Structural Transformation and Regional Growth Dynamics

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July 11, 2009

Abstract

This paper outlines a dynamic general equilibrium model of structural change that can capture many important empirical facts that other models cannot. Typically, structural change contributes to regional convergence, with workers exiting the relatively low paying agricultural sector disproportionately benefiting poorer, farming regions. Models that account for this, however, cannot match migration patterns and cannot address occasions of low regional convergence during structural change. Two regional groupings of the United States (the Northeastern versus Southern or Midwestern states) highlight these patterns. First, despite the Northwest's high agricultural employment share, the initial income difference, and therefore convergence, with the Northeast is modest. Specifically, in 1880, Midwestern earnings were 81% of Northeastern while the corresponding Southern figure is 43%. Second, all regions display substantial earnings increases in agriculture - with Midwest's relative income in agriculture rising from 43% to 65% while the South rose from 33% 72% between 1880 and 1980. Finally, both regions experienced massive declines (both over 90%) in their agricultural employment shares. Together, this is a quantitative puzzle: Models that capture structural change simultaneously with rising agricultural earnings imply far more convergence than one observes for the Midwest. To address this puzzle, I construct and calibrate a dynamic general equilibrium model with two key market frictions: a goods market friction - transportation costs between two regions - and a labour market friction between two sectors. I find the augmented model performs well and enables one to match the Midwestern experience.

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Contents

1 Introduction

Various time-series and cross-sectional growth data display a remarkably robust observation: aggregate growth is systematically related to an economy's sectoral composition. That is, there exists a strong negative relationship between the share of output and employment commanded by the agricultural sector and the overall level of economic activity - a phenomenon known as the "Kuznets fact" of growth. Various researchers, especially recently, have developed simple models to explain this, from increasing consumer goods variety (Greenwood and Uysal, 2005; Foellmi and Zweilmueller, 2006) or preference non-homotheticities (Kongsamut et al., 2001) to differential sectoral TFP growth (Ngai and Pissarides, 2007) or capital deepening (Acemoglu and Guerrieri, 2006).[2] While capturing the output and employment facts quite well, these models cannot match a number of other observations of interest to growth economists.

Specifically, regional incomes, sectoral wages, and household and firm location decisions display many potentially important patterns. To illustrate this point, one need only look at data for two regional groupings of the United States: the Northeastern[3] versus Southern[4] or Midwestern[5] states. That they have both important similarities and differences make them ideal groupings to study. Their economic evolution reveals unique growth experiences in need of reconciliation. A key difference, found in the top two rows of Table (1), is regional income differences over time, with far more convergence within the NE-S grouping. The relative overall earnings of Southern states to Northeastern manufacturing earnings rose from a mere 0.43 in 1880 to a nearly identical 0.92 in 1980 while the corresponding Midwestern ratios were, respectively, 0.81 and 1.00.[6] In terms of similarities, the same table compares the pattern of rising relative agricultural earnings.

[2] A concise review of the issues involved may be found in Matsuyama (2005).

[3] Northeastern States (NE): CT, MA, MD, ME, NH, NJ, NY, PA, RI, VT.

[4] Southern States (S): AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA, WV

[5] Midwestern States (MW): IA, IL, IN, MI, MN, MO, ND, NE, OH, SD, WI

[6] The last period of analysis is selected as 1980 since, after that date, there was a large and dramatic increase in the Northeastern earnings relative to all others. Given this model is attempting to capture long-term patterns, I ignore the data after 1980.

Table 1: Key Regional and Sectoral Data

	1880	1980	% Change
South/Northeast Earnings Ratio	0.43	0.92	114%
Midwest/Northeast Earnings Ratio	0.81	1.00	23%
Southern Ag/Nonag Earnings Ratio	0.33	0.72	118%
Midwest Ag/Nonag Earnings Ratio	0.43	0.65	51%
Southern Ag. Employment Share	0.73	0.03	-96%
Midwest Ag. Employment Share	0.55	0.04	-93%

Note that while the increase is higher in the South, it still significant in the Midwest. The key quantitative puzzle is that labour reallocation from agriculture to nonagriculture increases earnings in agriuclturally intensive regions yet we do not observe as large increase in Midwest earnings as we do in the South.

To address this question, I evaluate how declining transportation costs and improvements in human capital acquisition (lower learning costs), within the context of two US regions, may together better reflect the data. The intuition is straightforward. On the one hand, reduced sectoral switching costs for workers, made possible through lower learning costs, increase agricultural earnings. If more farm labour can move into nonfarm tasks then farm labour supply shrinks, thus increasing relative farm wages. This effect disproportionately benefits the agricultural region, such as the Midwest or South, and therefore leads to income convergence. On the other hand, transportation costs ensure a higher price of nonfarm goods in the agricultural region, which requires higher nominal incomes to compensate. As these costs decline, the relative peripheral nonfarm prices, and therefore relative nominal earnings, decline as well. This may offset the convergence achieved from lower learning costs. While the model developed later this paper makes these forces precise, this intuition identifies how the two market frictions might explain the data.

In a closely related model, Caselli and Coleman (2001) highlight reductions in learning costs as a mechanism of generating structural change. While generating the desired labour reallocation, their model also matches observed data for wages and regional income levels very well in the case of Northern versus Southern US states. Moreover, they demonstrate that structural change accounts for the majority of the convergence between the relatively poor Southern states and the richer Northeastern states over the past century. This paper will expand on their intuition by introducing greater complexity into the model, allowing one to capture a wider variety of structural change and regional growth experiences. Specifically, I will demonstrate that an additional factor - transportation cost reductions - is necessary to match data in high structural change but low convergence cases, such as between the Northeastern and Midwestern states. Here, there are only modest initial earnings differentials, despite low agricultural earnings and the Midwest's large agricultural workforce. One can reconcile these two observations with higher nonagricultural earnings in the Midwest. The question then becomes: what factor within a model of structural change can generate such a Midwestern premium? This paper will show that, at least along this dimension, the cost of transporting goods between regions may provide a solution.

Stepping back for a moment, a justification for why transportation costs are a plausible market friction is in order. To many, that such frictions influence the NE-MW states to a greater degree than S-NE states is not at all surprising. Indeed, much of the railway construction activity was directed at opening the west to settlement and economic development, with practically no agricultural output in the Midwest prior to 1840. Furthermore, the option of water-shipments allowed for easier distribution of Southern output. Data from the 1887 Report of the Senate Committee on Transportation Routes shows that to transport a bushel of wheat between Atlantic ports to Great Lake ports by rail averaged 21 cents. This is a significant charge, given the average price of a bushel of wheat was 104 cents over in 1870s.[7]. Harley (1980) compiles additional evidence on wheat and freight prices. Depending on the route, the 1880 per bushel rate to ship wheat from Chicago to New York at that time ranged between 8 to 15 cents. Further west, the rate was nearly double, with an additional cost to ship from Kansas City to Chicago at

[7] Average wheat prices available within the Statistical Abstracts of the United States

11 cents. The farm price of a bushel of wheat was 118 cents in New York, 101 in Indiana, 93 in Wisconsin, 82 in Iowa, and 73 in Kansas. Thus, the further west one is relative to New York, the higher the transportation costs and the lower the wheat price. While land-route rates between Southern and Northeastern locations is not provided, the rate to ship from Odessa, TX or New York to Liverpool, UK were nearly identical (10.4 versus 8.6 cents, respectively). This suggests that the ocean shipping rate from Southern ports to Northeastern ones were *substantially* lower than land-based routes between MW and NE. Indeed, the wheat price was very similar in Odessa to New York, with the wholesale bushel price at 112.[8] Thus, transportation costs seem to be a relevant force shaping Midwestern economic activity.

The contribution of this paper is neither methodological, since the modeling techniques to capture transportation and learning costs are well developed by Caselli and Coleman (2001) and Herrendorf et al. (2009), nor empirical, since the census data employed is readily available. Instead, the following is a careful analysis of how goods market and labour market frictions augment models of structural change to better match regional data. The paper will proceed as follows: Section (2) opens with a summary of various data concerning regional convergence trends and their significance for this paper; Section (3) outlines a model that embeds the human capital technology of Caselli and Coleman (2001) and transportation sector of Herrendorf et al. (2009) within a single model; Section (4) builds intuition by deriving explicitly the regional factor earnings wedge generated by transportation costs; Sections (5.1) and (5.2) present the model calibrations for the two regional groupings; and, finally, Sections (**??**) and (6) conclude the analysis with a critical discussion of the results and some final thoughts.

[8]The farm price was not available for Odessa at this time, so the wholesale price was used. The New York wholesale price, at 120 in Winter and 117 in Spring, is nearly identical to the annualised average farm price of 118, which suggests this is an acceptable approximation.

2 Regional Convergence Patterns

In addition to sectoral price and earnings data, one can use relative regional earnings over time to distinguish transportation versus learning cost reductions. Intuition is aided if one imagines a nation divided into one region focused on agriculture (Southern or Midwestern states) and another focused on manufacturing (Middle Atlantic and New England states). Regional income convergence may be driven by: (1) higher wages of all sectors of the poor region; (2) greater labour outflow from the lower paying agricultural sector in the poor region; or (3) higher relative agricultural earnings, which disproportionately benefits the agricultural region. One can view the second and third channels as resulting from structural change and the first channel from all other factors.

The two forces studied in this paper affect these channels in different ways. Lower cost of acquiring human capital enables a greater fraction of the rural-agricultural population to acquire manufacturing skills. The lower supply of agricultural workers (the second channel) results in a higher agricultural wage relative to manufacturing (the third channel). Transportation costs, however, create a wedge in the output prices between regions, with higher peripheral prices for manufactured goods requiring a compensatory increase of factor earnings in that region (the first channel). Thus, the greater is the importance of the first channel relative to the second and third, the lower is the impact of structural change on regional convergence.

Caselli and Coleman (2001) provide a mathematical decomposition of these convergence channels. A brief derivation is provided here and further details may be found in Appendix B of their paper. It begins are follows: a region's average wage is a labour-force weighted average of the wages of its specific sectors, it is clear that

$$\begin{aligned} w_t^r &= w_{ag,t}^r L_{ag,t}^r + w_{na,t}^r L_{na,t}^r \\ &= w_{ag,t}^r L_{ag,t}^r + w_{na,t}^r (1 - L_{ag,t}^r) \end{aligned} \tag{1}$$

where $w^r_{ag,t}$, $w^r_{na,t}$, $L^r_{ag,t}$, and $L^r_{na,t}$ are, respectively, the average agricultural wage, average non-agricultural wage, agricultural labour-force share, and non-agricultural labour-force share, for region r at date t.

In order to investigate a regional deviation from average, Equation (1) may be modified by adding a quantity equal to zero on the right-hand side. That is,

$$\begin{aligned} w^r_t &= w^r_{ag,t}L^r_{ag,t} + w^r_{na,t}L^r_{na,t} + w_{ag,t}L^r_{ag,t} - w_{ag,t}L^r_{ag,t} + w_{na,t}L^r_{na,t} - w_{na,t}L^r_{na,t} \\ &= (w^r_{ag,t} - w_{ag,t})L^r_{ag,t} + (w^r_{na,t} - w_{na,t})L^r_{na,t} + w_{ag,t}L^r_{ag,t} + w_{na,t}L^r_{na,t} \end{aligned} \tag{2}$$

As discussed earlier, the geographic groupings in this paper are "Peripheral", P, and "Core", C. Substituting these labels into Equation (2) and taking their difference relative to the national average, one finds that

$$\begin{aligned} \frac{w^P_t - w^C_t}{w_t} &= \frac{w^P_{ag,t} - w_{ag,t}}{w_t}L^P_{ag,t} + \frac{w^P_{na,t} - w_{na,t}}{w_t}(1 - L^P_{ag,t}) \\ &\quad -\frac{w^C_{ag,t} - w_{ag,t}}{w_t}L^C_{ag,t} - \frac{w^C_{na,t} - w_{na,t}}{w_t}(1 - L^C_{ag,t}) \\ &\quad +\frac{w_{ag,t} - w_{na,t}}{w_t}(L^P_{ag,t} - L^C_{ag,t}) \end{aligned} \tag{3}$$

Finally, one can take the difference between adjacent time periods and rearrange to arrive at the following decomposition (which is found as Equation (B3) in CC)

$$\begin{aligned} \frac{w^P_t - w^C_t}{w_t} - \frac{w^P_{t-1} - w^C_{t-1}}{w_{t-1}} &= \Delta\omega^P_{ag,t} \cdot \bar{L}^P_{ag,t} + \Delta\omega^P_{na,t} \cdot (1 - \bar{L}^P_{ag,t}) \\ &\quad -\Delta\omega^C_{ag,t} \cdot \bar{L}^C_{ag,t} - \Delta\omega^C_{na,t} \cdot (1 - \bar{L}^C_{ag,t}) \\ &\quad +\bar{\omega}^P_t \cdot \Delta L^P_{ag,t} - \bar{\omega}^C_t \cdot \Delta L^C_{ag,t} \\ &\quad +\Delta\omega_t \cdot (\bar{L}^P_{ag,t} - \bar{L}^C_{ag,t}) \end{aligned} \tag{4}$$

Where $\omega_t = \frac{w_{ag,t} - w_{na,t}}{w_t}$, $\omega^r_t = \frac{w^r_{ag,t} - w^r_{na,t}}{w_t}$, and $\omega^r_{j,t} = \frac{w^r_{j,t} - w_{j,t}}{w_t}$, for $r \in \{P, C\}$ and $j \in \{ag, na\}$. Intuitively, the first two lines capture the extent to which average sectoral wages within a region change, the third line captures the labour reallocation between sectors within a region, and the fourth line captures the change in national average sectoral wages.

The magnitudes of the various channels is provided in Table (2). Specifically, it displays the percentage point reduction in a measure of the level of earnings differences - the regional earnings gap relative to the overall earnings level. One can see that the majority of the NE-S convergence resulted from the second and third channels (columns (2) and (3), respectively). For the NE-MW comparison, the magnitude of these channels are not surprisingly lower. The interesting point for the MW-NE group is the *much lower* value on the first channel. That is, there may existed a divergent force between these two regions supressing some income growth in the MW. It will be demonstrated in Section (4) that declining transportation costs create downward earnings pressure in the region importing non-agricultural goods, thus explaining the suppressed inter-regional force.

3 The Model

At its core, the model is a dynamic two-region, two-sector model similar in many respects to dynamic real trade models. Both goods are available for consumption but one - called the agricultural good - faces a subsistence requirement, and therefore an income elasticity below unity, and the other - called the manufactured good - may also contribute to capital accumulation. The two regions may engage in trade of either good by incurring an iceberg transportation cost. Workers may also select either sector to work in, but must receive manufacturing skills in order to become employed in that sector. I outline the details below.

Table 2: Relative Magnitudes of Convergence Channels

Grouping	Total	Inter-Regional	Labour Reallocation	Inter-Sectoral
Northeast-South, 1940-80	0.411	0.223	0.112	0.070
Northeast-Midwest, 1940-80	0.145	0.050	0.066	0.029

US Data Source: Caselli and Coleman (2001) and author's calculations

3.1 Firms

3.1.1 Goods Producing

An agricultural sector and a manufacturing sector exist in each of two regions, populated by perfectly competitive firms. I assume that the competitive advantage of the one region - the "core" - is in manufacturing and will completely specialise in its production. By extension, both agricultural and manufacturing activities may be conducted in the other region - the "periphery". Each produces output using input factors of land, labour, and capital within constant returns to scale production technologies. To ensure a balanced growth path exists, assume a unit elasticity of factor substitution. Thus, for each region $i \in \{p, c\}$ and sector $s \in \{a, m\}$

$$Y_{st}^{i} = A_{st}^{i} {T_{st}^{i}}^{\gamma_s} {L_{st}^{i}}^{\alpha_s} {K_{st}^{i}}^{(1-\gamma_s-\alpha_s)}. \tag{5}$$

where Y, T, L, and K, respectively denote output, land, labour, and capital. By assumption, $A_{mt}^{p} = A_{mt}^{c}$ and $A_{at}^{p} > A_{at}^{c} = 0$ for all $t = [0, .., \infty)$. To simplify notation, the periphery agriculture is selected as the numeraire ($P_{at}^{p} = 1$). Manufacturing sector output may be consumed or invested in new capital goods, the stock of which depreciates at rate δ. Agricultural sector output may only be consumed and may not be stored. Regional land endowments are exogenously set, with the fraction in region 1 denoted by ω. The inclusion of land within the production functions ensures a deterministic distribution of manufacturing production between the regions by creating diminishing returns to scale in the regionally mobile factors (labour and capital).

Each firm exists in a competitive environment and, therefore, takes output prices, P_{st}^{i}, as given. In addition, factor markets are competitive and land rents, wages, and capital rents - respectively, a, w, and r - are also exogenous to each firm. They each use the production technology from Equation (5) to maximize profits,

$$\Pi^i_{st} \quad = \quad P^i_{st}Y^i_{st} - w^i_{st}L^i_{st} - a^i_{st}T^i_{st} - r^i_{st}K^i_{st} \quad \forall\ i = p, c \text{ and } s \in \{a, m\}.$$

This implies firm input demands must satisfy standard first-order necessary conditions,

$$\frac{\partial Y^p_{at}}{\partial T^p_{at}} = P^p_{mt}\frac{\partial Y^p_{mt}}{\partial T^p_{mt}} \quad = \quad a^p_t \tag{6}$$

$$\frac{\partial Y^p_{at}}{\partial K^p_{at}} = P^p_{mt}\frac{\partial Y^p_{mt}}{\partial K^p_{mt}} \quad = \quad r^p_t \tag{7}$$

$$P^c_{mt}\frac{\partial Y^c_{mt}}{\partial T^c_{mt}} \quad = \quad a^c_t \tag{8}$$

$$P^c_{mt}\frac{\partial Y^c_{mt}}{\partial K^c_{mt}} \quad = \quad r^c_t \tag{9}$$

$$\frac{\partial Y^p_{at}}{\partial L^p_{at}} \quad = \quad w^p_{at} \tag{10}$$

$$\frac{\partial Y^i_{mt}}{\partial L^i_{mt}} \quad = \quad \frac{w^i_{mt}}{P^i_{mt}} \quad \forall\ i = p, c \tag{11}$$

It is important to note the implicit assumption involved: land and capital are perfectly mobile across sectors. In contrast, labour may only move between sectors if it possesses the necessary manufacturing skills, the generation of which is covered later.

3.1.2 Transportation

Goods produced in one region may be transported to consumers in another region by incurring an iceberg-cost, Δ. Capital may also migrate between regions. That is, if one unit is shipped out of one region then Δ units arrive in the other region. This feature of the economy is modelled by assuming there exists a perfectly competitive transportation sector, where firms maximize profits earned through goods sold in one region that were purchased in another. This technology is similar to that utilised by Herrendorf et al. (2009), who further allow distinct food and non-food transportation costs. Formally, for D^i_{st} and B^i_{st} representing the quantity of good s delivered to (bought from) region i, we have the objective for all $i, j = p, c$, $i \neq j$, and $s \in \{a, m\}$

$$\max_{D^i_{st}, B^i_{st}} \pi_t = P^i_{at} D^i_{at} + P^i_{mt} D^i_{mt} - p^j_{at} B^j_{at} - p^j_{mt} B^j_{mt}.$$

The comparative advantage of the core region in manufacturing goods and the periphery in agriculture ensures $D^p_{at} = D^c_{mt} = B^p_{mt} = B^c_{at} = 0$. Furthermore, given the nature of the transportation costs, it must be the case that

$$D^i_{st} = \Delta B^j_{st} \quad \forall i, j = p, c, i \neq j$$

which, together with zero profit condition, implies

$$\Delta_t P^p_{mt} = P^c_{mt}, \tag{12}$$

$$P^c_{at} = 1/\Delta_t. \tag{13}$$

3.2 Households

There is a population normalized to unity in this economy. As is standard in models of structural change, each agent is endowed with preferences that treat consumer goods asymmetrically, with agricultural goods contributing to utility only above a subsistence level. This results in an income inelastic demand for agricultural goods which, when coupled with faster TFP growth in the agricultural sector, leads labour to shift to the manufacturing sector over time and for agriculture's share of consumption to decline. An agent's wealth is given by the present value of labour and non-labour income. Each agent selects a region of residence and, to simplify the forumulation of human capital accumulation, defers its sectoral labour decision to a regional household. That is, individual agents are soverign in every respect but for their choice of occupation. To ensure individual agents are indifferent between occupations, and therefore will not challenge household assignments, household consumption is evenly divided amongst its members.

Finally, non-labour income from land and capital rents is generated by ownership stakes available to all agents regardless of residency.

Formally, the household of region $i \in \{p, c\}$ employed in sector $s \in \{a, m\}$ faces the following problem

$$\max_{\{c^i_{at}, c^i_{mt}, L^i_{at}, L^i_{mt}, i\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left[\tau \log(c^i_{at} - \bar{a}) + (1-\tau)\log(c^i_{mt})\right]$$

subject to

$$\begin{aligned}\sum_{t=0}^{\infty}(P^i_{at}c^i_{at} + P^i_{mt}c^i_{mt}) &\leq \sum_{t=0}^{\infty}(L^i_{at}w^i_{at} + L^i_{mt}w^i_{mt}) + A_t \\ &\equiv L^i_{at}H^i_{at} + L^i_{mt}H^i_{mt} + A_t,\end{aligned}$$

where (H^i_{at}, H^i_{mt}) and A_t are, respectively, lifetime labour and non-labour earnings for region i from time t ontwards.

3.2.1 Occupational Choice

It is apparent from the above formulation that occupational choice enters the household problem only through its effect on lifetime wealth. An agent will be selected for manufacturing skills only if the lifetime earnings in that sector are sufficient to compensate for the foregone labour earnings while learning takes place. A clear discussion of the education process, which closely follows the education sector of Caselli and Coleman (2001), is necessary. Each agent is endowed with an "intellectual handicap," which determines the length of time required to acquire the manufacturing skills necessary to receive employment in that sector. This handicap is the product of a population wide parameter and an individual component: respectively, ξ_t and ζ_{jt}. The former captures an economy's underlying ability to train labour while the latter captures person-specific intellectual ability. The product, $\zeta_{jt}\xi_t$, thus represents the fraction of a period necessary to receive training and is restricted to the unit interval. The cost of switching sectors for person j

at time t is then given by $\zeta_{jt}\xi_t w_{mt}$ and the benefits are the increased labour earnings in manufacturing. Finally, given that the core region perfectly specializes in manufacturing, I will consider only the peripheral household's human capital decision. Simply put, the periphy selects an agent to engage in manufacturing production if selects sector m if and only if

$$\begin{aligned} H_{mt}^p - H_{at}^p &\geq \zeta_{jt}\xi_t w_{mt}^p, \\ \Rightarrow \bar{\zeta}_t &= \frac{1}{\xi}\frac{H_{mt}^p - H_{at}^p}{w_{mt}^p}, \end{aligned} \tag{14}$$

where $\bar{\zeta}_t$ is the cutoff value for an individual's learning handicap. Those with $\zeta_{jt} > \bar{\zeta}_t$ will select an agricultural occupation. To ensure a steady-state exists with at least some individuals without manufacturing skills, an exogenous survival rate λ is assumed. Dying peripheral agents are replaced by an equal number of newborn agents without any skills. To simplify the solution path for H_{st} one can place it within a recursive equation, for each $s \in \{a, m\}$, as

$$H_{st}^p = w_{st}^p + \frac{q_{t+1}}{q_t}\lambda H_{s(t+1)}^p. \tag{15}$$

where q_t is the price in the initial period for delivery of the numeraire (peripheral agriculture) in period t. It can be derived through the consumer's maximization problem that

$$\frac{q_{t+1}}{q_t} = \beta\frac{c_{at} - \bar{a}}{c_{a(t+1)} - \bar{a}}$$

Also note that the λ is placed in the equation since there is a probability an agent will die and lose the human capital prior to next period's production.

Given this structure, it is possible to derive the labour supply equations for each sector. Denote with l_s the average time (in terms of fraction of a period) a given generation spends in sector s and $F(\zeta_j) = \zeta_j^3$ the cumulative distribution function of the cross-section of individual handicap parameters. The population average time spent acquiring skills is then simply the mean value of $\zeta_{jt}\xi_t$ for those individuals who opted to switch. Given that, the time spend in the manufacturing sector is simply whatever time is left after acquiring skills. Mathematically, this may be represented by

$$l_{et}^p = \int_0^{\bar{\zeta}_t} \xi_t \zeta_j f(d\zeta_j) = (3/4)\xi \bar{\zeta}_t^4, \tag{16}$$

$$l_{mt}^p = \int_0^{\bar{\zeta}_t} (1 - \xi_t \zeta_j) f(d\zeta_j) = \bar{\zeta}_t^3 - l_{et}^p. \tag{17}$$

Next, one may derive the share of the population within each sector and receiving skills by employing the above time-shares and the assumed demographic process in this economy. First, the number of individuals in agricultural pursuits is simply the fraction of the previous period's agricultural labour force that is still alive plus the newborn individuals who do not opt to switch. Also, the average number in training is that fraction of newborns. That is,

$$L_{at}^p = (1 - L_{a(t-1)}^p)(1 - \lambda) l_{at}^p + L_{a(t-1)}^p \lambda, \tag{18}$$

$$L_{et}^p = (1 - L_{a(t-1)}^p)(1 - \lambda) l_{et}^p. \tag{19}$$

Manufacturing labour, given that is it able to move across borders, it not explicitly derived in this manner, but will be uniquely determined later through the interaction of aggregate labour supply, $l_{\cdot t}^p$ variables summing to one, and a yet to be present migration condition.

3.2.2 Land

Having covered two factors of production so far, there remains the issue of decisions over the immobile factor - land. I assume the existence of a market maker in land that will to purchase a plot of realestate for price R_t^i in region i at time t, denominated similarly to other prices in terms of peripheral agricultural goods. The timing of the land market is different to that of capital: land is traded at the beginning of each period, for use in production *during* that period. This contrasts with the end-of-period capital market since, unlike produced capital, land is exogenously endowed and does not depreciate, which negates the need to "order" it in advance.

Given the immobility of land, land prices in each region must be such that a certain series of transactions must not be profitable. Specifically, agents must be indifferent between using land for manufacturing production in one region and selling the land to the market maker and using the proceeds to purchase land in the other region. In addition, this kind of transaction may result in potential capital gains that are different between the region. So, the sum of each period returns and next period land-price, relative to the current land-price, must not diverge. This implies that if

$$\begin{aligned} P^p_{mt}\frac{\partial Y^p_{mt}}{\partial T^p_{mt}} + R^p_{t+1} &= \frac{R^p_t}{R^c_t}\left(P^c_{mt}\frac{\partial Y^c_{mt}}{\partial T^c_{mt}} + R^c_{t+1}\right) \\ \Leftrightarrow \quad \frac{a^p_t + R^p_{t+1}}{R^p_t} &= \frac{a^c_t + R^c_{t+1}}{R^c_t} \end{aligned} \tag{20}$$

holds, then no such transactions will be undertaken. Note that Δ is absent from the above condition since prices are already denominated in terms of peripheral agricultural goods and further note that to ensure a land arbitrage condition holds for every production period, I further assumed there is a land trading period in period $t = 0$. Finally, land prices are determined as the present discounted value of future land rents in the typical capital pricing equation

$$R^i_t = a^i_t + \frac{q_{t+1}}{q_t}R^i_{t+1} \quad \forall\, i \in \{p, c\}. \tag{21}$$

3.2.3 Other Household Decisions

The remaining household decision rules are more familiar. First, optimal allocation between consumption goods is such that the marginal rate of substitution equal the output price ratio,

$$\frac{U_m(c^i_{at}, c^i_{mt})}{U_a(c^i_{at}, c^i_{mt})} = \frac{1-\tau}{\tau}\frac{c^i_{at}-\bar{a}}{c^i_{mt}} \quad = \quad \frac{P^i_{mt}}{P^i_{at}} \quad \forall\, i \in \{p, c\}. \tag{22}$$

Second, their region of residence is selected to maximize utility. In equilibrium, migratory incentives will not exist, which implies total household utility is identical between regions; that is,

$$\tau \log(c^p_{at} - \bar{a}) + (1-\tau)\log(c^p_{mt}) \quad = \quad \tau \log(c^c_{at} - \bar{a}) + (1-\tau)\log(c^c_{mt}). \tag{23}$$

If we assume that all agents in the process of switching sectors do so in the periphery, then the share of the population living in the core is simply its labour force share, L^c_{mt}. Where students reside is of no consequence beyond its impact on where consumption takes place and, therefore, only affects the goods market clearing conditions.

3.3 Competitive Equilibrium

A competitive equilibrium in this economy is characterized by, for all $i \in \{p, c\}$ and $s \in \{a, m\}$, allocations $\{c^i_{st}, L^i_{st}, l^i_{st}, T^i_{st}, K^i_{st}, Y^i_{st}\}^{\infty}_{t=0}$, output prices $\{P^i_{st}\}^{\infty}_{t=0}$, factor prices $\{a_t, r_t, w^i_{st}\}^{\infty}_{t=0}$, and education sector variables $\{H_{st}, \bar{\zeta}_t\}^{\infty}_{t=0}$ such that: given output and factor prices, households maximize utility and firms maximize profits; households are indifferent between residing in either region; and both input and output markets clear.

The system of equations characterising such an equilibrium is given by Equations governing production and factor demands, (5) and (6)-(11); output prices, (12) and (13); land prices (20); human capital acquisition, (14) and (15); labour supply, (16-19); consumption, (22); residency, (23); the following input market clearing conditions

$$T^c_{mt} = 1 - \omega, \tag{24}$$

$$T^p_{at} + T^p_{mt} = \omega, \tag{25}$$

$$L^p_{at} + L^p_{mt} + L^p_{et} + L^c_{mt} = 1; \tag{26}$$

and, finally, the Euler equations, one for each region,

$$\frac{c^i_{m(t+1)}}{c^i_{mt}} = \beta \left[\frac{\partial Y^i_{mt}}{\partial K^i_{mt}} + 1 - \delta \right] \quad \forall\, i \in \{p, c\}. \tag{27}$$

In addition, agricultural and manufacturing goods markets must clear. Each region produces, consumes, exports, and imports goods. To simplify the following equations, I will impose at this point that the periphery imports manufactured goods and exports agricultural goods, while the core does the opposite. This follows given the nature of the comparative advantages assumed. Finally, with the total population normalized to unity and all people in the education sector living in the periphery by assumption, the population in the core and the periphery, respectively, is L^c_{mt} and $(1 - L^c_{mt})$. Hence,

$$\begin{aligned}
L^c_{mt} c^c_{at} &= D^c_{at} \\
(1 - L^c_{mt}) c^p_{at} + B^p_{at} &= Y^p_{at} \\
L^c_{mt} c^c_{mt} + K^c_{m(t+1)} + B^c_{mt} &= Y^c_{mt} + (1 - \delta) K^c_{mt} \\
(1 - L^c_{mt}) c^p_{mt} + K^p_{a(t+1)} + K^p_{m(t+1)} &= Y^p_{mt} + D^p_{mt} + (1 - \delta)(K^p_{mt} + K^p_{at})
\end{aligned}$$

Combining these with the results implied by the transportation firm problem solved earlier, we find that

$$L^c_{mt} c^c_{at} + \Delta (1 - L^c_{mt}) c^p_{at} = \Delta Y^p_{at} \tag{28}$$

and

$$\Delta L_{mt}^{c} c_{mt}^{c} + (1 - L_{mt}^{c}) c_{mt}^{p} + (K_{a(t+1)}^{p} + K_{m(t+1)}^{p} + \Delta K_{m(t+1)}^{c}) \\ = Y_{mt}^{p} + \Delta Y_{mt}^{c} + (1-\delta)(K_{at}^{p} + K_{mt}^{p} + \Delta K_{mt}^{c}) \tag{29}$$

4 Effects of Transportation Costs

This section will present a few derivations that may advance one's understanding of the underlying channels through which transportation costs affect the model's equilibrium.

To begin, note that firms operate in both regions within a perfectly competitive input and output market. This implies the standard result that price equals marginal costs of production. For the manufacturing sector of region i, this can be expressed as

$$P_m^i = \frac{1}{A_m} \left[\left(\frac{w_m^i}{\beta_L} \right)^{\beta_L} \left(\frac{a}{\beta_T} \right)^{\beta_T} \left(\frac{r}{1 - \beta_T - \beta_L} \right)^{1-\beta_T-\beta_L} \right].$$

It is clear that the ratio of marginal costs between the regions only depends on the ratio of manufacturing wages of those regions. In addition, the perfectly competitive nature of the transportation sector results in

$$\Delta P_m^p = P_m^c.$$

Thus,

$$\begin{aligned} \frac{MC_m^p}{MC_m^c} = \left(\frac{w_m^p}{w_m^c} \right)^{\beta_L} &= \frac{P_m^p}{P_m^c}, \\ &= \Delta^{-1}, \\ \Rightarrow \frac{w_m^p}{w_m^c} &= \Delta^{-1/\beta_L} \end{aligned} \tag{30}$$

The intuition is simple, the region importing manufactured goods faces a higher price for those goods due to the transportation cost. This higher price will encourage entry unless wages rise to ensure zero profit once again.

Alternatively, one could investigate the impact of the costs on agent migration decisions. First, recall that living standards are identical across regions by assumption. If, for whatever reason, the costs of a achieving a certain level of utility rise then incomes must rise as rise. Thus, if reductions in the transportation costs lower regional average price dispersion then it will also lower regional income dispersion. Mathematically, the equality of utility levels between residents of each region - Equation (23) - may be combined with optimal consumption allocation conditions - Equations (22) - and regional pricing conditions - Equations (12) and (13) - to arrive at the relative expenditure on each good for each region. That is,

$$\frac{P_a^c(C_a^c - \bar{a})}{P_a^(C_a^p - \bar{a})} = \frac{P_m^c C_m^c}{P_m^p C_m^p} \quad = \quad \Delta^{1-2\tau}, \tag{31}$$

For simplicity, first consider the case of zero agricultural subsistence consumption ($\bar{a} = 0$). The budget constraint for a manufacturing worker in region $i \in \{c, p\}$ is

$$P_a^i C_a^i + P_m^i C_m^i = w_m^i + r + a \equiv Z^i$$

Taking the ratio of this equation for regions P to C, and utilizing Equations (31), yields

$$\begin{aligned} \frac{Z^p}{Z^c} &= \frac{\Delta^{1-2(1-\tau)} + \frac{1}{\Delta^{1-2\tau}} \frac{P_m^c C_m^c}{P_a^c C_a^c}}{1 + \frac{P_m^c C_m^c}{P_a^c C_a^c}} \\ &= \frac{\Delta^{1-2(1-\tau)} + \frac{1}{\Delta^{1-2\tau}} \frac{1-\tau}{\tau}}{1 + \frac{1-\tau}{\tau}} \\ &= \frac{1}{\Delta^{1-2\tau}} \end{aligned} \tag{32}$$

where the second equality follows from the standard result that optimal expenditure shares equal $(1-\tau)/\tau$. Note that for $\Delta = 1$ we have $Z^p = Z^c$ (which implies $w_m^p = w_m^c$) and for $\Delta < 1$ we have $Z^p > Z^c$ ($w_m^p > w_m^c$). Moreover, if we ignore land and capital rent to illustrate the point,

$$\frac{\partial\left(\frac{w_m^p}{w_m^c}\right)}{\partial(1-\Delta)} = -\frac{\partial\left(\frac{w_m^p}{w_m^c}\right)}{\partial\Delta} = \frac{1-2\tau}{\Delta^{2\tau}} > 0.$$

Thus, as transportation costs fall ((1-Δ) $\downarrow$) peripheral manufacturing wages also fall relative to the core ($w_m^p/w_m^c \downarrow$). The key is the equality of utility levels between regions. Thus, to quickly repeat the intuition, higher peripheral manufactured goods prices require a higher peripheral income (wage) to maintain real standards of living.

It is noteworthy this result differs substantially from that found in Herrendorf et al. (2009). One can see the reason for this by examining the sign of $\frac{\partial Z^p/Z^c}{\partial\Delta}$ without the earlier assumption that $\bar{a} = 0$. The sign of this derivative is negative (as found earlier) if and only if

$$\frac{\partial(P_m^c C_m^c)}{\partial\Delta}\left[\frac{1}{\Delta^2} - \frac{Z^p}{Z^c}\right] < \frac{1-2\tau}{\Delta^{1-2\tau}} P_m^c C_m^c + (1-\tau)\frac{Z^p}{Z^c}\frac{\partial(\bar{a}P_a^c)}{\partial\Delta}.$$

Given that our earlier result that $Z^p = Z^c$ when $\Delta = 1$ still holds in the case when $\bar{a} > 0$, and through some additional manipulation, the above inequality implies that

$$\left.\frac{\partial Z^p/Z^c}{\partial\Delta}\right|_{\Delta=1} < 0 \quad\Leftrightarrow\quad \left|\frac{\partial S_{\bar{a}}^c}{\partial\Delta}\right| < \frac{1-2\tau}{1-\tau} S_m^c,$$

where S_m^c and $S_{\bar{a}}^c$ are, respectively, the share of a core-resident's income spent on manufactured goods and subsistence agriculture. This condition states that introducing transportation costs ($\Delta \downarrow$) will increase peripheral income if the response in subsistence spending is not too large. This condition relaxes as spending on manufactured goods increases. This highlights the likely source of the different prediction of Herrendorf et al. (2009): the agricultural consumption shares are different[9]. While my model increases peripheral living costs with transportation costs, due to a 70% initial manufacturing consumption

[9] I simulated simplified versions of my model (without labour market frictions, land, and durable capital) and found these alterations are not critical to my results

Table 3: Model Parameter Values

Variable	Value
Agricultural Utility Weight, τ	0.01
Depreciation, δ	0.36
Discount Factor, β	0.6
Labour Shares, α_a and α_m	0.6
Farm Land Share, γ_a	0.19
Non-Farm Land Share, γ_m	0.06
Survival Rate, λ	0.75
1880 Agricultural Labour Share (NE-S), L_{a1880}	0.484
1880 Agricultural Labour Share (NE-MW), L_{a1880}	0.391
1880 Transportation Cost (NE-S), Δ_{1880}	0.98
1980 Transportation Cost (NE-S), Δ_{1980}	0.99
1880 Transportation Cost (NE-MW), Δ_{1880}	0.75
1980 Transportation Cost (NE-MW), Δ_{1980}	0.98

Source: Lee et al (1957) and Caselli and Coleman (2001), online data appendix

share[10], their model, with a 14% manufacturing share, generates the opposite. This low level of manufactured goods spending means the above inequality may not hold. This point clearly demonstrates how identical forces may leads to strikingly different results for regions at different stages in the development process.

5 Calibration

The overall approach to identifying the importance and effects of transportation costs will be to calibrate the model to two distinct sets of data, one for each regional pair (NE-S and NE-MW). I will demonstrate that without allowing for transportation costs, the model will fail to capture all aspects of the data in one situation while it can in another. That is, human capital acquisition costs alone are sufficient to capture many aspects of the data in situations where transportation costs are likely less important but are insufficient where such costs are important. Following this demonstration, a critical discussion will examine in greater detail how the model's region-specific predictions compare to data.

To begin, the parameters (τ, β, δ, γ_a, γ_m, α_a, α_m, λ, L_{a1880}, Δ_{1880}, Δ_{1980}) may be

[10] Manufactured goods spending relative to agricultural spending for 1880 is roughly inferred from data in Caselli and Coleman (2001) and from the University of Virginia Historical Census records (online)

calibrated individually from existing literature or data with a model period corresponding to a decade in the data (1880 to 1980). Their values are presented in Table 3, and a brief description of sources and methods may be found in the appendix. The remaining parameters, (ω, ξ_{1880}, ξ_{1980}, $\bar{a}$, K_{1880}), are set jointly to target certain model outcomes with data. The target values will depend on which regional groupings are of interest. A baseline case with zero transportation costs and constant learning costs ($\xi_{1880} = \xi_{1980}$) is used initially. Specifically, the targets for the baseline case are the: (1) agricultural consumption share in 1880; (2) relative agricultural wages in 1880; (3) relative regional wages in 1880; and, (4), constant real return to capital. Beyond the baseline case, allowing an additional free parameter (ξ) will require an additional target. Thus, when appropriate, relative peripheral earnings in 1980 is targeted.

For clarity, a listing of the jointly determined parameters and their primary effect on the targets is in order. First, ω denotes the share of productive land allocated to the peripheral region. Increasing this parameter will primarily increase the relative share of peripheral average income, (w^p/w^c). Second, ξ is population-wide learning handicap parameter, with a higher value indicating greater difficulty for all agents in acquiring non-agricultural skills. This results in lower relative agricultural earnings, (w_a/w_m), and, by extension, (w^p/w^c). Third, $\bar{a}$ represents the subsistence parameter that influences the food consumption share, (c_a/c), and through food demand it also influences, (w_a/w_m). This influence is strongest in the initial period due to the low level of overall income, and hence a high level of relative food consumption. Adjusting those parameters jointly allows ones to target the outcomes denoted with stars. K_{1880} is also adjusted to ensure capital's marginal product is idential in the inidial period to the steady-state value.

5.1 NE-S Case

Using northern and southern states as the regional pairing, results for the baseline case are displayed in column (1) of Table (4), with stars denoting targets. This table essen-

Table 4: Model for NE-S

(a) Data and Model Outcomes

Variable	Data	Constant Learning Costs (1)	Declining Learning Costs (2)
$(c_a/c)_{1880}$*	0.30	0.30	0.30
$(c_a/c)_{1980}$	0.02	.03	0.05
$(L_a)_{1880}$*	0.48	0.48	0.48
$(L_a)_{1980}$	0.02	0.20	**0.08**
$(w_a/w_m)_{1880}$*	0.33	0.33	0.33
$(w_a/w_m)_{1980}$	0.72	0.08	**0.49**
$(w^p/w^c)_{1880}$*	0.43	0.43	0.43
$(w^p/w^c)_{1980}^{(*)}$	0.92	0.66	**0.92**

(b) Model Parameters

Case	ω	ξ_{1880}	ξ_{1980}	$\bar{a}$	K_1	Δ_{1880}	Δ_{1980}
(1)	0.61	1.79	1.79	0.23	0.08	0.98	0.99
(2)	0.59	1.75	0.91	0.23	0.08	0.98	0.99

tially agrees with the results of Caselli and Coleman (2001) and lends confidence to the comparability of this adjusted model. While nothing in Table (4) is a new contribution, reviewing the basic intuition will ease the transition to the second regional group. Notice that while the model does well at capturing the declining share of agriculture in consumption it fails to exhibit sufficiently declining agricultural labour share. It also fails along two other important dimensions found in the data: increasing agricultural relative wage and regional convergence.

Consider the effect of declining learning costs, $\xi_{1880} > \xi_{1980}$. The model parameters were re-calibrated to target relative 1980 regional earnings, whose ratio is denoted with $^{(*)}$ in the table. Clearly, despite not being targeted, the relative agricultural wages rose dramatically from what we observed in column (1). However, it did not rise sufficiently to match the data, suggesting more factors were at play than human capital accumulation in generating sectoral wage convergence in the southern states, which is a slightly different conclusion than reached by Caselli and Coleman (2001). In the next section, I will evaulate to what extent learning cost reductions capture the data in another regional context.

Table 5: Northeastern vs. Midwestern States

(a) Data and Model Outcomes

Variable	Data	Transportation Costs: None (1)	(2)	Declining (3)
$(c_a/c)_{1880}$*	0.30	0.30	0.31	0.30
$(c_a/c)_{1980}$	0.01	0.06	0.06	0.05
$(L_a)_{1880}$*	0.39	0.39	0.39	0.39
$(L_a)_{1980}$	0.03	0.06	0.06	0.06
$(w_a/w_m)_{1880}$*	0.43	0.43	0.45	0.43
$(w_a/w_m)_{1980}$	0.65	0.88	0.88	0.73
$(w^p/w^c)_{1880}$*	0.81	**0.72**	**0.75**	0.81
$(w^p/w^c)_{1980}^{(*)}$	1.00	0.99	0.99	1.00

(b) Model Parameters

Case	ω	ξ_{1880}	ξ_{1980}	$\bar{a}$	K_1	Δ_{1880}	Δ_{1980}
(1)	**0.96**	0.88	0.22	0.20	0.08	1.00	1.00
(2)	**0.999**	0.89	0.22	0.20	0.08	1.00	1.00
(3)	0.70	1.95	0.49	0.18	0.09	0.75	0.97

5.2 NE-MW Case

While declining learning costs of the previous section appear to do a fine job capturing the time series data between northern and southern states, it is unable to repeat this feat in the MW-NE comparison case. It is the upward pressure on southern earnings from costly goods transportation (essentially lifting some of the "burden" on the ω parameter to raise peripheral earnings) that will be essential in this new context.

Table (5) illustrates the various attempts to capture the data. The first two columns illustrate the failure of a model without transportation costs to reflect the underlying data. Specifically, the bold figures in the table highlight that the best matches to the data still exhibits too large an income difference between regions, with the MW 72% of NE despite allocating to it nearly all productive land. I conclude from this that the model's failure to match data, even with an extreme assumption on the distribution of land, is evidence of a missing mechanism in the model. Thus, this model - at best - give a too large relative agricultural earnings and too small relative regional earnings. The key

Table 6: NE-MW Counterfactuals

(a) Data and Model Outcomes

			Counterfactuals	
		Full Model	Transport Costs	Learning Costs
Variable	Data	(1)	(2)	(3)
$(c_a/c)_{1880}{}^*$	0.30	0.30	0.30	0.30
$(c_a/c)_{1980}$	.01	0.05	0.06	0.02
$(L_a)_{1880}{}^*$	0.39	0.39	0.39	0.39
$(L_a)_{1980}$	0.03	0.06	0.06	**0.21**
$(w_a/w_m)_{1880}*$	0.43	0.43	0.43	0.42
$(w_a/w_m)_{1980}$	0.65	0.73	0.72	**0.05**
$(w^p/w^c)_{1880}*$	0.81	0.81	0.81	0.81
$(w^p/w^c)_{1980}^{(*)}$	1.00	1.00	**1.33**	**0.70**

(b) Model Parameters

Case	ω	ξ_{1880}	ξ_{1980}	$\bar{a}$	K_1	Δ_{1880}	Δ_{1980}
(1)	0.70	1.95	0.49	0.18	0.09	0.75	0.97
(2)	0.70	1.95	0.49	0.18	0.09	0.75	0.75
(3)	0.70	1.95	1.80	0.18	0.09	0.75	0.97

issue is *simultaneously* matching the (w_a/w_m) and (w^p/w^c) targets.

By introducing transportation costs, one is able to influence (w^p/w^c). The intuition was provided earlier: higher transportation costs mainly increase peripheral earnings to compensate for higher prices. Column (3) reflects the introduction of a transportation cost parameter, which successfully allows the data to be targeted without an unreasonable ω value. Clearly, allowing for transportation costs is an important feature for structural change models to quantititatively capture small regional convergence patterns. That is, one may interpret these findings as suggesting that if structural change is observed in areas *without* a high degree of regional convergence, than transportation cost reductions may have played a role.

Finally, one may investigate the *ceteris paribus* impact of both reductions in learning costs and transportation costs. To determine each mechanisms impact on model outcomes, two policy experiments are conducted on the fully calibrated and complete model from Column (3) of Table (5). Specifically, Table (6) displays the outcomes of the model if transportation costs and remained at their respective 1880 values and learning costs close to it.[11] The results are consistent with earlier discussions.

First, column (2) of Table (5) displays the impact of holding transportation costs at their 1880 value of 0.75. So, had this occurred, and all else remained unchanged, this model predicts that the Midwest would have surpassed (by 33%) the Northeast in terms of income. This is entirely consistent with the earlier argument that high levels of transportation costs *increase* the relative income of the peripheral region. This point must not be under appreciated. The key to solving the quantitative puzzle that improved human capital accumulation drives structural change yet results in little convergence is to account for initially high levels of transport costs that decline over time.

Second, column (3) of Table (5) displays results for when learning costs declined only marginally to 1.80, instead of declining to 0.49. In this case, regional convergence would have been slightly negative, with Midwestern relative earnings falling to 0.70. Of greater importance is that relative agricultural wages would be substantially lower, with farm workers' relative earnings collapsing to 0.05 from 0.65. This again highlights Caselli and Coleman's argument that in order to capture the rising relative agricultural earnings found in data, one must consider improvements in human capital acquisition. Finally, the agricultural employment share would decline only to 0.21, also confirming the intuition that learning cost reductions enhance structural transformation.

6 Conclusion

This analysis strongly suggests that one must explicitly consider both labour market and goods market frictions in a model of structural change to accurately capture the wage, convergence, and employment share data. If goods market frictions are neglected, structural change resulting from improved methods of human capital accumulation, which allows

[11]Learning costs could not be increased further without other parameter changes as the model would drive agriucltural earnings too close to zero. The value of 1.80 in 1980, relative to its previous value of 0.49, however, sufficiently illustrates the impact of the ξ_{1908} parameter

for improved labour mobility, will imply increases in relative agricultural and peripheral-region earnings that are far too large. Alternatively, if labour market frictions are neglected, agricultural wages relative to nonagriculture will decline substantially. In any case, with current economic theory still without a dominant interpretation of structural transformation experiences, any attempt to highlight and evaluate unique implications of various market frictions is valuable.

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7 Appendix

7.1 Calibration Targets

Many of the parameter values are identical to those in Caselli and Coleman (2001). $/tau$ is set to what Caselli and Coleman (2001) report as the estimated value to which agriculture's share of consumption converges to in the data - 0.01. They further report that 0.013 as the share in 1996. The 0.6 value for the discount factor, β, follows from an annual discount rate of 5% (since $0.6 \approx 1/(1.05)^{10}$). A depreciation value, δ, of 0.36 follows from an annual depreciation rate of approximately 4%. Factor shares in production, which are land shares γ_a and γ_m and labour shares α_a and α_m, are assumed identical to Caselli and Coleman (2001), who cite a few existing estimates of agricultural and non-agricultural factor shares. Given an expected 40 years of life beyond a typical agent's education decision, the probability of dying within any given decade, λ, is set at 0.75. Next, initial labour shares in agriculture, L_{a1880}, for both the Northeastern versus Southern state grouping (NE-S) and the Northeastern versus Midwestern states (NE-MW) are from data collected by Lee et al. (1957) and provided through the data appendix of Caselli and Coleman (2001), with values of 0.485 and 0.38 respectively. Finally, the transportation cost parameters may be loosely set based on existing data. As previously noted, the rate to transport wheat from Kansas City to New York ranges, depending on the route, from one-quarter to one-third of the bushel's final value. Thus, $\Delta_{1880} = 0.75$. To determine Δ_{1980}, data from Glaeser and Kohlhase (2004) points to nearly a 90% decline in transport costs over the century, which implies $\Delta_{1980} = 0.98$. Admittedly, these are hardly precise estimates but the qualitative results hold for Δ_{1880} equal to 0.67 and 0.5.

c_a/c is chosen to be 0.3. This is a compromise between two sources. The *Historical Statistics of the United States* report 1880 nominal GDP as 11,942 (series Ca10) and the gross output of farms that is sold or consumed in the household is 3,021 (series Da1277). Given Caselli and Coleman (2001) report that approximately 12.2% of GDP is allocated to fixed capital formation, we have that the farm share of consumable GDP is 0.29. The second source, Series Cd378-410 of the *Historical Statistics*, notes that consumption of food and kindred products relative to all consumption expenditures in 1880 was 0.31. Thus, I select 0.30 as the model's initial agricultural share of total consumption target.

K_0 is the initial capital stock, chosen such that the marginal product of capital in the first period equals that in the steady-state. This follows the Kaldor fact of no general time trend in the return on capital.