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FULL ARTICLE



The social profitability of rural roads in a small open economy: Do urban agglomeration economies matter?

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UNU WIDER

Abstract

The effects of a rural roads programme depend on labour mobility, how the programme is financed, and agglomeration economies. If financed by a rural poll tax and cross-price effects and agglomeration economies are sufficiently small, the wage will rise, with some return migration. Taxes on trade act as countervailing distortions, yielding urban households some relief. Rural-urban commuting promotes the exploitation of agglomeration economies; taxes on international trade are then inferior to a poll tax. The change in the value, at producer prices, of the rural sector's net supply vector can be a poor measure of the programme's social profitability.

KEYWORDS

rural roads, social profitability, transport costs, agglomeration economies, small open economy

JEL CLASSIFICATION

H54, O18, O22, R13

1 | INTRODUCTION

All-weather roads promise to improve rural welfare. Farmers should enjoy better terms of trade and all villagers, as consumers, should pay less for urban goods. There are also benefits in the form of better schooling and a faster trip

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to a clinic or hospital. While estimating these benefits is a central and demanding task,¹ the wider consequences of extending the network of rural roads have been rather neglected. Heavier movements of goods and people will normally affect activities, prices and wages in towns, with associated effects on both urban and rural welfare. Neglecting these effects may lead to serious errors when evaluating the social profitability of large-scale programmes. In particular, by making rural life more attractive, such programmes may well stem rural-urban migration, thus slowing urban output and hence reducing the efficiency with which it is produced when there are agglomeration economies.

Whether policy-makers consider such effects is an open question. The authors of *Reshaping Economic Geography* (World Bank, 2009) do not address them directly, although their strictures on the folly of limiting rural-urban migration (*ibid.*: 140-2) rather lead one to infer that investing in rural roads, in whose financing the Bank has been heavily involved, potentially has at least one serious drawback.² To give a prime example of such involvement, India's *Pradhan Mantri Gram Sadak Yojana* (PMGSY) was launched in 2000, with the goal of covering some 178,000 habitations. About 136,000 had received a connection by 2018, at a cumulative cost of \$US 38 billion (World Bank, 2018). The original intention was to finance the programme by imposing a cess on high-speed diesel fuel, but the resulting proceeds have had to be supplemented by substantial draws on general revenues. Return migration did not enter into the deliberations of at least one earlier Finance Commission, and direct evidence on its extent is lacking; but one member remains persuaded that it is far from negligible, a belief also held concerning the provision of electricity connections.³

The object of this paper is to analyse the effects of such programmes on welfare when there are agglomeration economies, paying close attention to how the programme is financed and the mobility of rural labour. This calls for a general equilibrium treatment, in which the reallocation of resources depends on the extent to which goods are internationally tradeable at exogenously given world prices; for with these market opportunities, there is no lack of demand for such goods. Consider, for example, an open economy in which all goods are thus tradeable, labour is intersectorally immobile and unit transport costs between the ports, border crossings and towns are constant. Then prices in towns will be independent of the condition of the rural road network when improvements therein are financed by lump-sum taxes on rural households. If socially profitable, a better network will improve rural welfare, but leave urban activity and welfare unchanged.

In practice, a whole variety of goods are neither exported nor imported, nor are they likely to be under any conceivable constellation of domestic productivity levels and tastes. Domestic demand then comes into play. The structure adopted here involves three goods, all freely traded internally, with "iceberg" transport costs. The economy is "small" only in the sense that it is a price-taker in world markets. Villagers produce one good by means of labour, the two urban goods and land. In equilibrium, this good is always exported. Urban firms are concentrated in a single port-city. They produce a good that, in equilibrium, is also imported and another good that is traded only domestically, thus labelled the domestic good. The former is produced by means of labour, the rural good, the domestic good and capital; the domestic good, by unassisted labour. The production of urban goods is subject to Marshallian external economies.⁴ Rural workers are mobile, and thus available to urban firms. Urban households are engaged only in urban production. Trade and transport activities are competitively organised.⁵ The roads programme reduces transportation costs between the rural hinterland and the port-city. It can be financed by a rural poll tax, a tax on exports, or a tariff.

¹Studies of the effects of rural roads programmes on rural output, incomes and poverty in various developing countries include Fan et al. (2000), Jacoby (2000), Escobal and Ponce (2002), Jacoby and Minten (2009), Khandker et al. (2009), Warr (2010), Aggarwal (2018) and Takada et al. (2021). Stifel et al. (2016) estimate willingness to pay in Ethiopia. Hine et al. (2019) provide a useful review of the recent empirical literature.

²The authors of *Infrastructure for Development* (World Bank, 1994) were largely concerned with improving efficiency in the provision of infrastructure. Rural roads receive little attention, and rural-urban migration is hardly mentioned in any connection.

³Private communication.

⁴In keeping with the present paper's central concern with public finance and labour mobility, a simple specification is chosen. For surveys of the theoretical and empirical literature on agglomeration economies, see Behrens and Robert-Picoud (2015) and Combes and Gobillon (2015), respectively. Cottineau et al. (2016) demonstrate, using French data, that the size of agglomeration economies depends on the definition of what is "urban".

⁵Casaburi et al. (2013) analyse various market structures with reference to rural Senegal. In their partial equilibrium framework, rural output is assumed to be fixed, as are the only urban variables, viz. the urban prices of rural goods.



In order to keep things tractable, certain effects are ruled out. Schooling is unaffected, as is health, whatever the levels of air and water pollution and those personal contacts that propagate diseases.⁶ Agglomeration economies are represented as net of any congestion diseconomies. These and the three-good structure represent strong simplifying assumptions, the potential force of which must be borne in mind when judging the results. The former are discussed in the light of the latter in Section 9.

As in reality, the lack of all-weather rural roads does not bar rural workers from migrating to seek urban employment: they simply take up residence in the towns, though not necessarily permanently. The provision of such roads may, however, make daily commuting both feasible and attractive, which would rather promote the exploitation of agglomeration economies. There is some indirect evidence that PMGSY has furthered such mobility. Asher and Novosad (2020) use a regression-discontinuity approach on a sample of some 11,400 villages. They conclude that the programme has generated minor changes in agricultural outcomes, incomes and assets, but induced a substantial shift of workers out of agriculture. There is the limitation that these are estimates of local average treatment effects, but the shift is consistent with anecdotal evidence from surveys. At all events, commuting—as opposed to migration—is an important variation on the theme of mobility, and it is addressed in subsections 5.2, 7.2 and 7.3.

Underpinned by theoretical results, the sizes of diverse effects are explored using numerical examples, mostly with Cobb–Douglas technologies and preferences, treating the programme as “large”. These effects yield the equivalent variation. When there is rural–urban migration, improving the network generates substantially smaller aggregate net benefits if the elasticity of agglomeration efficiencies is at the upper end of empirical estimates and the programme is financed by poll taxes. Taxes on exports or imports perform much better. The converse holds when there is commuting; for easier daily travel rather promotes urban employment. Under both forms of mobility, the distribution of the aggregate between town and country is rather sensitive to agglomeration economies and the form of taxation. As for shortcuts, the change in the value, at the economy’s producer prices, of the rural net supply vector can differ substantially from aggregate net benefits—in both directions. On both counts, there is ample scope for policy decisions to damage welfare.

The plan of the paper is as follows. Section 2 sets out the basic structure, with migration and poll taxes as benchmark. Section 3 deals with prices and the wage in equilibrium, laying the basis for the analysis of the programme’s effects on social welfare in Section 4. The two main alternatives—taxes on trade and commuting—are treated in Section 5. Illustrative numerical examples follow, with calibration in Section 6 and programme effects in Section 7. The robustness of the findings to the assumptions about substitution in consumption, family structure, congestion, and to the values of key parameters is examined in Section 8. A concluding discussion follows in Section 9.

2 | THE MODEL

The country is a price-taker in world markets, as are households and firms in domestic ones. Goods 1 and 2 are tradable in world markets at the exogenous prices p_1^* and p_2^* . Villagers are net producers of good 1. What they do not consume themselves, they sell to agents in the city. This surplus can be consumed by urban households, used as an input to produce good 2, or exported. Like land in the rural sector, there is a specific urban fixed factor, capital, which is used in the production of good 2, so that both goods will be produced domestically. Good 3 is tradeable domestically, but not internationally. Initially, none of the goods is taxed.

The port-city is, in principle, independent of its hinterland; for goods 1 and 2 are internationally tradeable, and good 3 can be produced there to satisfy urban demand. The hinterland, in contrast, is dependent on the city; for although villagers can export good 1 in exchange for imports of good 2 (both through the city), they must trade with

⁶In a broad-ranging survey of urbanisation that dwells on the distinct possibility that there are too many mega-cities, Henderson (2002) emphasises the costs of congestion and pollution.



the city in order to obtain good 3. Let the rural sector's endowment of land be so large that, in equilibrium, good 1 is exported and good 2 imported.

The two locations—rural hinterland and port-city—are denoted by the index $k = 1, 2$, respectively, and the price of good i in location k by p_{ik} . With domestic prices tethered to world prices by arbitrage and domestic transport costs, then in the absence of commodity taxes, the farm-gate price of good 1 is $p_{11} = (1 - \tau_1)p_1^*$, where τ_1 is the fractional (iceberg) cost of transporting good 1 to the port-city. Villagers pay $p_{21} = (1 + \tau_2)p_2^*$ and $p_{31} = (1 + \tau_3)p_{32}$ for goods 2 and 3, respectively. Let $p_3 \equiv p_{32}$ denote the producer price of good 3. Then the rural price vector is

$$\mathbf{p}_1 = ((1 - \tau_1)p_1^*, (1 + \tau_2)p_2^*, (1 + \tau_3)p_3). \quad (1)$$

Households and firms in the city face prices $\mathbf{p}_2 = (p_1^*, p_2^*, p_3)$. The aggregate *net* output of good i in location k is denoted by Y_{ik} , with the standard convention that net inputs of goods have a negative sign.

All households supply their labour endowments completely inelastically. It is assumed that urban households' endowments of capital are such that, in all allocations, some workers from rural households are engaged in urban production.

Various possibilities—and complications—arise from rural workers' mobility. If they commute to urban jobs, they pay fares and lose time in travelling; and if they buy goods in the towns, their families make some expenditures at urban prices. If, instead, they move to towns, they may lose their claims on the imputed rents from the family's land; in that event, a new urban household is formed, but without claims on the incomes derived from the urban fixed factor. Then again, the rural household may remain an extended family unit, pooling all income, but making some expenditures at urban prices.

The following serves as benchmark: migrants remain members of the extended rural family,⁷ but all rural family expenditures are made at village prices, a defensible simplification if urban and village prices do not differ strongly and migrants make up a sufficiently small fraction of the population belonging to rural households.

The government now undertakes a rural roads programme. This improvement in the network and its perpetual maintenance are produced by unassisted rural workers. In keeping with the above assumptions on labour mobility, they are paid the going urban wage w . The latter being mutually and simultaneously determined with the spatial allocation of labour, the programme exerts particular effects when there are agglomeration economies, which should be borne in mind throughout what follows.

2.1 | The rural economy

Rural households, which are identical, choose inputs of goods and labour, L_1 , in rural production so as to maximise profits, taking prices as given. The technology is represented by $F(Y_1, L_1) = 0$, where $Y_{i1} < 0 (i = 2, 3)$. Aggregate profits are

$$R_1 = p_{11}Y_{11} + p_{21}Y_{21} + p_{31}Y_{31} - wL_1. \quad (2)$$

Aggregate income is $M_1 = R_1 + w\bar{L}_1 - T_1$, where \bar{L}_1 is the aggregate labour endowment and $T_1 (= wL_{1p})$ is the sum paid in poll taxes to finance the programme's requirement of L_{1p} units of labour.

A rural household's preferences over the three goods are represented by the function U_1 . Since these households are identical, an individual household's decision problem may be written in the form

⁷Commuting is treated in Section 5.2. An alternative family structure is discussed in Section 8.2.



$$\max_{(\mathbf{X}_1, \mathbf{Y}_1)} U_1(\mathbf{X}_1) \text{ s.t. } (2), R_1 + w\bar{L}_1 - T_1 \geq \mathbf{p}_1 \mathbf{X}_1, F(\cdot) = 0, (\mathbf{X}_1, -Y_{21}, -Y_{31}, L_1) \geq \mathbf{0}, \quad (3)$$

where $\mathbf{X}_1 = (X_{11}, X_{21}, X_{31})$ denotes the aggregate final consumption bundle. Problem (3) is separable in the spheres of production and consumption. Applying the envelope theorem to the former (maximising M_1 is equivalent to maximising R_1), we obtain

$$dM_1 = \mathbf{Y}_1 \cdot d\mathbf{p}_1 + (\bar{L}_1 - L_1)dw - T_1, \quad (4)$$

where the second-order term $L_{1p}dw$ is neglected and, at the optimum, \mathbf{X}_1 , \mathbf{Y}_1 , L_1 and M_1 are functions of (\mathbf{p}_1, w) .

Let the programme yield a reduction $d\boldsymbol{\tau} (< \mathbf{0})$ ⁸ in $\boldsymbol{\tau} = (\tau_1, \tau_2, \tau_3)$. Recalling (1), the resulting change in the rural price vector is

$$d\mathbf{p}_1 = (-p_1^* d\tau_1, p_2^* d\tau_2, p_3 d\tau_3 + (1 + \tau_3)dp_3).$$

The sign of the change in p_{31} is ambiguous, despite the reduction in τ_3 ; for p_{31} also depends on w , which may rise.

It follows from the envelope theorem and $Y_{11} > X_{11}$ that, *cet. par.*, the programme will make villagers better off if it satisfies two conditions. First, that T_1 be not so large as to reduce M_1 . Secondly, that the programme not lead to a sharp fall in w whenever some villagers already have urban jobs, although such a fall would be mitigated by a sharp fall in p_{31} .

Let $V_1(M_1, \mathbf{p}_1, w)$ be the associated indirect utility function. Then

$$dV_1 = \nabla M_1 \cdot (d\mathbf{p}_1, dw) \cdot \frac{\partial V_1}{\partial M_1} + \nabla V_1 \cdot d\mathbf{p}_1.$$

Let $\mathbf{Z}_1 = (Y_{11} - X_{11}, Y_{21} - X_{21}, Y_{31} - X_{31})$ denote the rural sector's vector of *net* supplies⁹ of goods to the city, transactions that are accompanied by supplies of $\bar{L}_1 - L_1 - L_{1p}$ units of labour. Denote by $\text{diag}(-p_1^*, p_2^*, p_3)$ the matrix with the said diagonal elements and all off-diagonal elements equal to zero, and by \mathbf{Z}_1' the transpose of \mathbf{Z}_1 . Then using Hotelling's lemma and Roy's identity and collecting terms, the change in V_1 induced by the vector $d\boldsymbol{\tau}$ may be written

$$\begin{aligned} dV_1 &= [\mathbf{Z}_1' \cdot \text{diag}(-p_1^*, p_2^*, p_3) d\boldsymbol{\tau} + (1 + \tau_3)Z_{31}dp_3 + (\bar{L}_1 - L_1)dw - T_1] \cdot \partial V_1 / \partial M_1, \\ &\equiv [(B_1^r - T_1) + (1 + \tau_3)Z_{31}dp_3 + (\bar{L}_1 - L_1)dw] \cdot \partial V_1 / \partial M_1. \end{aligned} \quad (5)$$

The sum of the direct effects of the reduction in $\boldsymbol{\tau}$, evaluated at \mathbf{p}_2 and denoted by B_1^r , is positive; for each of its three terms is positive. If $B_1^r > T_1$, the programme will increase rural households' income at \mathbf{p}_2 , a valuation to which we return in later sections. Its effect on V_1 through the induced changes in the wage and producer price of good 3 is ambiguous. Ignoring second-order terms and holding quantities constant, $(1 + \tau_3)Z_{31}dp_3 + (\bar{L}_1 - L_1)dw$ is the change in migrant workers' earnings minus the change in rural households' expenditures on good 3.

Remark 1. The term $B_1^r - T_1$ is of considerable practical significance; for \mathbf{Z}_1 is observable *ex ante*, and those planning the programme are charged with forecasting \mathbf{p}^* and estimating $d\boldsymbol{\tau}$ and the associated cost T_1 .

⁸All elements of $d\boldsymbol{\tau}$ are negative.

⁹Recalling the sign convention for net inputs, $Y_{11} - X_{11} > 0$, $Y_{21} - X_{21} < 0$, $Y_{31} - X_{31} < 0$; that is to say, rural households have an aggregate net demand for good 2 in the amount $|Y_{21} + X_{21}|$, and analogously for good 3.



The programme's effect on the quantity of good 1 delivered to the port-city plays an important role. The net supply of good 1 at the farm gate is $Z_{11} = Y_{11}(p_1, w) - X_{11}(M_1, p_1)$, which becomes $(1 - \tau_1)Z_{11}$ at the port-city. The programme will yield an increase in the latter directly by reducing τ_1 . It will also affect rural supply and demand through the changes it induces in prices and incomes:

$$d[(1 - \tau_1)Z_{11}] = -Z_{11}d\tau_1 + (1 - \tau_1)[\nabla Y_{11} \cdot (dp_1, dw) - \nabla X_{11} \cdot (dM_1, dp_1)].$$

Now, $p_2^* Z_{21} d\tau_2 + p_3 Z_{31} d\tau_3$ is equal to B_1^r less that component arising from the increase in p_{11} , that is, $B_1^r + p_1^* Z_{11} d\tau_1$. Hence, from (4) and (5), the quantity of good 1 delivered at the port-city increases or decreases according as

$$\begin{aligned} & -(1 - p_{11})^{-1} [p_1^* Z_{11} d\tau_1 + b_{11}(B_1^r - T_1)] + [\nabla Y_{11} \cdot (dp_1, 0) - \nabla X_{11} \cdot (0, dp_1)] \\ & + (1 - \tau_1) \left[\partial Y_{11} / \partial w - (b_{11} / p_{11})(\bar{L}_1 - L_1^0) \right] dw \gtrless 0, \end{aligned} \quad (6)$$

where $b_{11} \equiv p_{11} \partial X_{11} / \partial M_1$ denotes the marginal expenditure share for good 1. Taking the three bracketed expressions in turn, $p_1^* Z_{11} d\tau_1$ is the negative of the increase in the marketed surplus at the farm gate arising from the reduction in τ_1 , valued at p_1^* ; $b_{11}(B_1^r - T_1)$ is the increase in expenditure on good 1 arising from the gain in income valued at p_2 . The second expression is positive if substitutability in consumption is such that $\nabla X_{11} \cdot (0, dp_1) \leq 0$, a weak condition in view of the change in p_1 .¹⁰ The third expression is the partial response of Z_{11} to w . This establishes:

Lemma 1. *If $|p_1^* Z_{11} d\tau_1| \geq b_{11}(B_1^r - T_1)$ and $\nabla X_{11} \cdot (0, dp_1) \leq 0$, the quantity of good 1 delivered at the port-city will fall only if the wage increases.*

2.2 | The urban economy

Sector 2 comprises n numerous and identical firms, which produce (net) output by means of labour, capital, and inputs of goods 1 and 3. Firms maximise profits, taking prices as given. Labour and capital are necessary and substitutable in production; the associated unit input requirements for goods 1 and 3 are fixed, at a_{12} and a_{32} , respectively. The value added per unit of output is denoted by $\hat{p}_2 = p_2^* - p_1^* a_{12} - p_3 a_{32}$.

Production is subject to Marshallian external economies.¹¹ If firm j chooses the factor bundle (l_j, k_j) , let its level of output—given an efficient input bundle of goods 1 and 3—be given by $A_2 \phi(L_2) f(l_j, k_j)$ where $L_2 = l_j + L_2(-j)$ is the level of total employment in sector 2, ϕ and f are increasing and differentiable in their arguments, f is homogeneous of degree one, and A_2 is a constant. The firm's revenue, net of the costs of intermediate inputs and wages, is $R_j = \hat{p}_2 A_2 \phi(L_2) f(l_j, k_j) - w l_j$, which is returned to the households that supply k_j .

When choosing a production plan, let each firm make Nash conjectures concerning the plans of the rest. Then, ignoring the negligible influence on ϕ of its contribution to L_2 , firm j will choose l_j so as to equate (private) marginal revenue with (private) marginal cost: $\hat{p}_2 A_2 \phi(L_2) \cdot \partial f(l_j, k_j) / \partial l_j = w$. In a symmetric equilibrium, each firm chooses the same input of capital, k_2 , so as to exhaust the aggregate endowment thereof, and the same level of employment, l_2^0 , where the latter satisfies the foregoing marginal condition and, in aggregate, $L_2 = n l_2^0$.

¹⁰Even in the extreme case of perfect complements, in which the goods are consumed in the ratio $(1 : b_{21} : b_{31})$, $\nabla X_{11} \cdot dp_1 \leq 0$ if the associated price index $p_{11} + b_{21} p_{21} + b_{31} p_{31}$ does not fall.

¹¹Capital is supplied inelastically, so that total output will move with total employment.



$$\hat{p}_2 A_2 \phi(n_2^0) \cdot (\partial f(l_j, k_2) / \partial l_j) |_{l_j=l_2^0} = w, \forall j. \quad (7)$$

Good 3 is produced by unassisted labour. The unit input requirement is given by $l_3 \cdot g(L_2, L_3)$, where g is non-increasing and differentiable in both arguments and l_3 is a constant. The sector is competitively organised, so that its producer price is equal to unit cost,

$$p_3 = l_3 \cdot g(L_2, L_3) \cdot w, \quad (8)$$

and there are no profits to return to urban households.

The relation between urban employment and the wage is influenced by the presence of external economies. Differentiating (7) totally, noting (8), and rearranging, we obtain

$$\begin{aligned} (1 + p_3 a_{32} / \hat{p}_2) dw = & \left[\hat{p}_2 A_2 (\phi(n_2^0) f_{ll} + n \phi' \cdot f_l) - a_{32} w l_3 \cdot (w / \hat{p}_2) \cdot g_l \right] d l_2^0 \\ & - [(p_3 a_{32} / \hat{p}_2) w \cdot (g_{L_3} / g)] d L_3 \equiv \xi_2 \cdot d l_2^0 - \xi_3 \cdot d L_3, \end{aligned} \quad (9)$$

where $f_l = \partial f(l_2, k_2) / \partial l_2 |_{l_2^0}$, $g_l = \partial g(n_2^0, L_3) / \partial L_2$ and $g_{L_3} = \partial g(n_2^0, L_3) / \partial L_3$. The sign of ξ_2 is ambiguous. The term $\hat{p}_2 A_2 (\phi(n_2^0) f_{ll})$ is negative, but the other two terms, which arise from agglomeration economies, are both positive. Using (7) and (8) once more, some manipulation yields ξ_2 as a weighted sum of certain elasticities:

$$\xi_2 = \frac{w}{l_2^0} \left[\frac{l_2^0 f_{ll}}{f_l} + \frac{n l_2^0 \cdot \phi'}{\phi} - \frac{p_3 a_{32}}{\hat{p}_2} \cdot \frac{l_2^0 \cdot g_l}{g} \right] \equiv w \zeta / l_2^0. \quad (10)$$

The term $l_2^0 f_{ll} / f_l$ is the elasticity of the marginal product of labour with respect to labour, as perceived by the individual firm and evaluated at l_2^0 . The term $n l_2^0 \cdot \phi' / \phi$ is the elasticity of the function representing the effects of external economies on the efficiency of production in sector 2. The third term is the product of the ratio of the cost of inputs of good 3 to the price of value added and the *partial* elasticity of the function representing the effects of external economies on the efficiency of production of good 3, arising from total employment in sector 2. Thus, (9) may be written

$$(1 + p_3 a_{32} / \hat{p}_2) (dw/w) + [(p_3 a_{32} / \hat{p}_2) \cdot \epsilon_{33}] (dL_3 / L_3) = \zeta \cdot (d l_2^0 / l_2^0),$$

where $\epsilon_{33} \equiv g_{L_3} L_3 / g$ is the partial elasticity of g w.r.t. L_3 . This establishes:

Lemma 2. *Employment in sector 2 and the wage rate will move in opposite directions if $\zeta < 0$ and ϵ_{33} is sufficiently close to zero.*

In practice, ζ is almost surely negative; for empirical estimates of the elasticities associated with agglomeration effects are quite close to zero (see Section 6), whereas the own-elasticity of the marginal product of labour is not.¹² The ratio of the cost of inputs of good 3 to the price of value added is at most 1 if, and only if, $p_2^* - p_1^* a_{12} - p_3 a_{32} \geq p_3 a_{32}$. Since the l.h.s. is the sum of payments to labour and the fixed factor per unit of gross output, this condition, too, almost surely holds empirically.

Urban households are identical. Their aggregate income is

¹²If f is Cobb–Douglas, $l_2^0 f_{ll} / f_l = -(1 - \alpha_{r2})$, where α_{r2} is the elasticity of output w.r.t. labour.



$$M_2 = n[\hat{p}_2 A_2 \phi(n l_2^0) \cdot f(l_2^0, k_2) - w l_2^0] + w \bar{L}_2, \quad (11)$$

where \bar{L}_2 is their total endowment of labour. As consumers, their decision problem is

$$\max_{(X_2 | M_2, p_2)} U_2(X_2) \quad \text{s.t. } M_2 \geq p_2 X_2, \quad (11), \quad \text{and } X_2 \geq 0.$$

Let $V_2(M_2, p_2)$ denote the corresponding indirect utility function. Proceeding as in subsection 2.1 and noting that $[Y_{32} + (1 + \tau_3)Z_{31}]$ is the total absorption of good 3 within the urban economy itself, Roy's identity, (8) and some manipulation yield

$$\begin{aligned} dV_2 = & \{[\bar{L}_2 - n l_2^0 - l_3 \cdot g(L_2, L_3)(Y_{32} + (1 + \tau_3)Z_{31} + a_{32}Y_{22})]dw + \frac{\hat{p}_2 Y_{22}}{n l_2^0} \cdot \frac{n l_2^0 \cdot \phi'}{\phi} n d l_2^0 \\ & - w l_3 [Y_{32} + (1 + \tau_3)Z_{31} + a_{32}Y_{22}]dg\} \cdot \partial V_2 / \partial M_2, \end{aligned} \quad (12)$$

where $\hat{p}_2 Y_{22} / n l_2^0$ is value added per worker in sector 2, $a_{32}Y_{22}$ is the intermediate demand for good 3 and $dg = g_l d l_2^0 + g_{L_3} d L_3$. The level of aggregate urban employment is $n l_2^0 + l_3 \cdot g(L_2, L_3)Y_{32} > \bar{L}_2$, since some workers from rural households are engaged in urban production. In equilibrium, the urban economy's excess demand for labour over its own endowment is exactly met by migrants' supply, whereas the labour needed to meet rural demand for good 3 is $-l_3 g \cdot (1 + \tau_3)Z_{31}$. In view of Lemma 2, this establishes:

Lemma 3. *If $\zeta < 0$ and ϵ_{33} is sufficiently close to zero, then urban welfare is decreasing in the wage if the sum of migrants' labour supply and the labour needed to meet the urban intermediate demand for good 3 exceeds the labour needed to meet the total rural demand for that good.*

Remark 2. In the absence of agglomeration economies, the standard, sharper condition holds: urban welfare is decreasing or increasing in the wage according as the said sum is greater or smaller than the labour needed to meet total rural demand for good 3.

3 | THE WAGE RATE AND PRICES IN EQUILIBRIUM

If deliveries of good 1 at the port-city increase and the whole increase is not absorbed there, exports of good 1, E_1 , will increase. By Walras's Law, the value of the economy's net exports at world prices must be zero in equilibrium: $p_1^* E_1 + p_2^* E_2 = 0$. Together with Lemma 1, this identity underpins the argument yielding:

Proposition 1. *If, in the absence of agglomeration economies, (i) the cost shares of good 3 in the production of goods 1 and 2 are sufficiently small, (ii) households' expenditure shares for good 3 are not close to 1, and (iii) the programme would yield an export surplus at an unchanged wage, then it will induce an increase in the wage.*

Proof. See Appendix A.

Lemma 2 then yields:

Corollary 1. *If $\zeta < 0$ and g is sufficiently weakly decreasing in L_3 , then Proposition 1 holds in the presence of agglomeration economies, with corresponding contractionary effects on urban activity and productivity.*



Lemma 3 yields:

Corollary 2. *In the absence of agglomeration economies, the programme will improve urban welfare if, and only if, the labour needed to meet rural demand for good 3 exceeds the sum of the labour supplied by migrants and the labour needed to meet urban intermediate demand for good 3. In their presence, the said condition is not sufficient.*

An analysis of the condition for the labour market to clear yields alternative sufficient conditions—some a bit weaker than those in Proposition 1, others stronger—for the wage to increase. The market-clearing condition can be written in the form

$$L' + L'' \equiv [L_1 + gl_3(1 + \tau_3)(-Y_{31} + X_{31})] + [L_2 + gl_3(a_{32}Y_{22} + X_{32})] = \bar{L}_1 + \bar{L}_2 - L_{1p}, \quad (13)$$

where the first expression in brackets is the total employment of labour engaged in producing good 1 and satisfying rural demand for good 3, the second is the employment of labour to meet the corresponding requirements of urban production and consumption, and L_{1p} is zero in the absence of the programme. When the latter is undertaken, the sum of such employments must fall by the programme's requirement of labour:

$$dL' + dL'' \equiv d[L_1 + gl_3(1 + \tau_3)(-Y_{31} + X_{31})] + d[L_2 + gl_3(a_{32}Y_{22} + X_{32})] = -L_{1p}. \quad (14)$$

A consideration of cross-price effects points to the following result:

Proposition 2. *Suppose the technology for producing good 1 and the preferences of rural households are Cobb–Douglas, and let urban households' preferences be such that their expenditure share for good 3 varies sufficiently weakly with the wage.¹³ Then, in the absence of agglomeration economies, the programme will induce an increase in the wage if it does not reduce rural income net of the poll tax, T_1 , needed to finance it.*

Proof. See Appendix A.

Although the assumptions about substitutability are stronger than those in Proposition 1, they can be weakened somewhat. Corollary 1 also holds.

4 | CHANGES IN WELFARE

Let the social welfare function, W , have the arguments V_1 and V_2 and be differentiable in both. From (5) and (12), and noting that $dp_3 = l_3(gdw + wdg)$, the change in welfare yielded by the programme is

$$dW = \beta_1[(B_1^T - T_1) + (1 + \tau_3)Z_{31}dp_3 + (\bar{L}_1 - L_1 - L_{1p})dw] \\ + \beta_2[(\bar{L}_2 - nI_2^0)dw - (Y_{32} + (1 + \tau_3)Z_{31})dp_3 + \hat{p}_2Y_{22} \cdot (\phi'/\phi)ndI_2^0], \quad (15)$$

where $\beta_k = W_k \cdot \partial V_k / \partial M_k$ is the social value of a small increase in income accruing to households in location k .

Putting aside distributional considerations until Sections 6–8, the sum of the two expressions in brackets is the change in aggregate net benefits. Since $L_3 = \bar{L}_1 + \bar{L}_2 - L_1 - L_{1p} - nI_2^0$,

¹³This need hold only locally. The limiting general case is Cobb–Douglas.



$$B = (B_1^r - T_1) + (L_3 dw - Y_{32} dp_3) + \hat{p}_2 Y_{22} \cdot (\phi' / \phi) n d l_2^0. \quad (16)$$

The term $B_1^r - T_1$ is the net benefit accruing to rural households that arises directly from the reduction in transport costs when the sector's net supplies are valued at *urban* prices. This is a consequence of the assumptions that world prices are fixed, so that goods 1 and 2 can be transformed into one another at the fixed ratio p_1^* / p_2^* , and that good 3 is produced exclusively in the port-city. The economy's producer price vector is therefore \mathbf{p}_2 , and B_1^r is the change in the value of the rural sector's net supply vector at \mathbf{p}_2 .

The term $L_3 dw - Y_{32} dp_3$ arises from the programme's effects on the wage and the price of good 3, which are related by (8). From the latter, we have

$$L_3 dw - Y_{32} dp_3 = -w l_3 g(L_2, L_3) \cdot Y_{32} \cdot (dg/g) = -w L_3 \cdot (dg/g) = -p_3 Y_{32} \cdot (dg/g), \quad (17)$$

and hence, from (16),

Proposition 3. *In the absence of external economies, the programme will generate the aggregate net benefit $B_1^r - T_1$.*

The intuition for this familiar result is that, facing a fixed world price for good 2, firms in sector 2 are never constrained by domestic demand. The production of good 3, in contrast, is wholly driven by it, and if there are no agglomeration economies, the programme's gross benefits are just B_1^r , provided the change in τ is sufficiently small.

Allocations will be Pareto-efficient in that setting, but not in the presence of agglomeration economies. In virtue of Corollary 1, the wage increases, thus inducing an increase in p_3 , which lowers domestic demand for good 3, and hence the level of efficiency in its production. From (16) and (17), recalling (9) and (10), the loss is

$$\Lambda = \frac{p_2^* - p_1^* a_{12}}{\hat{p}_2} \cdot \frac{1}{\zeta} \left[\left(p_3 Y_{32} \cdot \frac{l_2^0 g_l}{g} - \hat{p}_2 Y_{22} \cdot \frac{n l_2^0 \cdot \phi'}{\phi} \right) \frac{dw}{w} + p_3 Y_{32} \epsilon_{33} \left(1 + \zeta \cdot \frac{l_2^0 g_l}{g} \right) \frac{dL_3}{L_3} \right]. \quad (18)$$

It is seen that the components of urban value added are weighted by their respective elasticities with respect to agglomeration economies. To summarise:

Proposition 4. *If the production of urban goods is subject to external economies and the programme is financed by a rural poll tax, then the measure $B_1^r - T_1$ overestimates the aggregate net benefit by the amount Λ .*

5 | VARIATIONS: TAXES AND COMMUTING

A rural poll tax is analytically clear, but a non-starter in practice. Rural-urban migration is unhindered, but daily commuting to urban jobs is ruled out. An examination of robustness to other assumptions is deferred to Section 8.

5.1 | Taxes

Taxes on exports and imports have the advantage of administrative simplicity. In less developed countries, most rural households keep no books, which effectively rules out bringing them within a VAT or income-tax net. An excise tax



on the rural good would also face nigh-on insuperable problems of collection in villages, since farmers supply their kitchens from their barns and can pay labourers in kind.

Such considerations aside, taxes on international trade have a certain virtue in the presence of agglomeration economies. A tariff on imports subsidises domestic production of the good in question and taxes its domestic consumption; the converse holds for a tax on exports. Although distortionary in themselves, both would tend, *cet. par.*, to reduce the programme's contractionary effects on urban activity.

A tax on exports directly counteracts the programme's effect on the price of good 1 at the farm gate, thus making return migration less attractive, while lowering the price of good 1 in the port-city. The financing requirement is now $t_1 p_1^* E_1 = wL_{1p}$, where t_1 denotes the (endogenous) ad valorem rate on exports. The farm gate price is $p_{11} = (1 - \tau_1 - t_1)p_1^*$; so that $dp_1 = (-p_1^*(d\tau_1 + t_1), p_2^* d\tau_2, p_3 d\tau_3 + (1 + \tau_3)dp_3)$. Proceeding as in Section 2.1, we obtain

$$dV_1 = [(B_1^r - t_1 p_1^* Z_{11}) + (1 + \tau_3)Z_{31} dp_3 + (\bar{L}_1 - L_1)dw] \cdot \partial V_1 / \partial M_1, \quad (19)$$

which differs formally from (5) only in that the levy $t_1 p_1^* Z_{11}$ replaces T_1 .

Urban firms and households enjoy the more favourable price $p_{12} = (1 - t_1)p_1^*$, so that the expression in braces on the r.h.s. of (12) is augmented by $t_1 p_1^* (a_{12}Y_{22} + X_{12})$:

$$dV_2 = \{[\bar{L}_2 - n_2^0 - l_3 \cdot g(L_2, L_3)(Y_{32} + (1 + \tau_3)Z_{31})]dw + \hat{p}_2 Y_{22} \cdot (\phi' / \phi) n_2^0 + t_1 p_1^* (a_{12}Y_{22} + X_{12}) - w l_3 [Y_{32} + (1 + \tau_3)Z_{31}] dg\} \cdot \partial V_2 / \partial M_2.$$

Proceeding as in Section 4, we obtain

$$B = B_1^r - t_1 p_1^* (Z_{11} - (a_{12}Y_{22} + X_{12})) + L_3 dw - Y_{32} dp_3 + \hat{p}_2 Y_{22} \cdot (\phi' / \phi) n_2^0. \quad (20)$$

Since $E_1 = (1 - \tau_1)Z_{11} - (a_{12}Y_{22} + X_{12})$, it follows that $t_1 p_1^* (Z_{11} - (a_{12}Y_{22} + X_{12}))$ exceeds the required revenue $wL_{1p} (= t_1 p_1^* E_1)$. This yields the counterpart of Proposition 3:

Proposition 5. *If, in the absence of any external economies, the programme is financed by an export tax on good 1, then the size of the deadweight loss is $t_1 p_1^* \cdot (\tau_1 Z_{11})$.*

By directly lowering input costs for the firms producing good 2, the tax promotes an increase in employment and output, with further effects in the presence of agglomeration economies. Eqn. (9) becomes

$$[1 + p_3 a_{32} / \hat{p}_2] dw = \xi_2 \cdot dL_2^0 - \xi_3 \cdot dL_3 + t_1 p_1^* a_{12} w / \hat{p}_2. \quad (21)$$

The change in the wage will be smaller than that with a rural poll tax; for by lowering the price of good 1 at the farm gate, an export tax reduces return migration. The counterpart of Λ in (18) is, when $g_{L3} = 0$,

$$\Lambda(t_1) = \frac{p_2^* - p_1^* a_{12} (1 + t_1 (dw/w)^{-1})}{\hat{p}_2} \cdot \frac{1}{\zeta} \left(p_3 Y_{32} \cdot \frac{l_2^0 g_l}{g} - \hat{p}_2 Y_{22} \cdot \frac{n_2^0 \cdot \phi'}{\phi} \right) \frac{dw}{w} + t_1 p_1^* \cdot (\tau_1 Z_{11}),$$

where the term $t_1 \cdot (dw/w)^{-1}$ is the ratio of the tax rate to the proportional change in the wage. Whether the combined effect of this reduction in costs and the smaller change in the wage will more than offset the loss $t_1 p_1^* \cdot (\tau_1 Z_{11})$ is unclear. This matter will be examined in the numerical examples.



The analysis of a tariff on good 2, t_2 , proceeds analogously (see Appendix A). Rural households are now directly burdened through their uses of that good, rather than facing a lower price of good 1. Urban firms' higher profits compensate urban consumers.

5.2 | Rural-urban commuting

Let the cost of a round-trip be a fixed fraction τ_ℓ of the wage, so that commuters receive the net wage $w_1 \equiv (1 - \tau_\ell)w$. Suppose commuting is the only form of mobility. If the programme is financed by a rural poll tax, aggregate rural income is $M_1 = R_1(w_1) + w_1(\bar{L} - L_1) - T_1$, and (5) becomes

$$dV_1 = [(B_1^r - w(\bar{L}_1 - L_1)d\tau_\ell - T_1) + (1 + \tau_3)Z_{31}dp_3 + (\bar{L}_1 - L_1)dw] \cdot \partial V_1 / \partial M_1.$$

The benefit $|w(\bar{L}_1 - L_1)d\tau_\ell|$ cannot arise when workers migrate, the cost of the single trip being negligible in comparison. The said benefit increases the demand for good 3.

On the supply side, the reduction in τ_ℓ has the direct effect of increasing w_1 , so making commuting more attractive and rural employment less so. The resulting movement of rural workers will put downward pressure on the urban wage; but if commuters earlier supplied only a small fraction of the aggregate employment in urban production, the net wage w_1 will rise. The reduction in τ_ℓ therefore promotes urban economic activity. Agglomeration economies will mitigate the adverse effects on urban households.

6 | NUMERICAL EXAMPLES: CALIBRATION

The natural choice of numéraire in the present setting is an internationally traded good. Let it be good 1, and choose units of measure such that the price of good 2 is also 1, yielding the normalisation $p_1^* = p_2^* = 1$, and hence $\mathbf{p}_1 = (1 - \tau_1, 1 + \tau_2, (1 + \tau_3)p_3)$ and $\mathbf{p}_2 = (1, 1, p_3)$. For clarity of presentation, these forms will be used only in final steps of derivations or calculations. In no essential way does the normalisation affect the choice of values of other parameters.

Let the technology in the rural sector be Cobb–Douglas. The solution of decision problem (3) yields the aggregate supply function:

$$Y_{11}(\mathbf{p}_1, w) = \left[A_1 \left(\frac{\alpha_{21} p_{11}}{p_{21}} \right)^{\alpha_{21}} \left(\frac{\alpha_{31} p_{11}}{p_{31}} \right)^{\alpha_{31}} \left(\frac{\alpha_{\ell 1} p_{11}}{w} \right)^{\alpha_{\ell 1}} \right]^{1/\alpha_{h1}}, \quad (22)$$

where $\alpha_{h1} = 1 - \alpha_{21} - \alpha_{31} - \alpha_{\ell 1}$ is the elasticity of output w.r.t. the fixed factor land. Aggregate income is $M_1 = \alpha_{1h} p_{11} Y_{11}(\mathbf{p}_1, w) + w(\bar{L}_1 - L_{1p})$.

Let the value-added function f in sector 2 be Cobb–Douglas, where $\alpha_{\ell 2}$ is the elasticity of value added w.r.t. labour. In the presence of agglomeration economies, let the function $\phi(L_2)$ be iso-elastic with parameter ϵ_2 and normalised such that $\phi(L_2) = 1$ when aggregate employment in sector 2 has the level that rules in the absence of such economies, denoted by $L_2(0)$: $\phi(L_2) = [L_2/L_2(0)]^{\epsilon_2}$.

Good 3 is produced by unassisted labour; the input-output coefficient, $l_3 g(L_2, L_3)$, is normalised in the same way, with $l_3 = 1$ and $g = [(L_2 + L_3)/(L_2(0) + L_3(0))]^{-\epsilon_3}$. In the absence of agglomeration economies, $p_3 = w$.

Households' preferences are Cobb–Douglas. The taste parameter for consumption of good i in location k is denoted by b_{ik} . The final demand for good i at location k is $X_{ik} = b_{ik} M_k / p_{ik}$, $i = 1, 2, 3, k = 1, 2$. The true cost-of-living index is the Kónus price index $\kappa(\mathbf{p}_k) = p_{1k}^{b_{1k}} p_{2k}^{b_{2k}} p_{3k}^{b_{3k}}$.

In the absence of agglomeration economies, it is possible to derive an equation expressing the relationship between the transport cost factors and the wage rate. This equation reveals how all the various parameters contribute to the sensitivity of that relationship, and is thus helpful in judging where particular care is needed in choosing their values.

With the normalisation $p_1^* = p_2^* = 1$, (22) can be written as



$$Y_{11}(\mathbf{p}_1, w) = c_{11} Q_1(\tau) w^{-(\alpha_{31} + \alpha_{\ell 1})},$$

where $c_{11} = (A_1 \alpha_{21}^{\alpha_{21}} \alpha_{31}^{\alpha_{31}} \alpha_{\ell 1}^{\alpha_{\ell 1}})^{1/\alpha_{h1}}$ and

$$Q_1(\tau) \equiv (1 - \tau_1)^{(1 - \alpha_{h1})/\alpha_{h1}} (1 + \tau_2)^{-\alpha_{21}} (1 + \tau_3)^{-\alpha_{31}} \quad (23)$$

is an exact index of rural producers' terms of trade for any given w . Likewise,

$$Y_{22}(\mathbf{p}_2, w) = c_{22} [(1 - a_{12} - a_{32}w)/w]^{\alpha_{\ell 2}/(1 - \alpha_{\ell 2})}, \quad (24)$$

where $c_{22} = A_2 (A_2 \alpha_{\ell 2})^{\alpha_{\ell 2}} K_2^{1 - \alpha_{\ell 2}}$. Aggregate urban income $M_2(\mathbf{p}_2, w) = (1 - \alpha_{\ell 2}) \hat{p}_2 Y_{22} + w \bar{L}_2$.

Before the programme is undertaken, the equation relating $Q_1(\tau)$ and w is (see Appendix B)

$$\frac{1}{w} \left[\frac{\gamma_{11} Q_1(\tau)}{w^{\alpha_{31} + \alpha_{\ell 1}}} + \gamma_{22} \left(\frac{1 - a_{12}}{w} - a_{32} \right)^{\alpha_{\ell 2}/(1 - \alpha_{\ell 2})} \right] = [(b_{11} + b_{21}) \bar{L}_1 + (b_{12} + b_{22}) \bar{L}_2], \quad (25)$$

where $\gamma_{11} = [1 - \alpha_{21} - (b_{11} + b_{21})\alpha_{h1}]c_{11}$ is a constant and

$$\gamma_{22} = [1 - a_{12} - (b_{12} + b_{22})(1 - \alpha_{\ell 2})(1 - a_{12} - a_{32}w)]c_{22},$$

which depends on w , but rather weakly, the product $(b_{12} + b_{22})(1 - \alpha_{\ell 2})a_{32}$ being empirically small. When the programme's improvement $-\Delta\tau$ is financed by a rural poll tax, the resulting $Q_1(\tau - \Delta\tau)$ on the l.h.s. of (25) is matched by the additional term $-(b_{11} + b_{21})L_{1p}$ on the r.h.s. Now, $b_{1k} + b_{2k}$ is the combined expenditure share of internationally traded goods in location k . It is unlikely to differ much between town and country. If, as is common, their labour endowments are roughly the same, then a programme that costs, say, 1 percent of GDP, will decrease the r.h.s. somewhat more, part of GDP accruing to the owners of the fixed factors, whereby labour's share is larger; but that decrease is not very sensitive to the size of $b_{1k} + b_{2k}$. Turning to the l.h.s., such programmes normally yield a proportional fall in Q_1 that is an order of magnitude greater, which implies a substantial proportional increase in the wage rate. The said expenditure shares are present in γ_{11} and γ_{22} , but their respective multiplicands are less than 0.5 – see below.

The complete set of parameter values is set out in Table 1. In peasant agriculture, the cost-shares of urban goods—artificial fertilisers, other chemicals, fuel, machines and certain urban services—are small; such goods play virtually no role in livestock and forestry activities. Let $\alpha_{21} = \alpha_{31} = 0.05$.¹⁴ Let labour claim two-thirds of value added, i.e., $\alpha_{\ell 1} = 0.6$, so that the residual $\alpha_{h1} = 1 - \alpha_{21} - \alpha_{31} - \alpha_{\ell 1} = 0.3$ accrues to the owners of land in the form of rents, actual and imputed. Fifty-fifty sharecropping, with like sharing of the costs of most urban goods, is a common form of lease. Fixed rents are substantially lower, in keeping with the tenant's share of risk bearing, so rounding to $\alpha_{h1} = 0.3$ is defensible. The value of c_{11} must be sufficiently large to yield a surplus for export, which is accomplished by choosing the TFP parameter A_1 .

Turning to the technology in sector 2, let $\alpha_{\ell 2} = 0.5$ and the (fixed) input-output coefficients a_{12} and a_{32} for goods 1 and 3 be 0.1. In the absence of human capital here, the choice $\alpha_{\ell 2} = 0.5$ is broadly consistent with Mankiw et al. (1992), who settle on shares of one-third each for labour, human and physical capital. Where the values of ϵ_2 and ϵ_3 are concerned, Henderson (2002) reports localisation elasticities for various industries in the range 0.05 to 0.08, to which must be added the contribution of general economies of urbanisation. Let $\epsilon_2 = \epsilon_3 = 0.2$, which represent extremely strong economies of agglomeration. Recalling (10) and footnote 12, these values imply $\zeta < 0$, so that Lemma 2 holds, and hence Corollary 1.

Rural households consume a substantial fraction of their own output. Let the expenditure shares be $b_{11} = 0.4, b_{21} = 0.3, b_{31} = 0.3$. Urban households' tastes for good 1 are a bit weaker, being influenced by the port and its trade. Let $b_{12} = 0.3, b_{22} = 0.4, b_{32} = 0.3$.

¹⁴Cultivation in India is rather dependent on them. Srivastava et al. (2017) report a cost-share of about 25 per cent, where total costs include the imputed value of family labour, but—importantly—exclude managerial time and rents, actual and imputed. This would imply $\alpha_{21} + \alpha_{31} \approx 0.17$.

**TABLE 1** Constellation of parameter values

Parameter	Value	Description
Rural		
A_1	2.9	TFP parameter
α_1	(0.05, 0.05, 0.6, 0.3)	elasticity of output w.r.t. goods 2, 3, labour and land
\mathbf{b}_1	(0.4, 0.3, 0.3)	taste parameters
\bar{L}_1	2.5207	labour endowment
τ	(0.1, 0.1, 0.1)	transport cost factors without programme
$\tau - \Delta\tau$	(0.05, 0.05, 0.05)	transport cost factors with programme
L_{1p}	0.025	programme input requirement
Urban		
A_2	1.5	TFP parameter
\mathbf{a}_2	(0.1, 0.1)	input-output coefficients for goods 1 and 3 in sector 2
α_{r2}	0.5	elasticity of value added w.r.t. labour in sector 2
ϵ_i	(0, 0); (0.2, 0.2)	elasticity of agglomeration function in sector $i = 2, 3$
\mathbf{b}_2	(0.3, 0.4, 0.3)	taste parameters
\bar{L}_2	2.0	labour endowment
K_2	1.5	specific factor endowment
\mathbf{p}^*	(1, 1)	world prices of goods 1 and 2

The transport cost parameters before the roads programme are a uniform 10 percent ($\tau_i = 0.1$). In semi-arid upland Orissa, PMGSY roads increased net output prices by at least 5 percent (Bell & van Dillen, 2014). For Bangladesh, Ahmed and Nahiduzzaman (2016) estimate that rural roads reduce the costs of transporting goods and passengers by 35 percent and 65 percent, respectively. Accordingly, let the programme considered here halve them. With the normalisation of the world prices of goods 1 and 2 to unity, the rural and urban price-vectors before the programme are $\mathbf{p}_1 = (0.9, 1.1, 1.1, p_3)$ and $\mathbf{p}_2 = (1, 1, p_3)$, respectively, where $p_3 = w l_3 g(L_2, L_3)$.

To complete the setting, there are rural and urban households' factor endowments. For the purposes of comparison, it will be convenient to choose certain of these values such that $w = 1$ in equilibrium before the programme is undertaken. Land is subsumed under the TFP-value $A_1 = 2.9$. The respective labour endowments are $\bar{L}_1 = 2.5207$ and $\bar{L}_2 = 2.0$. Urban households own, in aggregate, 1.5 units of the specific factor (K_2) employed in producing good 2. With $A_2 = 3/2$, the TFP-scalar in the absence of agglomeration economies, these yield the desired pattern of exports of good 1 and matching imports of good 2, with rural households supplying a fair proportion of their labour to urban production.

To place the programme's effects in relation to the economy's macroeconomic magnitudes in its absence, which would be observable at the time of evaluating the programme *ex ante*, its labour requirement is $L_{1p} = 0.25$, or 1 per cent of the rural labour force. This corresponds to 0.72 per cent of rural income and 0.42 per cent of GDP. At about 0.3 per cent, PMGSY's demands are somewhat lower. Setting a baseline programme for developing countries that balances the goal of providing access against the required marginal (perpetual) costs, Rozenberg and Fay (2019) choose 1 per cent.

7 | PROGRAMME EFFECTS: WAGES, PRICES AND MOBILITY

It should be noted that all allocations are derived without any appeal to $-\Delta\tau$ and L_{1p} being sufficiently small: the programme in question is treated as "large". In what follows, it will suffice to concentrate on a few key magnitudes. Their levels in diverse configurations of agglomeration economies, taxation and mobility are set out in Table 2; the corresponding details are reported in Table A1 in Appendix B.

**TABLE 2** Key magnitudes in equilibrium: taxation and mobility

Transport Tax Agglomeration elasticity	$\tau_i = 0.1$	$\tau_i = 0.05$		$\tau_i = 0.05$		$\tau_\ell = 0.2$	$\tau_i = 0.05, \tau_\ell = 0.1$	
	none ^a	poll	poll	export	export	none ^a	poll	poll
	$\epsilon = 0$	$\epsilon = 0$	$\epsilon = 0.2$	$\epsilon = 0$	$\epsilon = 0.2$	$\epsilon = 0$	$\epsilon = 0$	$\epsilon = 0.2$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
w	1.0	1.054	1.048	1.030	1.027	1.167	1.132	1.136
$1 - L_1/\bar{L}_1$	0.251	0.229	0.212	0.246	0.238	0.102	0.157	0.167
$\kappa(p_1)$	1.015	1.025	1.026	1.006	1.007	1.063	1.047	1.044
$\kappa(p_2)$	1.0	1.016	1.017	1.001	1.002	1.047	1.038	1.035
$p_1^* E_1/\text{GDP}$	0.144	0.166	0.178	0.156	0.162	0.191	0.188	0.181

^aThe functions ϕ and g representing agglomeration economies are normalized so as to yield, in the absence of the roads programme, the same allocation as that in which there are no agglomeration economies.

Source: Author's calculations.

7.1 | Migration

The benchmark allocation (see column (1)) is that wherein there is neither a roads programme ($\tau_i = 0.1, i = 1, 2, 3$) nor agglomeration economies ($\phi = 1, \epsilon_i = 0$).¹⁵ Sector 1 accounts for almost 50 percent of GDP, sector 3 almost two-thirds of urban value added. One quarter of rural households' labour endowment, i.e., $1 - L_1/\bar{L}_1$, is supplied to urban production. Exports are almost 15 percent of GDP, so that although the economy is a price-taker in world markets, transactions in domestic markets are preponderant. Wages, actual and imputed, account for 72 and 79 per cent, respectively, of rural and urban households' total incomes. The cost-of-living indices are $\kappa(p_1) = 1.0152$ and $\kappa(p_2) = 1$. The sum of the labour supplied by rural households to urban production and the need to meet intermediate demand for good 3, $a_{32}Y_{22}$, is far smaller than the labour needed to meet their demand for good 3, thus satisfying Corollary 2.

If financed by a rural poll tax, the programme will increase the value of the index $Q_1(\tau)$ from 0.775 to 0.883, an improvement of 13.9 percent. *Ceteris paribus*, this will induce an increase in the output of good 1 and hence in the marketed surplus at the farm gate. Coupled with lower iceberg losses on the way to the port-city, exports—and hence imports—will also increase, again *cet. par.* Equilibrium is brought about by a change in the wage, mutually and simultaneously with a spatial reallocation of labour. Taxes on international trade dull the programme's incentive effects somewhat, while still leaving the qualitative outcome unchanged.

The resulting allocations in four variations are summarised in columns (2)–(5). In keeping with the above reasoning, there is a notable rise in the export-to-GDP ratio when the programme is financed by a poll tax (see column (2)), and it is stronger still in the presence of agglomeration economies (see column (3)); for larger imports of good 2 partly displace domestic production, and so reduce urban factor productivity. These adjustments are induced by an increase in the wage, accompanied by some return migration, whereby the former is a bit larger and the latter somewhat smaller in the absence of agglomeration economies, when the contractionary pressures on urban activity are correspondingly lower.

A tax on exports has this in common with a rural poll tax: the direct burden falls on the direct beneficiaries. By depressing the inland price, it also weakens the programme's incentives to expand the production of good 1. In the absence of agglomeration economies (see column (4)), the required rate is 2.69 percent, which offsets just over one half of the reduction in τ_1 , so that $Q_1(\tau)$ increases only half as much, to 0.826.

¹⁵Recall that the normalisations $\phi(L_2) = [L_2/L_2(0)]^{\epsilon_2}$ and $I_3 = 1, g = [(L_2 + L_3)/(L_2(0) + L_3(0))]^{-\epsilon_3}$ yield identical allocations in the absence of the programme for all values of ϵ .



Thus, rural output, income and the marketed surplus all respond more modestly to the programme than under a poll tax, and the export-GDP ratio likewise. The increase in the wage rate is correspondingly smaller and fewer migrants return.

In the presence of agglomeration economies (see column (5)), the tax partly counteracts the associated market failure. The rate is slightly lower than in their absence, exports being slightly higher. The resulting wage rate is also a bit lower, but not enough to prevent a slight increase in the producer price of good 3. The withdrawal of rural migrant workers from urban production is not large, and notably far smaller than that under a poll tax.

7.2 | Commuting

The base case cannot be exactly the same as that in column (1); for there is the time-wedge between $w_1 = (1 - \tau_\ell)w$ and w . In order to bring the base cases closer together, the rural labour endowment in the commuting variant is increased by the (endogenous) time spent commuting such that the net endowments in both variants then take the value 2.5207. In effect, the programme augments villagers' labour endowments.

The allocation in the absence of the programme is given in column (6), with τ_ℓ set at the stiff value 0.2. Rural households devote 2.263 units of their labour endowment to cultivation and 0.310 units to urban employment and travelling. A strict comparison of the wage rates is impossible; but for reference, its level is one-sixth higher than its counterpart with migration, thus yielding a producer price of good 3 higher in the same proportion, together with the lower net rural wage of 0.933. The level of foreign trade is correspondingly higher.

As argued in Section 6, let the programme halve τ_ℓ , thereby making commuting much more attractive and so, in contrast to mobility in the form of migration, promoting employment in urban production. When financed by a rural poll tax, the resulting allocation in the absence of agglomeration economies is given in column (7). Despite the improvement in $Q(\tau)$, the rural sector's levels of output and employment fall, by 2.9 per cent and 6.1 per cent, respectively. With more commuters and shorter commuting time, the urban wage falls by 3.0 percent, but the net wage w_1 rises, by 12.1 per cent. Both cost-of-living indices fall somewhat, as does the export-GDP ratio.

In the presence of agglomeration economies, the greater inflow of labour into the port-city enhances productivity there. Relative to the base case, the wage falls a little less (see column (8)), a consequence of the attendant improvement in productivity. The spillover effects include a slightly larger withdrawal of labour from rural production and a mitigation of the programme's adverse effects on urban production and incomes.

If, instead, the programme were financed by an export tax, commuting to urban jobs would be even more attractive, with still heavier pressure on the wage rate. In the absence of agglomeration economies, the wage rate is 6.3 per cent lower, at 1.093. Whereas a tariff on good 2 yields virtually the same outcome in the absence of agglomeration economies, it is decidedly inferior in their presence. Urban households enjoy the additional profits stemming from protection, but pay a higher price for good 2 as consumers, now with no relief on the price of good 1. Rural households also face higher prices, including a more favourable producer price, which makes commuting less attractive, and thus works against urban economic activity on the supply side.¹⁶

7.3 | Social profitability

The natural measure of the programme's effects on welfare is the equivalent variation (EV), namely, the lump-sum transfer such that households would be indifferent between having that sum with the initial transport costs and enjoying the programme to reduce τ_i to 0.05 ($i = 1, 2, 3$) and τ_ℓ to 0.1. Since all households supply their labour

¹⁶Full details of the allocations with trade taxes are available upon request.

**TABLE 3** EV as % of income: taxation, agglomeration economies and rural mobility

	Poll tax		Export tax		Tariff	
	€ = 0	€ = 0.2	€ = 0	€ = 0.2	€ = 0	€ = 0.2
Migration						
Rural households	4.49	4.29	4.11	4.06	4.18	4.13
Urban households	1.28	−0.56	1.65	0.63	1.65	0.67
All households	3.13	2.24	3.07	2.61	3.11	2.67
Commuting						
Rural households	8.05	8.46	9.11	8.41	9.18	8.35
Urban households	−0.96	0.34	−0.74	0.00	−0.75	−0.63
All households	4.04	4.85	4.72	4.73	4.76	4.23

perfectly inelastically, their money-metric welfare is inversely proportional to the level of the index $\kappa(\mathbf{p}_k)$. The levels of M_k for the calculations in Table 3 are reported in Table A1 in Appendix B.

The EV accruing to rural households is rather insensitive to how the programme is financed and the strength of agglomeration economies. It is quite strikingly sensitive to whether the improvement in the network enables commuting to urban jobs. Inhabitants of villages lacking all-weather roads can always migrate for extended periods or permanently. The provision of such roads is likely, by improving villagers' standard of living, to induce some migrants to return home. If rural mobility takes the form of commuting, there will be the direct effect of an increase, *cet. par.*, in the urban wage net of commuting costs, and hence in the value of rural households' labour endowments, the net wage being their opportunity cost of labour. There is no such direct effect associated with migration.

Agglomeration economies are disadvantageous to urban households when there is migration, whether the programme be financed by a poll or trade taxes; for the programme induces return migration and so reduces urban production. Conversely, they do better with agglomeration economies if there is commuting; for the programme then induces greater supplies of labour to urban production.

There is also the matter of aggregate efficiency. If there are no agglomeration economies and commuting is prohibitively expensive, but agents are free to choose their place of residence, the setting is first-best. If, instead, commuting is a real option, but not the place of residence, the latter restriction is a distortion. In the numerical examples, trade taxes are clearly superior to a poll tax in the absence of agglomeration economies; but in their presence, the converse holds.

In the light of Proposition 3, it is instructive to examine the performance of the measure $B_1^r - T_1$. Consider, first, the variant in which there is migration, a poll tax and no agglomeration economies: $B_1^r = 0.2065$, evaluated at the (observable) pre-programme quantities, so that the aggregate net amount is 0.1802. The exact measure, $EV_1 + EV_2$, is 4.4 percent higher, at 0.1882. A partial equilibrium approach to evaluation might well stop at estimating the increase in rural incomes, yielding 0.1902. Although this is almost spot on in aggregate, about one sixth accrues to urban households. With agglomeration economies, $B_1^r - T_1$ is essentially unchanged at 0.1804, and so exhibits a large overestimate, implying that Δ , the loss arising from weaker external effects as urban employment contracts, is large. Serious errors also arise in the case of taxes on trade. If mobility takes the form of commuting, the errors run in the other direction, modestly in the absence of agglomeration economies, but seriously (20 percent too low) in their presence.

8 | ROBUSTNESS: OTHER FACTORS

First, there is the ease of substitution in final consumption. Second, there is rural family structure as an influence on migration decisions. Third, there are the numerical values of ϵ and the programme's cost.



8.1 | Substitution in consumption

The domestic good is produced by means of unassisted labour; the wage rate is therefore quite strongly connected to the level of demand for that good. Cobb–Douglas preferences imply that goods are rather good substitutes and cross-price elasticities are zero. To investigate more limited substitutability, consider CES-preferences with the elasticity of substitution $\sigma = -0.5$:

$$U_k(\mathbf{X}_k) = \frac{1}{b_{1k}/X_{1k} + b_{2k}/X_{2k} + b_{3k}/X_{3k}}, \quad \sum_{i=1}^3 b_{ik} = 1, \quad k = 1, 2.$$

Income effects now take on a stronger role, whereas the changes in the price of good 3 have a lesser one. The Marshallian demand functions are

$$X_{ik} = \frac{(b_{ik}/p_{ik})^{0.5} M_k}{\sum_{j=1}^3 (b_{jk} p_{jk})^{0.5}}, \quad i = 1, 2, 3, \quad k = 1, 2.$$

In keeping with the values of the taste parameters when preferences are Cobb–Douglas, let $b_{11} = 0.40, b_{21} = 0.30, b_{31} = 0.30$, and $b_{12} = 0.30, b_{22} = 0.40, b_{32} = 0.30$.

In the base variant (column (2) in Table 2), the programme is indeed rather more profitable. The wage rate is somewhat higher, at 1.074, and the level of final consumption of good 3 is also higher in both town and country.¹⁷ Both EV_1 and EV_2 are correspondingly greater than those with Cobb–Douglas preferences: at 4.92 and 1.40 per cent, respectively, with an aggregate improvement of 3.44 percent, they are about 10 per cent larger.

8.2 | Rural family structure

Thus far, rural workers have been footloose in employment, while keeping one foot firmly in the extended family. On the supply side, the opportunity cost is the value of the marginal product of labour in rural production. At the other extreme, migrants lose all claims on the imputed rent from the family's holding in exchange for an exclusive claim on their urban wages. Their opportunity cost would be the value of the average product of labour in rural production. Suppose they have the right of return in the event that rural life became more attractive.

Each family worker on the farm receives $m_1 = (p_{11}Y_{11} + p_{21}Y_{21} + p_{31}Y_{31} - T_1)/L_1$. The following condition must hold in equilibrium: $v_1(\mathbf{p}_2, w) = v_1(\mathbf{p}_1, m_1)$, where v_1 denotes a rural worker's indirect utility function. If the said rent is sufficiently large, the wage will be higher in this variant than in the alternative, both with and without the programme. The latter's social profitability depends, however, on how much the wage responds. The adjustment of the wage in Section 7 is almost surely smaller; for the concavity of the technology implies that, in any neighbourhood, the value of the marginal product is less sensitive to movements in employment than that of the average product, and the sharing of family income involves all members wherever they are employed, not just those resident in the village. It follows that the results in Section 7 and 8.1 understate the absolute magnitudes of the programme's effects when migrants give up their family ties.

¹⁷The full details of the allocation are available upon request.



8.3 | Congestion, programme costs and scale

Suppose congestion costs depend only on the level of urban production. Then the parameter ϵ represents the joint, net effect of congestion and agglomeration economies. The selected value 0.2 is rather on the high side, but the results indicate that linear interpolation will yield sufficiently accurate results for intermediate values. In the light of the empirical evidence, the half-way value of 0.1 suggests itself.

Turning to the programme's costs, suppose the requirement L_{1p} were to double. In the base variant (column (2) in Table 2), the wage rate would indeed be slightly higher, at 1.0560, thereby inducing a slightly greater contraction of urban activities.¹⁸ At 3.70 per cent of rural income, EV_1 would be somewhat more modest, but still substantial. Urban households, in contrast, would experience a slightly larger increase. The aggregate gain would be 2.70 per cent of GDP instead of 3.13 per cent.

Lastly, there is scalability. Suppose, in the base variant, that both the reductions in τ and the associated cost were half as large. Then EV_1 and EV_2 would be 64 and 54 per cent of their base-variation values, respectively, yielding 62 per cent in aggregate, and so implying moderate concavity.

9 | CONCLUDING DISCUSSION

Four simplifying assumptions that underpin the foregoing analysis merit discussion. First, labour is homogenous. In fact, rural-urban migrants are predominantly young males, and if married, they often leave without their families, at least for some period. In most agrarian settings, return migration will then have stronger effects on rural production, but perhaps less marked ones on urban production. These males are also the main prospective commuters if that option arises, so that the converse will then hold, with female villagers drawn more heavily into cultivation and tending livestock. In father's absence, boys may get more involved in farm or other work and their sisters in household tasks, with their schooling suffering accordingly. Aggarwal (2018) finds evidence that access to employment opportunities drew teenagers out of school, though enrolment among young children improved.

Second, there are the direct effects of easier access, for both children and their teachers, to the schools themselves. This should improve the quality of rural life, but as just noted, when school attendance is not rigorously enforced, the new road may serve rather to promote child labour. On balance, urban activities are unlikely to be much affected by these particular responses. As for other amenities, better access to health facilities in a local or regional town can be interpreted as one element in the reduction of the transport parameter τ_3 . Return migration, but not commuting, becomes more attractive.

Third, there are no "regional" goods, which are produced and consumed only in each location, and whose presence strengthens the role of domestic demand. Important among them are retail and some wholesale trade, construction, and personal and housing services. In the hinterland, a substantial share is produced in local towns, whose character and scale leave little scope for the operation of agglomeration economies. Such economies are pervasive in cities, so that the production of urban "regional" goods would fall under their influence. For present purposes, the three-good structure is the lower limit for an open economy. Expanding it to five goods would be a move towards realism, but purchased at a high cost in terms of complexity, and without a clear indication that, qualitatively, the theoretical results would be overturned.

Fourth, the costs of urban congestion have been netted out only for firms. Yet a city's air and water are polluted, and a host of communicable diseases flourishes in such settings. These public "bads", which intensify with the city's endogenous size, ought to have a place in households' preference orderings. The same holds, analogously, for certain

¹⁸The details are available on request.



pecuniary externalities: there is no urban rental gradient, which would respond more to migration than to commuting.

With these cautionary reservations, some firm conclusions can still be drawn. A programme's effects on welfare depend on the interplay between how it is financed and the form of rural workers' mobility. If commuting remains unattractive, new roads almost surely will induce some return migration and an increase in deliveries of rural goods to cities. If that increase is not wholly absorbed there and such goods constitute the economy's principal exports, heavier imports of urban goods will result and urban activity will contract, almost always with an increase in the wage rate.

In the absence of agglomeration economies, theory and numerical examples indicate that urban households may benefit quite substantially, whether the programme be financed by a poll tax on rural households or taxes on international trade. If agglomeration economies are sufficiently strong, the contractionary effects of return migration and higher imports can lower urban welfare when the programme is financed by a poll tax. Taxes on trade, in contrast, operate as countervailing distortions to the market failure stemming from such externalities by offsetting part of the improvement in the rural sector's terms of trade. Numerical examples indicate that whereas rural households would do almost as well, urban households would enjoy modest net benefits.

Mobility in the form of commuting puts the urban wage under pressure. In the absence of agglomeration economies, rural households will do much better still; but in the numerical examples, urban households lose. Agglomeration economies relieve the pressure on the wage due to cheaper commuting. In the numerical examples, rural households gain somewhat less under all three taxes, the tariff being least favoured. Urban welfare improves slightly under a poll tax, is unchanged under an export tax, and is modestly lower under a tariff.

Practitioners charged with programme evaluation usually prefer tractable, partial equilibrium methods. Does the change in the value, at the economy's producer prices, of the rural sector's net supply vector closely approximate the true, net aggregate benefit? When commuting remains unattractive and agglomeration economies are strong, that measure yields a substantial overestimate. The converse holds when mobility takes the form of commuting. The distribution of the true aggregate is also rather sensitive to the form of taxation. Grounds enough for a resort to general equilibrium analysis.

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APPENDIX A: PROOFS

Proof of Proposition 1

There are three preliminary steps. First, Lemma 1 establishes (weak) sufficient conditions such that the delivery of good 1 at the port-city will rise if the wage fails to increase.

Second, if the wage does increase, so will p_3 ; but if the cost shares of good 3 in the production of goods 1 and 2 are sufficiently small, then in equilibrium, both M_1 and M_2 will increase with w .

Third, there is the response of the level of final demand for good 2. Consider the case wherein the three goods are consumed in the fixed proportions $1:b_{2k}:b_{3k}$ ($k=1,2$). Then the demand for good 2 is $X_{2k} = b_{2k}M_k(w)/(p_{1k}b_{1k} + p_{2k}b_{2k} + p_{3k}b_{3k})$. Differentiating totally, and noting (8), we have

$$\frac{dX_{2k}}{dw} = \frac{b_{2k}M_k/w}{(p_{1k}b_{1k} + p_{2k}b_{2k} + p_{3k}b_{3k})} \left[\frac{w}{M_k} \frac{dM_k}{dw} - \frac{p_{3k}b_{3k}}{p_{1k}b_{1k} + p_{2k}b_{2k} + p_{3k}b_{3k}} \right],$$

where the derivatives of X_{2k} and M_k w.r.t. w encompass the associated change in p_{3k} . The second term in brackets is the expenditure share for good 3, which is much less than 1 in practice. The first term in brackets is the elasticity of M_k w.r.t. w . Since some migrants have urban jobs and the cost share of good 3 in the production of good 1 is small, the said elasticity of M_1 must be fairly close to 1. That of M_2 will be smaller than 1, but not by much if the elasticity $n_2^0 \cdot \phi' / \phi$ is small, as is the case in practice. In equilibrium, therefore, the aggregate level of final demand for good 2 is increasing in the wage. This will hold *a fortiori* if there is any measure of substitution between goods 2 and 3 in consumption.

If the wage remains unchanged, the output of good 2 and urban income, prices and demand will do likewise; so that the whole of the increase in the delivery of good 1, $\Delta[(1 + \tau_1)Z_{11}]$, will be exported. By assumption, the economy imports good 2 ($E_2 < 0$); so that, in equilibrium, imports of good 2 must increase in the amount $p_1^* \Delta[(1 + \tau_1)Z_{11}] / p_2^*$. Given that w is unchanged, the latter quantity must be equal to the change in rural demand for good 2—a result that will come about only by the merest fluke when rural prices change only in proportion to the change in τ —or there will be a contradiction.

If, when w remains unchanged, $p_1^* \Delta[(1 + \tau_1)Z_{11}] + p_2^* \Delta[(1 + \tau_2)Z_{21}] > 0$, there will be an export surplus, which points to a required fall in the output of good 2, and hence, in virtue of Lemma 2, an increase in the wage. For suppose, on the contrary, that w falls, so that the output of good 2 increases, M_2 falls, and hence also urban final demand for goods 1 and 2. The hypothesised fall in w will also increase the size of the delivery of good 1 to the port-city. The resulting effects on E_1 entail a higher volume of imports than if w were unchanged.

The hypothesised fall in w will result in a fall in M_1 , and hence lower rural demand for good 2. Since urban demand for good 2 also falls, the increase in imports of good 2 contradicts the increase in the output of good 2 induced by the hypothesised fall in w .

There remains only the possibility that the wage increases. Then the converse of all of the above would apply. The accompanying reduction in the output of good 2 and the increase in urban demand for it would make room for imports to increase in response to the increase in exports of good 1, whereby the latter would be weakened by the attendant effects on rural supply and income. ■

Proof of Proposition 2

Suppose the wage does not change, so that $dL^u = 0$. With the normalisation $g/l_3 = 1$, so that $p_3 = w$ and $p_{31} = (1 + \tau_3)w$, (14) becomes



$$dL' = d[L_1 + (1 + \tau_3)(-Y_{31} + X_{31})] = -L_{1p}.$$

Since the output price p_{11} increases and the input prices p_{21} and p_{31} decrease, L_1 will also increase, unless goods 2 and 3 are highly substitutable for labour in the production of good 1. The same holds for the derived demand for good 3 in rural production, $-Y_{31}$, and for rural final demand, X_{31} , provided T_1 is not so large as to reduce M_1 substantially. The latter effect is unlikely to accompany a socially profitable programme, thus yielding a contradiction.

Suppose, therefore, and rather counter-intuitively, that the programme increases M_1 but induces a fall in w . By itself, the latter will result in an increase in L_1 , albeit with an attendant substitution effect on $-Y_{31}$, and it will reduce M_1 , with an attendant substitution effect on X_{31} . If the cross-price effects are sufficiently small, inspection of $M_1 = R_1 + w(\bar{L}_1 - L_{1p})$ indicates that, *cet. par.*, the hypothesised fall in w will likely induce a rise in L' . As for L^u , a fall in w will result in an increase in L_2 and Y_{22} , but a fall in M_2 , thus leaving only the effect of the fall in p_3 on X_{32} to pull in the opposite direction.

Noting that the programme has the direct effect of reducing transportation costs, with consequent effects on w and p_3 , (14) may be decomposed into the form

$$\begin{aligned} dL' + dL^u &\equiv \nabla[L_1 + (1 + \tau_3)(-Y_{31} + X_{31})] \cdot d\tau + \nabla[L_1 + (1 + \tau_3)(-Y_{31} + X_{31})] \cdot (dw, dp_3) \\ &\quad + \nabla[L_2 + (a_{32}Y_{22} + X_{32})] \cdot (dw, dp_3) = -L_{1p}, \end{aligned}$$

where $dp_3 = dw$ in virtue of $g'_3 = 1$, and L^u depends on τ only through w and p_3 . Under the assumption that the rural technology and preferences are Cobb–Douglas, $wL_1 = \alpha_{\ell 1}p_{11}Y_{11}$, $-p_{31}Y_{31} = \alpha_{31}p_{11}Y_{11}$, and $p_{31}X_{31} = \beta_{31}M_1$, where $\alpha_{\ell 1}$, α_{31} and β_{31} are the respective, constant cost-shares. Suppose w , and hence p_3 , stays unchanged. Then substituting into the foregoing condition and recalling (4), we have,

$$(1/w) \cdot d[(\alpha_{\ell 1} + \alpha_{31})p_{11}Y_{11}] + \beta_{31}(Y_{11}dp_{11} + Y_{21}dp_{21} + Y_{31}d\tau_3 - wdL_1^0 - T_1) = -L_{1p}.$$

If, at worst, the programme would leave rural net incomes unchanged under these conditions, we have a contradiction.

Proceeding to the terms involving changes in w and p_3 with τ held constant, substitution and some manipulation yield, at length,

$$\nabla[L_1 + (1 + \tau_3)(-Y_{31} + X_{31})] \cdot (dw, dp_3) = -\frac{1}{w} \left[\frac{(\alpha_{\ell 1} + \alpha_{31})p_{11}Y_{11} + \beta_{31}M_1}{w} - H - \beta_{31}(\bar{L}_1 - L_1 - L_{1p}) \right] dw,$$

where

$$H \equiv (\alpha_{\ell 1} + \alpha_{31})p_{11} \left(\frac{\partial Y_{11}}{\partial w} + (1 + \tau_3) \frac{\partial Y_{11}}{\partial p_{31}} \right) + \beta_{31}(1 + \tau_3)^2 \frac{\partial Y_{11}}{\partial p_{31}} < 0.$$

Since $M_1 = R_1 + w(\bar{L}_1 - L_{1p})$ and $R_1 + wL_1 > 0$, $\nabla[L_1 + (1 + \tau_3)(-Y_{31} + X_{31})] \cdot (dw, dp_3)$ and $dw (= dp_3)$ have opposite signs.

Turning to L^u , this may be written

$$L^u = (1 - \beta_{32})L_2 + \left[(1 - \beta_{32})a_{32} + \beta_{32} \left(\frac{p_2^* - a_{12}p_1^*}{w} \right) \right] Y_{22} + \beta_{32}\bar{L}_2,$$

where β_{32} will vary if preferences are not Cobb–Douglas. The expression in brackets is decreasing in w , as are L_2 and Y_2 . Hence, L^u is decreasing in w if β_{32} varies sufficiently weakly with w .



As a final step, suppose the programme induces a fall in the wage. Then $dL^r + dL^u > 0$, which is a contradiction. ■

Remark 3. If urban households' preferences are Cobb–Douglas, analogous calculations yield

$$\begin{aligned} dL^u &= \nabla[L_2 + a_{32}Y_{22} + X_{32}] \cdot (dw, dp_3) \\ &= \frac{1}{w} \left[(\alpha_{r2}\hat{p}_2 + a_{32}w) \frac{\partial Y_{11}}{\partial w} + \alpha_{r2} \left(\frac{\partial \hat{p}_2}{\partial w} - \frac{\hat{p}_2}{w} \right) \cdot Y_{22} - \frac{\beta_{32}}{w} \left(a_{32}Y_{22} + \frac{1 - \alpha_{r2}}{w} \cdot \hat{p}_2 Y_{22} \right) \right] dw, \end{aligned}$$

where all the terms in brackets are negative.

A tariff on good 2

The term $-t_1 p_1^* Z_{11}$ in (19) is replaced by $t_2 p_2^* (1 + \tau_2) Z_{21}$. Urban firms enjoy higher profits, in the amount $t_2 p_2^* Y_{22}$, against which is the loss $t_2 p_2^* X_{22}$ inflicted on urban households. In (20), the term $-t_2 p_2^* (X_{22} - (1 + \tau_2) Z_{21} - Y_{22})$ replaces $-t_1 p_1^* (Z_{11} - (a_{12} Y_{22} + X_{12}))$. Now, imports are $-E_2 = (X_{22} - (1 + \tau_2) Z_{21} - Y_{22})$, and since tariff revenues, $-t_2 p_2^* E_2$, are only collected when the programme is undertaken, the deadweight loss in the absence of agglomeration economies is $t_2 p_2^* \Delta \tau_2 Z_{21}$, where $\Delta \tau_2$ is the associated reduction in τ_2 . Eqn. (9) becomes

$$[1 + p_3 a_{32} / \hat{p}_2] dw = \xi_2 \cdot dL_2^0 - \xi_3 \cdot dL_3 + t_2 p_2^* w / \hat{p}_2,$$

and the argument that follows (21) goes through, *mutatis mutandis*.

APPENDIX B: CALIBRATION AND NUMERICAL DETAILS

The equation relating w and $Q(\tau)$ in Section 6

Exports of good 1 are equal to the excess of the delivery at the port-city over urban demand for good 1, and imports of good 2 are equal to the excess of domestic demand over domestic production:

$$E_1 \equiv (1 - \tau_1) Z_{11} - (a_{21} Y_{22} + X_{12}); \quad E_2 \equiv Y_{22} - X_{22} - (1 + \tau_2)(-Y_{21} + X_{21}). \quad (A1)$$

With the normalisation of world prices, Walras's law implies $E_1 + E_2 = 0$.

The constant cost-share property of Cobb–Douglas technologies and preferences yields

$$p_{ik} X_{ik} = b_{ik} M_k; \quad -p_{i1} Y_{i1} = \alpha_{i1} p_{11} Y_{11}, i = 2, 3.$$

Substituting into (A1), we obtain

$$E_1 = (1 - \tau_1)(Y_{11} - b_{11} M_1 / p_{11}) - (a_{21} Y_{22} + b_{12} M_2 / p_{12}),$$

and

$$E_2 = Y_{22} - b_{22} M_2 / p_{22} - (1 + \tau_2)(\alpha_{21} p_{11} Y_{11} + b_{21} M_1 / p_{21}).$$



where $\mathbf{p}_1 = ((1 - \tau_1), (1 + \tau_2), (1 + \tau_3)p_3)$ and $\mathbf{p}_2 = (1, 1, p_3)$. In the absence of agglomeration economies, $p_3 = w$. Substituting into (22), (24), $M_1 = \alpha_{1h}p_{11}Y_{11} + w(\bar{L}_1 - L_{1p})$ and $M_2 = (1 - \alpha_{\ell 2})\hat{p}_2Y_{22} + w\bar{L}_2$, and noting that $\hat{p}_2 = 1 - a_{12} - a_{32}w$, some manipulation and rearrangement of the terms in $E_1 + E_2 = 0$ yields (25).

TABLE A1 Allocations in equilibrium: a rural poll tax, an export tax and commuting

Transport Tax Agglomeration elasticity	$\tau_i = 0.1$	$\tau_i = 0.05$		$\tau_i = 0.05$		$\tau_\ell = 0.2$	$\tau_i = 0.05, \tau_\ell = 0.1$	
	none ^a	poll	poll	export	export	none ^a	poll	poll
	$\epsilon = 0$	$\epsilon = 0$	$\epsilon = 0.2$	$\epsilon = 0$	$\epsilon = 0.2$	$\epsilon = 0$	$\epsilon = 0$	$\epsilon = 0.2$
Rural	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
p_{11}	0.90	0.95	0.95	0.9231	0.9244	0.90	0.95	0.95
p_{21}	1.10	1.05	1.05	1.05	1.05	1.10	1.05	1.05
p_{31}	1.10	1.1067	1.1099	1.0812	1.0837	1.2832	1.1889	1.1768
Y_{11}	3.4945	3.5928	3.6354	3.5338	3.5603	3.9106	3.7978	3.7666
$-Y_{21}$	0.1430	0.1625	0.1645	0.1553	0.1567	0.1600	0.1718	0.1704
$-Y_{31}$	0.1430	0.1542	0.1556	0.1509	0.1518	0.1371	0.1517	0.1520
L_1	1.8871	1.9430	1.9871	1.9007	1.9219	2.2627	2.1243	2.1004
M_1	3.4642	3.6544	3.6505	3.5742	3.5769	3.4564	3.6782	3.6810
X_{11}	1.5397	1.5387	1.5370	1.5488	1.5479	1.5362	1.5487	1.5500
X_{21}	0.9448	1.0441	1.0430	1.0212	1.0220	0.9427	1.0509	1.0517
X_{31}	0.9448	0.9906	0.9867	0.9917	0.9902	0.8081	0.9281	0.9384
E_1	0.8625	1.0402	1.1038	0.9582	0.9968	1.1905	1.2016	1.1618
$(EV_1/M_1) \cdot 100$		4.49	4.29	4.11	4.06		8.05	8.46
Urban								
p_{12}	1.00	1.00	1.00	0.9731	0.9744	1.00	1.00	1.00
p_{22}	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
p_{32}	1.00	1.0540	1.0570	1.0297	1.0321	1.1666	1.1323	1.1207
w	1.00	1.0540	1.0476	1.0297	1.0274	1.1666	1.1323	1.1358
Y_{22}	1.35	1.2722	1.1913	1.3106	1.2651	1.1332	1.1726	1.2227
$-Y_{12}$	0.135	0.1272	0.1191	0.1311	0.1265	0.1133	0.1173	0.1223
$-Y_{32}$	0.135	0.1272	0.1191	0.1311	0.1265	0.1133	0.1173	0.1223
L_2	0.54	0.4796	0.4516	0.5089	0.4921	0.3805	0.4074	0.4241
Y_{32}	2.0936	2.0732	2.0475	2.0860	2.0722	2.0390	1.9733	2.0046
L_3	2.0936	2.0732	2.0660	2.0860	2.0817	2.0390	1.9733	1.9781
M_2	2.54	2.6134	2.5682	2.5835	2.5604	2.7770	2.7258	2.7532
X_{12}	0.762	0.7840	0.7705	0.7965	0.7884	0.8331	0.8178	0.8260
X_{22}	1.016	1.0454	1.0273	1.0334	1.0242	1.1108	1.0903	1.1013
X_{32}	0.762	0.7439	0.7289	0.7527	0.7442	0.7141	0.7222	0.7370
E_2	-0.8625	-1.0402	-1.1038	-0.9582	-0.9967	-1.1905	-1.2016	-1.1618
$(EV_2/M_2) \cdot 100$		1.28	-0.56	1.65	0.63		-0.96	0.34

Notes: World prices at the port-city: $p_1^* = p_2^* = 1$.
 $(EV_k/M_k) \cdot 100$ relative to the base case $\tau_i = 0.10$.
^aThe functions ϕ and g representing agglomeration economies are normalized so as to yield, in the absence of the roads programme, the same allocation as that in which there are no agglomeration economies.
Source: author's calculations.



Resumen. Los efectos de un programa de carreteras rurales dependen de la movilidad de la mano de obra, de la financiación del programa y de las economías de aglomeración. Si se financia con un impuesto de capitación rural y los efectos de los precios cruzados y las economías de aglomeración son lo suficientemente pequeños, el salario aumentará, con cierta migración de retorno. Los impuestos sobre el comercio actúan como distorsiones compensatorias, lo que proporciona a los hogares urbanos un cierto alivio. Los desplazamientos diarios del campo a la ciudad favorecen la explotación de las economías de aglomeración; los impuestos sobre el comercio internacional son entonces inferiores a un impuesto de capitación. La variación del valor, a precios de productor, del vector de oferta neta del sector rural puede ser una medida deficiente de la rentabilidad social del programa.

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