Appendix C

to

"Transportation Costs, Agricultural Productivity and Cross-Country Income Differences"*

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Consider a stripped down version of the model presented in Section 3, in which there are no decreasing returns ($\alpha = \sigma = 1$), no intermediate inputs ($\beta = \theta = 1$), and the demand for food is determined solely by the subsistence food requirement ($\phi = 0$). The latter assumption implies that consumers in each region consume only $\overline{a}$ of the agricultural good. In this environment, trade is driven by Ricardian productivity differences. The fact that the West is more productive in agriculture and the East more productive in non-agriculture, implies here $\varepsilon_{aW} > \varepsilon_{aE}$ and $\varepsilon_{mE} > \varepsilon_{mW}$ respectively. The model is deliberately stripped down to make the discussion as transparent as possible.

First, I illustrate how the trade regime and the labor mobility regime interact with the subsistence constraint to affect the allocation of labor. Consider initially the case of autarky, in which each region produces its own agricultural and non-agricultural goods. The market clearing condition for the agricultural commodity in region $j \in \{E, W\}$, $c_{aj} n_j = Y_{aj}$, implies that in an autarkic equilibrium, the share of employment allocated to agricultural production in each region j is,

$$\frac{n_{aj}}{n} = \frac{\overline{a}}{A\varepsilon_{aj}} \cdot \frac{n_j}{n} \tag{1}$$

*This appendix is not intended for publication. It illustrates some key points analytically, in a more simplified environment than the original one in the paper.

When the constraint on labor mobility is binding, $\frac{n_j}{n}$ is fixed and equal to $\frac{\overline{n}_j}{n}$. Then equation (1) says that, in the presence of a subsistence constraint in food consumption, the share of labor that each region devotes to the agricultural sector depends negatively on the productivity in farming. This might run contrary to conventional wisdom, since in general when an activity is distorted, agents tend to substitute away from that activity to reduce the impact of the distortion. Due to the subsistence constraint in food consumption agents cannot substitute away from farming, but instead have to devote even more resources to farming. Therefore, in autarky when labor cannot move across locations, the region which is less productive in agriculture (the East) has to devote more resources to farm production, other things equal. Furthermore, the larger the share of people living in the agriculturally unproductive region the larger the economy-wide share of labor in agriculture.

On the other hand, under the perfect labor mobility regime, $\frac{n_j}{n}$ is endogenous. In principle, individuals can avoid the low productivity in farming in the East by choosing to locate in the West, which would presumably reduce the economy-wide share of labor in agriculture. It can be shown however that the equilibrium of this simplified model has a corner solution, whereby individuals locate in only one region. The decision weighs not only the relative productivity in farming but also the absolute productivity in non-agriculture. If agents all locate in the East (West), then the economy-wide share of employment in agriculture would be higher (lower) than that under the restricted labor regime.

Given that the autarky relative prices of the two regions differ, with the West having a comparative advantage in agriculture, $\frac{\varepsilon_{mW}}{\varepsilon_{aW}} < \frac{\varepsilon_{mE}}{\varepsilon_{aE}}$, there is an incentive, in the absence of transport costs, to trade. Trade offers a way to mitigate the negative relationship between labor in agriculture and agricultural productivity. Suppose that the West and the East can trade now. The region that is unproductive in farming, the East, can circumvent its inefficiency in farming by simply importing agricultural goods from the productive region, the West. To see this, consider the market clearing condition for the agricultural good in the East under trade, which implies,

$$\frac{n_{aE}}{n} = \frac{\left(\overline{a} \cdot - \frac{M_{aE}}{n_E}\right) \frac{n_E}{n}}{A \cdot \varepsilon_{aE}} \tag{2}$$

where M_{aE}/n_E are the per capita imports of food in the East from the West. From (2) it

is clear that the share of labor devoted to farming in the East depends on the productivity of the local agricultural sector only to the extent that the local food requirements are not covered by imports. In the extreme case, in which all subsistence consumption was met by imports, the connection between the Eastern labor share in farming and its agricultural labor productivity would disappear.

Again here we can look at the trade equilibrium employment share in agriculture under the mobile and the restricted labor regimes. Under perfect labor mobility you can only have a trade equilibrium with complete specialization. In this case only the West produces and exports food, and the Eastern share of labor in agriculture is zero. While such a trade equilibrium is possible under imperfectly mobile labor as well, under this regime we can also have a trade equilibrium in which the West completely specializes in agricultural production, and the East is incompletely specialized (or one in which the West is incompletely specialized and the East completely specializes in manufactures).

Next, consider the key role that transportation productivity plays for aggregate productivity, by affecting whether the two locations trade. To illustrate this we have to be more explicit about the trade equilibrium. I will focus the discussion on a trade equilibrium with incomplete specialization for the East only (complete specialization for the West in farming) and binding restrictions to labor mobility. This framework is closer to the general version of the model, in the sense that it does not have complete specialization.

In this simple case, with one factor of production, equilibrium prices can be solved for with knowledge of the production technologies alone. The price of the non-agricultural good in the East (the numeraire) is normalized to unity, which implies that the wage rate in the East is $w_E = A\varepsilon_{mE}$. Wage equalization across manufacturing and transportation in the East imply that the relative price of transportation is $p_t = \frac{A\varepsilon_{mE}}{A_t}$. From the first order condition of the exporter in the East it follows that the price of a manufactured good arriving in the West from the East will be $p_{mW} = 1 + \frac{A\varepsilon_{mE}}{A_t}$. Free mobility of labor across agriculture and manufacturing in the East imply a relative price of food in the East of $p_{aE} = \frac{\varepsilon_{mE}}{\varepsilon_{aE}}$. Given that the relative price of imported agricultural goods in the East must be the same as that of the locally produced ones (by arbitrage), the price of food in the West is, $p_{aW} = p_{aE} - p_t$. The wage rate in the West is $w_W = p_{aW} A\varepsilon_{aW}$. Given relative prices, the labor allocations across sectors, can be solved for in each region. Since the West produces only agricultural goods we

have that, $\frac{n_{aW}}{n} = 1 - \frac{\overline{n}_E}{n}$. From the economy-wide agricultural market clearing condition, the share of employment devoted to agriculture in the East is,

$$\frac{n_{aE}}{n} = \frac{\overline{a}}{A\varepsilon_{aE}} - \frac{\varepsilon_{aW}}{\varepsilon_{aE}}\frac{n_{aW}}{n} \tag{3}$$

From the market clearing conditions for transportation and Eastern labor, we can solve for the share of labor in manufacturing in the East,

$$\frac{n_{mE}}{n} = \frac{\frac{\overline{n}_E}{n}\left(1 + \frac{c_{mE}}{A_t}\right) - \frac{n_{aE}}{n} - \frac{1}{A_t}\left(A\varepsilon_{aW} - \overline{a}\right)\left(1 - \frac{\overline{n}_E}{n}\right)}{1 + \frac{A\varepsilon_{mE}}{A_t}} \tag{4}$$

where $c_{mE} = \varepsilon_{mE}\left(A - \frac{\overline{a}}{\varepsilon_{aE}}\right)$.

In order to have a trade equilibrium in which the West produces only the agricultural good and the East produces both goods, the following conditions have to be satisfied: (1) it must not be worth for the West to produce the manufacturing good at home, $\frac{p^{tr.}_{mW}}{p^{tr.}_{aW}} < \frac{p^{aut.}_{mW}}{p^{aut.}_{aW}}$, where the superscripts $aut.$ and $tr.$ stand for equilibria under autarky and trade respectively, and (2) the relative cost of the agricultural good should be the same for the East under autarky and trade, $p^{aut.}_{aE} = p^{tr.}_{aE}$. The second condition will always hold in the equilibrium analyzed here. However, inefficiencies in the transportation sector, manifested through a lower A_t, raise $p^{tr.}_{mW}$ and reduce $p^{tr.}_{aW}$, making the first condition less likely to hold. In particular, there is a cutoff level of transportation productivity,

$$\overline{A}_t = \frac{\left(1 + \frac{\varepsilon_{mW}}{\varepsilon_{aW}}\right)A\varepsilon_{mE}}{\frac{\varepsilon_{mE}}{\varepsilon_{aE}} - \frac{\varepsilon_{mW}}{\varepsilon_{aW}}}$$

below which it is not profitable for the two regions to trade, even if in a transportation free world they would. If A_t falls below the cutoff, the two regions behave as autarkic economies.

Note also that, transport productivity affects the amount of resources devoted to the transportation sector, when goods are being exchanged. In particular, the Leontief nature of the export technologies implies that as a result of the increase in A_t, the share of labor devoted to transporting given amounts of goods will fall. From (4) one can show that, a higher transportation productivity will reduce the share of labor in transportation and will raise the share of labor in non-agriculture.