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## Migration and pollution

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# **MIGRATION AND POLLUTION<sup>\*</sup>**

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## **Abstract**

We explore the links between migration of labour and location specific (urban) pollution, suggesting a sense in which pollution can be welfare improving. In a conventional Harris-Todaro model of urban-rural migration, individuals migrate so as to equate the expected urban wage (given a downward rigid real wage in the urban sector) to the real wage. Unemployment is endogenously determined. Interpreting unemployment as damage, urban pollution (damage denoted in units of labour) can also support the same equilibrium with the value of damage equal to the value of resources otherwise lost through unemployment. However, if the damage function implies an uninternalized externality (due to urban congestion, for instance), an internalization gain can be realized through the use of a Pigouvian tax (or instrument) that discourages migration. Thus if pollution is introduced into a Harris-Todaro model with no such features, environmental damage displaces unemployment to support a similar outcome. Internalizing the externality then yields a welfare gain. We characterize the optimal Pigouvian tax in such a case and show that it is, in general, non-zero. In this sense, then, pollution can be welfare improving perhaps suggesting an alternative view of congestion and other adverse environmental effects facing urban dwellers in the developing world.

**JEL Classification: O1,O18,J6,Q21**

**Keywords:** Migration, Damage, Pollution, Unemployment

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## **I. Introduction**

The idea that introducing or intensifying pollution can, in certain circumstances, increase welfare seems at first glance odd, if not strongly counter intuitive. In this paper, however, we show how in a Harris-Todaro (1970) model of rural-urban migration, pollution that is concentrated in the urban area can serve to substitute for urban unemployment and can in certain circumstances be beneficial when the comparison is to a with unemployment equilibrium. Essentially, the argument is that if migrants take into account the money metric welfare equivalent of damage in their migration decisions, then introducing pollution in urban areas will tend to reduce urban unemployment. We show that where damage is denominated in units of labor (such as travel time lost to congestion), for any given Harris-Todaro equilibrium with no damage there exists a damage level giving the same equilibrium allocation of labor in the urban and rural sectors, but with no unemployment. Damage merely substitutes for unemployment both in the migration decision and in the full employment condition in the labor markets.<sup>1</sup>

We then argue that, given this equivalence, we can formulate an explicit damage function generating the damage level needed for equivalence to the no pollution Harris-Todaro unemployment equilibrium. If we use an exponential damage function defined over the amount of labor in the urban sector (reflecting congestion costs), the power in the function gives the ratio between marginal and average damage. This represents an uninternalized externality, and welfare gains can be achieved relative to the market (uninternalized) equilibrium by using an internalization mechanism such as a Pigouvian migration tax. For this to be the case

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<sup>1</sup> For a recent discussion of other alternative approaches to modelling the incentives for rural-urban migration in the Harris-Todaro model see Agesa (2000).

the downward rigid urban real wage in the Harris-Todaro formulation must be allowed to vary.

In this sense, then, pollution can serve to be welfare improving by first displacing resource wasteful activities such as unemployment, and secondly by creating opportunities for further gains through the internalization of external effects. While only a possibility, the thrust of the argument is that urban specific congestion and degradation, while distasteful to most people, nevertheless has the benefit in some developing countries of slowing urban migration driven by non-market interventions tilted in favor of urban employees as discussed by Harris and Todaro.

## II. The Models

Consider a small open economy facing fixed world prices of the two goods it produces – an agricultural good ( $A$ ) and a manufactured good ( $M$ ). Amounts of the two goods are denoted by  $Q_A$  and  $Q_M$  respectively. The relative price of agricultural goods in terms of manufactured goods is  $p$  and is taken as being determined in world markets.

The production function for the agricultural sector is:

$$Q_A = F_A(T_A, L_A) \quad (1)$$

where  $T_A$  is a fixed factor – land and  $L_A$  is labor.

Similarly, the output of the manufacturing sector is:

$$Q_M = F_M(K_M, L_M) \quad (2)$$

where  $K_M$  is capital in the manufacturing sector, and  $L_M$  is labour. Labour is the sole mobile factor across sectors. The two other factors are fixed, and sector specific.

### The Harris-Todaro version of the Model

In a traditional Harris-Todaro (1970) model the labour market equilibrium condition is written as:

$$\bar{W}_M \left( \frac{L_M}{L_M + U} \right) = p \frac{\partial F_A}{\partial L_A} \quad (3)$$

where  $\bar{W}_M$  is the fixed urban wage and  $U$  is unemployment. The left hand side of (3) represents the expected wage and the right hand side represents the agricultural wage (equal to the value marginal product of labor in agriculture). This is the Harris-Todaro equilibrium migration condition.

Profit maximizing producers in the urban sector hire labour until the marginal product of labor in this sector equals the fixed urban wage, i.e.

$$\bar{W}_M = \frac{\partial F_M}{\partial L_M} \quad (4)$$

Labour market clearing requires that

$$L_M + L_A + U = \bar{L} \quad (5)$$

where  $\bar{L}$  is the total availability of labor.

Equations (3), (4) and (5) provide a system of three equations in three unknowns,  $L_A$ ,  $L_M$  and  $U$ , given the supply of land in agriculture and capital in the urban sector; the well-known Harris-Todaro model. The downward rigid real wage in the urban sector generates sector specific unemployment; government intervention to discourage migration is merited.

Relative to the earlier Lewis (1954) model which was taken to support trade protection of the modern sector to draw surplus labour receiving its average not marginal product out of the traditional sector, surplus labour (unemployment) in the Harris Todaro model is in the urban not the rural sector. Trade protection which

typically serves to promote the size of the manufacturing sector (if the country is a net importer of manufactures) will increase unemployment and compound traditional welfare costs of protection. Harris and Todaro also discussed restrictions on internal migration within countries as a welfare improving policy in such circumstances.

### **The Equivalent Pollution Model**

Given the Harris-Todaro structure, we can also formulate a closely related model of urban rural migration in which environmental damage is sector (location) specific, and its costs to workers enter the migration decision for labour. In such a model, sector specific environmental damage operates similarly to unemployment in deterring migration to the urban sector.

For simplicity, suppose that there is pollution only in the urban sector and the damage from pollution is denominated in units of labour. Pollution can thus be thought of as reducing the efficiency of labour employed in the urban sector through congestion, poor air quality, higher incidence of disease and other externality effects. The costs of such damage are borne fully by urban workers. Urban firms pay a wage equal to the marginal product of labour but the effective wage (in money metric terms) received by workers is the wage net of the average damage inflicted.

We consider an equilibrium in which the per worker cost of pollution (or damage) in the urban sector is exactly equal to the expected costs of unemployment in the Harris-Todaro model. The differential between urban and rural wage rates will now equal average damage per urban worker. As differing amounts of damage will be associated with differing levels of migration we also need to remove the fixed urban wage which we now allow to vary.

Thus, instead of equation (5) we will now have a market clearing condition in the labour market

$$L_M + L_A + D = \bar{L} \quad (5')$$

where  $D$  is urban environmental damage denominated in units of labour. From the production side the urban wage again equals the marginal product of labor, and we have

$$W_M = \frac{\partial F_M}{\partial L_M}. \quad (4')$$

However, in this case, the new labor market equilibrium condition is

$$W_M \left( \frac{L_M}{L_M + D} \right) = p \frac{\partial F_A}{\partial L_A} \quad (3')$$

(3'), (4') and (5') again provide equilibrium conditions for the three unknowns:  $L_A$ ,  $L_M$  and  $W_M$ .

In this formulation,  $D$  can be chosen in such a way that its labour equivalent exactly equals unemployment, and the value of  $W_M$  in this model is exactly equal to the fixed urban wage  $\bar{W}_M$  in the earlier Harris-Todaro model. The two models are thus equivalent in generating the same equilibrium outcome. Environmental damage displaces unemployment, or alternatively unemployment in Harris-Todaro models can be reinterpreted as damage.<sup>2</sup>

### III. Optimal Policy in the Equivalent Damage Model

The equilibrium solution for the pollution equivalent model is, however, not production efficient in the Pareto sense since there is now an externality that can be internalized. To see this, we can characterize Pareto efficiency and the associated

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<sup>2</sup> Other recent literature has focused on tax issues rather than environmental issues in the context of rural-urban migration in the Harris-Todaro model; see Gupta (1993), Partridge and Rickman (1997), Bhatia (2002) and Chau and Khan (2001).

Pigouvian tax needed to support an efficient allocation as a market outcome. For analytical tractability we consider the exponential damage function  $D = L_M^\lambda$ .<sup>3</sup>

Thus, a Pareto efficient allocation can be characterized as a solution to the optimisation problem:

$$\begin{aligned} \max X_M \\ \text{subject to: } X_A \geq \bar{X}_A \text{ and } L_M + L_M^\lambda + L_A = \bar{L}. \end{aligned}$$

If we consider the Lagrangean:

$$L = F_M(K_M, L_M) + \mu_1 [F_A(T_A, L_A) - \bar{X}_A] + \mu_2 [L_M (1 + L_M^{\lambda-1}) + L_A - \bar{L}] \quad (6)$$

where  $\mu_1$  and  $\mu_2$  are Lagrange multipliers, first order conditions yield:

$$\frac{\partial F_M}{\partial L_M} + \mu_2 Z = 0 \quad (7a)$$

$$\mu_1 \frac{\partial F_A}{\partial L_A} + \mu_2 = 0 \quad (7b)$$

where

$$Z = (1 + L_M^{\lambda-1}) + L_M(\lambda - 1)L_M^{\lambda-2}$$

Combining (7a) and (7b) yields the efficiency condition

$$\frac{\partial F_M}{\partial L_M} = \mu_1 \frac{\partial F_A}{\partial L_A} \left( (1 + L_M^{\lambda-1}) + (\lambda - 1)L_M^{\lambda-1} \right) \quad (8)$$

This condition has a simple interpretation. When a worker leaves the agricultural sector for the manufacturing sector there is a drop in agricultural output, measured by the marginal product of labor in the agricultural sector but there is also a loss due to added congestion in the urban sector (the term  $Z$ ). At the optimum the marginal product of labor in the manufacturing sector must compensate for these two losses

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<sup>3</sup> See the use of this same damage function in Abrego and Whalley (2001).



evaluated at the shadow price of a unit of agricultural output  $\mu_1$ . This, then, characterizes efficient production in this economy.

It is easy to see that the efficiency condition (8) will not be generated by a perfectly competitive price mechanism. The marginal rate of transformation between the two goods will, in a competitive equilibrium, be equated to the relative price ratio  $p$ . This does not satisfy (8).

From (3') we obtain

$$\frac{\partial F_M}{\partial L_M} \frac{\partial L_A}{\partial F_A} = p(1 + L_M^{\lambda-1}) \quad (9)$$

whereas for Pareto efficiency (from (8)) this marginal rate of transformation should be

$$\frac{\partial F_M}{\partial L_M} \frac{\partial L_A}{\partial F_A} = \mu_1 \left( (1 + L_M^{\lambda-1}) + (\lambda - 1)L_M^{\lambda-1} \right) \quad (10)$$

An optimal Pigouvian tax reflects the difference between the MRT under Pareto efficiency and the MRT without a tax. In other words we want to set

$$p(1 + t)(1 + L_M^{\lambda-1}) = \mu_1 \left\{ (1 + L_M^{\lambda-1}) + (\lambda - 1)L_M^{\lambda-1} \right\} \quad (11)$$

where  $t$  is the rate for the Pigouvian tax. From (11) we can solve for  $t$  as:

$$t = \frac{\mu_1}{p} \left\{ 1 + \frac{(\lambda - 1)L_M^{\lambda-1}}{(1 + L_M^{\lambda-1})} \right\} - 1 \quad (12)$$

If  $\mu_1 = p$ , this corresponds to a case where no distortions exist in output markets, and domestic prices equal world prices. In this case, with utility maximizing behaviour by

households,  $t = \frac{(\lambda - 1)L_M^{\lambda-1}}{(1 + L_M^{\lambda-1})}$  which yields an optimal tax rate given as the ratio of

marginal to average damage.

If, however, there are distortions in output markets so that  $\mu_1 \neq p$ , then the optimal (second best) Pigouvian tax will need to be correspondingly modified. In the special case where

$$\mu_1 = \frac{p(1 + L_M^{\lambda-1})}{(1 + L_M^{\lambda-1}) + (\lambda - 1)L_M^{\lambda-1}} \quad (13)$$

then the optimal tax rate  $t = 0$ . This is a case where output market distortions and distortions of migration decisions via urban environmental damage offset each other.

Generally, however, some optimal Pigouvian tax on the use of labour in the urban sector will be called for, and gains relative to a competitive migration equilibrium with an uninternalized externality can be achieved. In this sense then, urban specific pollution (damage) when introduced into a no pollution Harris-Todaro model can be beneficial in providing welfare gains relative to a no pollution Harris-Todaro equilibrium with unemployment. Urban damage displaces urban unemployment, and then yields an externality that can be internalised.

#### IV. Concluding Remarks

This short paper suggests that the generally held view that urban pollution (congestion, health effects) is bad is subject to analytical challenge. In a Harris-Todaro model of urban-rural migration, if unemployment is thought of as damage then urban specific environmental damage has similar effects on migration, and a form of model equivalence can be shown between with and without pollution variants of related models. If an explicit damage function is then considered, internalization gains beyond this equilibrium are possible and hence introducing pollution (damage) into a Harris-Todaro model can lead to welfare improvements in this sense.

This is not to say that urban pollution in Asia and elsewhere is necessarily good, merely to make the point that it can offset bad effects elsewhere (unemployment). In particular cases it can be viewed as welfare improving when introduced into a no pollution model with unemployment in urban areas since it first displaces unemployment, then creates an externality that can be internalized.

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