents under the equal-treatment constraint. Just as the ability to differentiate the fiscal treatment of immigrants and natives implies that it is never optimal to impose binding immigration quotas, so a requirement that natives and immigrants must be treated equally implies that binding immigration quotas may, in some cases, enhance domestic welfare.

IV. Pollution Policy with Optimal Immigration Taxes

As just observed, if the government can apply its fiscal instruments to native residents and immigrants in a discriminatory way, immigration quotas are unnecessary because fiscal instruments dominate quotas from the viewpoint of domestic welfare. This section analyzes optimal policy when the government can choose s_n and s_m independently and immigration quotas can therefore be ignored. As before, we also assume that the government can impose a tax of τ per unit of output in the polluting industry.

The analysis of fiscal policy in this setting must take into account the interdependence of pollution and migration levels. Migrants influence the level of domestic pollution y through their impact on employment in the domestic polluting industry as well as through their impact on trans-boundary pollution. We have also assumed, however, that the supply of immigrants to the domestic country depends on environmental quality there. Pollution and migration levels are thus simultaneously determined.

Formally, this interdependence is captured by substituting $x_2 = g(h_2[w, \tau])$ into (3) and $m = \mu(w + s_m, y)$ into (3) and (4), thus forming a system of two equations determining the equilibrium levels of the endogenous variables (w, y) in terms of the policy parameters (τ, s_m). (Note that s_n does not enter this system, so that the equilibrium levels of employment, output, pollution, and wages are independent of it.) Total differentiation of (3) and (4) yields

$$\begin{bmatrix} 1-\phi'\mu_y & -\alpha g'\frac{\partial h_2}{\partial w} - \phi'\mu_I \\ -\mu_y & H-\mu_I \end{bmatrix} \begin{bmatrix} dy \\ dw \end{bmatrix} = \begin{bmatrix} \phi'\mu_I & \alpha g'\frac{\partial h_2}{\partial \tau} \\ \mu_I & -\frac{\partial h_2}{\partial \tau} \end{bmatrix} \begin{bmatrix} ds_m \\ d\tau \end{bmatrix}. \tag{14}$$

The determinant of the matrix on the left-hand side is

$$A = (1-\phi'\mu_y)H - \mu_I - \mu_y \alpha g' \frac{\partial h_2}{\partial w}. \tag{15}$$

We assume, as is reasonable,[8] that

$$1 - \phi'\mu_y > 0 \tag{16}$$

from which it follows that $A < 0$. One can then calculate the comparative statics response of (y, w) to the policy parameters (s_m, τ):

$$\frac{\partial w}{\partial s_m} = \frac{\mu_I}{A} < 0 \qquad \frac{\partial w}{\partial \tau} = \frac{\alpha g'\mu_y - (1-\phi'\mu_y)}{A}\frac{\partial h_2}{\partial \tau} < 0 \tag{17.1}$$

$$\frac{\partial y}{\partial s_m} = \frac{(\alpha g'\frac{\partial h_2}{\partial w} + \phi' H)\mu_I}{A} \qquad \frac{\partial y}{\partial \tau} = \frac{\alpha g'(\frac{\partial h_1}{\partial w} - \mu_I) - \phi'\mu_I}{A}\frac{\partial h_2}{\partial \tau}. \tag{17.2}$$

As expected, an increase in subsidies to migrants depresses the equilibrium wage, as shown in (17.1). A higher tax on pollution depresses the wage; *cf.* (7)). A larger transfer to immigrants increases domestic pollution but this effect could in principle be offset by a sufficiently large reduction in trans-boundary pollution, so that the impact is theoretically ambiguous in sign. A higher pollution tax reduces domestic pollution; it also discourages immigration and thus increases trans-boundary pollution. Its impact on the domestic environment is thus also ambiguous. If trans-boundary pollution effects are small, however, $\partial y/\partial s_m > 0 > \partial y/\partial \tau$.

The government optimization problem, as before, is to maximize domestic welfare subject to the budget constraint (5). The Lagrangian for this problem is $\mathcal{L} = nv(w + s_n + \pi/n, y) + \lambda(\tau g - s_n n - s_m m - z)$. The first-order condition for s_n again yields (10); in addition, we have

$$\frac{\partial \mathcal{L}}{\partial s_m} = -mv_1 \frac{\partial w}{\partial s_m} + nv_y \frac{\partial y}{\partial s_m} + \lambda \left(-m - s_m \left[\mu_I \left(1 + \frac{\partial w}{\partial s_m} \right) + \mu_y \frac{\partial y}{\partial s_m} \right] + \tau g' \frac{dh_2}{ds_m} \right) = 0 \tag{18.1}$$

$$\frac{\partial \mathcal{L}}{\partial \tau} = v_I \left(-m \frac{\partial w}{\partial \tau} - g \right) + nv_y \frac{\partial y}{\partial \tau} + \lambda \left(-s_m \left[\mu_I \frac{\partial w}{\partial \tau} + \mu_y \frac{\partial y}{\partial \tau} \right] + g + \tau g' \frac{dh_2}{d\tau} \right) = 0. \tag{18.2}$$

These expressions simplify somewhat using (10). One can solve (18.1) for s_m and then substitute into (18.2). Substitution from the comparative-statics results in (17) and substantial algebraic manipulation (see Appendix) establishes that

$$\left(n \frac{v_y}{v_I} + m \frac{\mu_y}{\mu_I} \right) \alpha + \tau = 0. \tag{6''}$$

Using this result in (18.1) and further substitutions show in addition that

$$-s_m + \left(n \frac{v_y}{v_I} + m \frac{\mu_y}{\mu_I} \right) \phi' = \frac{m}{\mu_I}. \tag{19}$$

Although (6″) and (19) must hold simultaneously, it is helpful to think of (6″) as the policy rule for determining the optimal pollution tax and to think of (19) as the rule for the optimal fiscal treatment of immigrants.

Condition (6″) is very similar to the standard Pigovian formula for a corrective pollution tax, (6). The difference between the two is that (6″) includes also the marginal cost of pollution to immigrants, $m\mu_y/\mu_I$.[9] Indeed, one might simply view (6″) as the extension of the first-best Pigovian rule to allow for the effects of environmental quality on immigrant welfare. While reasonable, the result is still surprising in at least two respects. First, optimal policy in our model is designated to maximize the welfare of domestic residents *only*; the welfare of immigrants per se has been explicitly *excluded* from the objective function of policymakers. Why should optimal policy reflect the preferences of "outsiders" whose welfare is a matter of indifference to policymakers? Second, although the valuation of the environment by immigrants enters into the formula for the optimal pollution tax (6″), it does *not* enter into the optimal tax rule (6′) for the case considered in Section III where the government uses immigration quotas, even though we have made *no* change in our assumptions about the evaluation of the environment by immigrants. If immigrant valuations of pollution enter into the optimal pollution tax rule in one case, why not in the other?

The answers to these questions are related to the optimal taxation of immigrants. The first term on the left-hand side of (19), $-s_m$, is the direct fiscal contribution of an additional immigrant. The second term on the left-hand side of (19) is the benefit to both domestic residents and to the immigrant population of the reduction in trans-boundary pollution that results from one additional immigrant. The term μ_I^{-1} on the right-hand side of (19) is the derivative of the inverse supply function of immigrant labor, that is, the increase in the domestic wage that must occur in order to attract one additional immigrant. Adding an additional immigrant requires an increase in the earnings of all workers, and this entails a net loss of real income to the domestic population equal to the size of the immigration population, m, times the change in the domestic wage. Thus, the term on the right-hand side of (19) is the cost to domestic residents resulting from a one-unit increase in the level of immigration. Hence, (19) implies that the fiscal and trans-boundary pollution benefits of an additional immigrant should be equated to the loss of real income resulting from the more favorable terms that must be offered if one additional immigrant is to be attracted to the domestic economy from abroad.

The interpretation of (19) is particularly transparent when there is no trans-boundary pollution. In this case, letting $w_m = w + s_m$ denote the net income of an immigrant and letting $\epsilon_s = w_m \mu_I / m$ denote the elasticity of the immigrant supply curve, (19) reduces to

$$-\frac{s_m}{w_m} = \frac{1}{\epsilon_s}, \tag{20}$$

that is to say, *the proportional rate of taxation on immigrant income should be equal to the inverse of the elasticity of immigrant supply*. This result is familiar from international trade theory: it is simply the rule for the optimal "tariff"—in this case, the optimal immigrant tax—for a country that is open but not small with respect to external markets. (If the elasticity of supply is very large, as would be true if the country is relatively small in the international market for immigrant labor, the optimal tax on immigrant's income is small; in fact, it approaches zero as the supply becomes infinitely elastic. In this "small, open" case, the best domestic policy is simply to allow immigrants to enter freely, until the domestic wage is reduced to that abroad.)

The reason why the preferences of immigrants for environmental quality enter into condition (6″) for optimal pollution policy is now apparent. In a regime of optimal fiscal treatment of immigrants, immigrant labor is a source of rents to the domestic economy; loosely speaking, the greater the supply of immigrant labor, the greater the opportunity to capture rents from immigrants through the use of fiscal instruments. Domestic policy makers do not care about the welfare of immigrants per se, but they do care about the supply of immigrants, which affects the domestic labor market and the domestic fiscal system. They should therefore take the *preferences* of immigrants into account, even if they do not take their *welfare* into account. These considerations do *not* apply in the case of binding immigrant quotas, which imply an excess supply of immigrants at the prevailing net wage. In this case, any benefits to immigrants from improvements in domestic environmental quality only increase the quota rents that accrue to immigrants, which does not enhance domestic welfare. Hence the optimal pollution tax rule in the quota case, (6′), ignores the effect of pollution on immigrants.

In popular debate, immigration tolls are often regarded as onerous impositions on immigrants, and in the present analysis they do indeed represent transfers of income from immigrants to domestic residents. But it is interesting to observe that they also create an incentive for the domestic country to be responsive to immigrant preferences in a way that is absent when immigration is quota-constrained. There is a parallel here with the literature of club theory and local public goods, in which it is often assumed that local jurisdictions are like atomistic firms, facing a perfectly elastic supply of potential residents at an exogenously determined level of utility (localities are "utility-takers"). In such circumstances, the motivation of localities to maximize land rents or some measures of club "profits" induces efficient provision of local public goods as well as efficient local taxation.[10] In the present analysis, the domestic country similarly has an incentive to follow an environmental policy that meets efficiency criteria incorporating immigrant welfare, although the country is *not* atomistic and actually faces an upward-sloping labor supply curve.

V. Extensions and Conclusions

The foregoing analysis has established conditions under which immigration and trans-boundary spillovers can affect a country's optimal pollution taxes, and it has examined the optimal immigration policy in the presence of pollution. (We remind the reader that "optimal" here means optimal from the viewpoint of a jurisdiction's native residents.) When an immigration quota is imposed, domestic welfare is maximized by ignoring the effects of pollution on immigrant welfare; furthermore, pollution taxes will be set at levels higher than suggested by standard first-best welfare criteria. However, immigration quotas are generally inferior policy instruments when non-uniform fiscal treatment of native and immigrant households is administratively and politically feasible. Provided that domestic environmental policy is optimally structured, it is welfare-improving to eliminate quotas, or to establish the fiscal treatment of immigrants in such a way as to render any quotas non-binding. When a country does not impose immigration quotas, optimal fiscal treatment of immigrants requires taking into account the effect of immigrants on trans-boundary pollution and on the terms-of-trade with respect to the rest of the world. If these objectives are pursued in an optimal fashion, domestic environmental policy may be set according to standard Pigovian principles—including, now, the impact of pollution on immigrants as well as domestic residents. In particular, even in the presence of trans-boundary pollution, there is no rationale for relaxation of domestic pollution controls in order to promote immigration and thus reduce the amount of pollution generated abroad.

As indicated briefly in the introduction, the preceding analysis lends itself to a variety of interpretations. For instance, industry 1 could represent the agricultural sector of an economy with industry 2 representing the urban sector. The assumption that labor is freely mobile between industries then also means that there is free migration between rural and urban areas. The "pollution" associated with industry 2 could be interpreted to include all sorts of externalities associated with urbanization, including not only pollution itself but also congestion, crime, or other urban disamenities; of course, some of these externalities could also be positive rather than negative. Although we have emphasized the application of our analysis in the international context, it can also shed light on the relationships between internal migration and local fiscal and development policy *within* a country. Think of the suburbs surrounding a central city in a metropolitan area as the "home country" in our model. Suburban governments cannot usually control "immigration" from central cities directly, but they can and do limit population growth through land-use controls (see, e.g., Brueckner (1995)). Suburban residents encounter traffic congestion, crime, environmental pollution, and other disamenities both in the suburban areas where they reside and in the cities where they work and shop. The disamenities that suburban residents experience in cities are a form of interjurisdictional spillover or "trans-boundary pollution."

In trade-theory terms, the immobile factors in our model are industry-specific factors. As a variation on the model, we could follow the Heckscher-Ohlin-Samuelson tradition of assuming that all factors are intersectorally mobile.[11] By the Rybczynski theorem, an increase in immigration would then raise output of the labor-intensive sector and *reduce* that of the capital intensive sector. If the labor-intensive sector were non-polluting, domestic pollution would *fall* as immigration increases. These effects, which cannot arise in the present model, present interesting questions for future research on regional development and environmental impact.

It is perhaps unconventional to link international migration, environmental issues, and tax and transfer policy as we have done here. We nevertheless believe that it is appropriate and useful to do so, both from a normative and from a predictive viewpoint, because public policies in these areas all affect wages, employment, and the distribution of income in important ways. The impacts of migration on labor markets, on the fiscal system, on public goods and service utilization, and on local amenities and environmental quality (including a wide array of "neighborhood" effects) often dominate public debates about migration policy. The effects of taxes and public spending on economic development, growth, and the distribution of income, including the extent to which public programs confer net benefits on migrants, are crucial considerations in fiscal policy debates. And, finally, environmental policy debates often revolve around the effects of environmental taxes, fines, and regulations on economic development, employment, wages, land values, and profits. It is thus apparent that migration, environmental, and fiscal policies are closely interrelated in their consequences, if not in their formulation.[12] It should of course be borne in mind that international migration and environmental quality are rather sluggish variables in comparison to international flows of some goods and services or financial capital, and the long-run consequences of economic policies are sometimes neglected in popular debates. To interpret our analysis appropriately in the context of international migration issues, it is important to keep in mind that the time-frame of the analysis is likely to be rather long.

One limitation of our analysis is that it provides only a passive role for the source country from which immigrants and trans-boundary pollution emerge. An analysis of the simultaneous determination of policy in both countries would clearly be valuable. A natural approach to that problem would be to suppose that the countries play a Nash non-cooperative game in their respective policy instruments, so that each, in equilibrium, is acting optimally given the policies of the other. The present analysis could be viewed as a first step in this larger research program, since our analysis of optimal policy for the domestic country can be regarded as the formulation of a best reply to the policies of the other country, which have been taken as exogenously fixed throughout this paper.

In conclusion, it may be helpful to put our analysis into a broader context. In Europe, many of the industries of the former communist countries use obsolete and environmentally-harmful technologies, and these industries produce large amounts of trans-boundary pollution. Many of these industries are not competitive even in the absence of effective environmental control, so the imposition of environmental regulations or taxes would exacerbate already severe employment problems for workers. Under these conditions of slack labor markets, it is not surprising to find that many workers seek to migrate to the countries of Western Europe. One of the probable benefits of greater East-West migration is that more of the environmentally-costly plants in the East might close. However, East-West migration can impose burdens on the destination countries, which may thus be reluctant to relax their immigration quotas. At least in part, there is concern that immigrants may impose fiscal burdens on host countries, as well as affecting labor markets and real wages there.[13] Our analysis does not allow us to draw conclusions about optimal policy in particular real-world cases, but it does show that a country's optimal immigration policy depends on the interaction between immigration and trans-boundary pollution, on the one hand, and on the use of optimal tax/transfer policies with respect to the immigrant population, on the other. Explicit analysis of the inter-relationships between these policy questions can help to identify the real tradeoffs that societies face, and can contribute to the formulation of more informed policies.

Appendix

This Appendix explains the derivation of equations (6″) and (19) in the text.

First, use (10) and divide through the first-order conditions for s_m and τ by v_I, eliminating λ. Using (17) and (18.2) and multiplying through by $A/(dh_2/d\tau)$ yields

$$\begin{aligned}&-m(\alpha g'\mu_y - [1-\phi'\mu_y]) + \frac{nv_y}{v_I}\left(\alpha g'\frac{\partial h_1}{\partial w} - [\alpha g' + \phi]\mu_I\right)\\&\quad -s_m\mu_I(\alpha g'\mu_y - [1-\phi'\mu_y]) - s_m\mu_y\left(\alpha g'\left[\frac{\partial h_1}{\partial w} - \mu_I\right] - \phi'\mu_I\right)\\&\quad +\tau g'\left(A + [\alpha g'\mu_y - (1-\phi'\mu_y)]\frac{\partial h_2}{\partial w}\right) = 0. \qquad \text{(A.1)}\end{aligned}$$

Substituting for A from (15), the last term in (A.1) simplifies. Gathering terms in s_m and cancelling, (A.1) yields

$$-m(\alpha g'\mu_y - [1-\phi'\mu_y]) + n\frac{v_y}{v_I}\left(\alpha g'\frac{\partial h_1}{\partial w} - [\alpha g' + \phi']\mu_I\right)$$
$$-s_m\left(\mu_y\alpha g'\frac{\partial h_1}{\partial w} - \mu_I\right) + \tau g'\left([1-\phi'\mu_y]\frac{\partial h_1}{\partial w} - \mu_I\right) = 0. \quad \text{(A.2)}$$

For notational simplicity, define

$$M = n\frac{v_y}{v_I} + m\frac{\mu_y}{\mu_I}.$$

We can then write (A.2) as

$$-(\alpha M + \tau)g'\mu_I + \left(\alpha M + \tau - m\alpha\frac{\mu_y}{\mu_I} - s_m\alpha\mu_y - \phi'\mu_y\tau\right)g'\frac{\partial h_1}{\partial w}$$
$$-\mu_I\left(M\phi' - \frac{m}{\mu_I} - s_m\right) = 0. \quad \text{(A.3)}$$

Next, substituting from (17) into (18.1), and multiplying through by A/μ_I yields

$$-m\left(1 + \frac{A}{\mu_I}\right) - s_m\left(\mu_I\left[1 + \frac{A}{\mu_I}\right] + \mu_y\left[\alpha g'\frac{\partial h_2}{\partial w} + \phi' H\right]\right)$$
$$+\frac{nv_y}{v_I}\left(\alpha g'\frac{\partial h_2}{\partial w} + \phi' H\right)\frac{A}{\mu_I} + \tau g'\frac{\partial h_2}{\partial w} = 0. \quad \text{(A.4)}$$

Substituting for A from (15) yields

$$-\frac{m}{\mu_I}\left([1-\phi'\mu_y]H - \mu_y\alpha g'\frac{\partial h_2}{\partial w}\right) - s_m H + n\frac{v_y}{v_I}\left(\alpha g'\frac{\partial h_2}{\partial w} + \phi' H\right) + \tau g'\frac{\partial h_2}{\partial w}. \quad \text{(A.5)}$$

Rearranging,

$$(\alpha M + \tau)g'\frac{\partial h_2}{\partial w} + \left(M\phi' - \frac{m}{\mu_I} - s_m\right)H = 0. \quad \text{(A.6)}$$

Now solve (A.6) for

$$-\frac{m}{\mu_I} - s_m = -M\phi' - \frac{(\alpha M + \tau)g'\partial h_2/\partial w}{H} \quad \text{(A.7)}$$

and substitute into (A.3). Multiplying through by H/g' yields

$$-(\alpha M + \tau)H\mu_I + (\alpha M + \tau)H\frac{\partial h_1}{\partial w} - \alpha\mu_y(\alpha M + \tau)g'\frac{\partial h_1}{\partial w}\frac{\partial h_2}{\partial w} - \alpha\mu_y M\phi' H\frac{\partial h_1}{\partial w}$$
$$-\phi'\mu_y\tau H\frac{\partial h_1}{\partial w} + \mu_I(\alpha M + \tau)\frac{\partial h_2}{\partial w} = 0. \quad \text{(A.8)}$$

Collecting terms in $\alpha M + \tau$, (A.8) yields

$$(\alpha M + \tau)\frac{\partial h_1}{\partial w}A = 0 \quad \text{(A.9)}$$

which implies (6″) since $\partial h_1/\partial w < 0$ and $A < 0$ by (16). Given (6″), (19) follows immediately from (A.7).

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Notes

1. When the jurisdictions between which migration occurs are nations, it is natural to use terms like "immigration," "foreign," etc. and we often use these terms for concreteness. However, as discussed further below, the issues under study also arise in the context of internal migration, in which the jurisdictions in question would correspond to state/provincial governments or local governments.
2. Though our analysis does not *require* the existence of trans-boundary pollution, it does allow for it. A number of authors (*e.g.*, Mäler (1991) and Burtraw (1993)) have studied trans-boundary pollution problems. The buildup of greenhouse gases and the danger of global warming is one obvious example of trans-boundary pollution, but there are many others. For example, data reported in Newbery (1990, p. 303) show net imports or exports of sulfur dioxide pollution in Europe. In 1987, of the 307,000 tons of depositions in Scandinavia whose origin could be traced, only some 59,000 tons, or 19%, originated in the Scandinavian countries themselves. Nearly as much (16%) reached Scandinavia from the (then) German Democratic Republic, 14% came from Poland, and another 11% came from the (then) Soviet Union. Since much of the intra-Scandinavian SO_2 must have flowed from one Scandinavian country to another, and since a disproportionate share of the "undocumented" pollution (SO_2 deposited in Scandinavia whose origin is undetermined) probably originates outside of the region, it is clear that a very large fraction of sulfur pollution in Scandinavian countries originates outside of their borders. As discussed further in the conclusion, liberalization of migration policies in Western Europe could facilitate the restructuring of industrial production in Eastern Europe, including the closing of environmentally-damaging plants.
3. See Markusen (1975) for an early analysis of optimal tariff and tax policy for an economy that experiences trans-boundary pollution and that is open but may not be small. Markusen shows how standard optimal tariff arguments must be modified when the trade policy of a large open economy has significant effects on the output of polluting trading partners.
4. As discussed further below, the assumption of domestic ownership is equivalent to the assumption of foreign ownership coupled with 100% profit taxation, with the proceeds of the profits tax distributed to domestic residents on an equal per capita basis. Exclusively domestic ownership of profits is one of several ways in which domestic residents differ from immigrants in our model. It may be noted that certain global efficiency results can be established in the special case where immigrants and domestic residents are identical (Wellisch, 1994; 1995).
5. Thus, while the domestic country is "small" with respect to the markets for traded goods, is not necessarily small relative to the external labor market; these assumptions are consistent with the notion that output markets are more fully integrated, perhaps on a global scale, than labor markets.
6. With many goods, however, one could examine more explicitly the detailed structure of commodity taxation, a topic examined in recent analyses of optimal taxation with tourism such as Hämäläinen (1996) (and references therein).

7. Oates and Schwab (1988) discuss the role of local capital taxes, as well as regulation, in a model with pollution, focusing on a one-sector model in which a uniform tax on capital can serve as an indirect tax on pollution. Bovenberg and de Mooij (forthcoming) considers interactions between capital taxes and explicit environmental taxes in a one-sector setting; like Oates and Schwab, and in contrast to the present analysis, labor is treated as immobile. It would be of some interest to extend the present two-sector model to allow for distortionary taxes on capital; for example, in the Harberger tradition, one sector could be interpreted as the corporate sector of the economy, subject to a distortionary tax on capital income, while the other is the untaxed non-corporate sector.
8. An additional immigrant changes the amount of trans-boundary pollution by $\phi' < 0$. This makes the country a more attractive place to reside, increasing the level of migration by μ_y (holding other factors constant). Condition (16) insures that this self-reinforcing effect of migration is not so strong as to make the system unstable. In particular, (16) *must* hold if either migrants are insensitive to pollution ($\mu_y = 0$) or there is no trans-boundary pollution ($\phi' = 0$).
9. Totally differentiating $\mu(I, y) =$ constant shows that $dI/dy = -\mu_y/\mu_I$ is the change in income that would keep the level of immigration fixed in the face of an incremental increase in y, that is, it is the marginal cost to each immigrant of incremental environmental damage. (This type of relationship underlies empirical studies that estimate the values of environmental and other (dis)amenities using hedonic wage/compensating differential methods; see, *e.g.*, Rosen (1986) for discussion and references to the literature.)
10. See, e.g., Berglas and Pines (1981), Wildasin (1986, sec. 4.3) and references therein.
11. We thank Søren Bo Nielsen and Lars Sørgard for suggesting this idea.
12. Recent discussions (e.g., Bovenberg and Cnossen (1995), Goulder (1995), and references therein) have emphasized the connections between environmental and other aspects of fiscal policy, including distortionary taxes on labor. Nielsen *et al*. (1995) study environmental policy in a model with unemployment, and Rauscher (1995) examines the location of industrial activity and environmental policy.
13. Many of these concerns arise also in the case of migration from Mexico (and elsewhere in Latin America) to the US, as became apparent during the intense debate over the North American Free Trade Agreement. See Hufbauer and Schott (1992) and Martin (1993) for discussion of pollution and migration issues in relation to NAFTA.

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