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Structural Change Out of Agriculture: Labor Push versus Labor Pull†

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A declining agricultural employment share is a key feature of economic development. Its main drivers are: improvements in agricultural technology combined with Engel's law release resources from agriculture ("labor push"), and improvements in industrial technology attract labor out of agriculture ("labor pull"). We present a model with both channels and evaluate the importance using data on 12 industrialized countries since the nineteenth century. Results suggest that the "pull" channel dominated until 1920 and the "push" channel dominated after 1960. The "pull" channel mattered more in countries in early stages of the structural transformation. This contrasts with modeling choices in recent literature. (*JEL* E23, N10, N53, O10, O47).

> *It is quite wrong to try founding a theory on observable magnitudes.... It is the theory which decides what we should observe.*
> — Albert Einstein, quoted by Werner Heisenberg (1972, 63)

The process of economic development is always and everywhere characterized by substantial reallocations of resources out of agriculture.[1] While most economists agree that this structural transformation has been driven by productivity increases, there is no consensus on whether technological progress in agriculture or in manufacturing has been more important. Yet, given the continuing importance of the agricultural sector in today's poor economies, it is crucial to have a proper understanding of the historical determinants of structural change. To address this, we propose a simple model that encompasses both sources of structural change to

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[1] Perhaps with the exception of a few very small open economies like Hong Kong and Singapore.

show how to identify their relative importance in the data. We use this model to explore the historical experience of 12 countries that have completed their process of structural reallocation, using data from the nineteenth century onward.[2]

Already Colin Clark (1940), Simon S. Kuznets (1966), and Hollis B. Chenery and Moises Syrquin (1975) documented the process of structural transformation—the fall in the share of agriculture in output and employment that accompanied long-run increases in income per capita. As an example, in 1800, the US economy employed around three-fourths of its labor force in the agricultural sector. The sector accounted for more than half of total output. Two hundred years later, only 2.5 percent of the labor force remained in the agricultural sector, and the share of agricultural production in gross domestic product (GDP) was close to 1 percent. Over these two centuries, US output per capita increased more than 25 times.

Although development economists and economic historians have long been interested in this process of structural transformation, there has been (and still is) substantial debate about the relative role technological progress in the agricultural and the manufacturing sectors played in the process, with classical and more recent contributions on both sides.

On the one hand, there is a continuing tradition that places the emphasis of the transformation on the manufacturing sector. W. Arthur Lewis (1954) presents a model where capital accumulation in the modern sector raises urban wages and attracts surplus labor from the agricultural sector. Reinvestment of profits keeps the process going. Similarly, John R. Harris and Michael P. Todaro (1970) present a two sector model in which rural-urban migration results from positive differences between the expected urban (industrial) real income and agricultural product per worker. Both theories suggest that productivity advantages in manufacturing raise urban incomes and drive the process of structural change. In this view, increasing industrial wages attract low-paid or underemployed labor from agriculture into manufacturing. Following Thorvaldur Gylfason and Gylfi Zoega (2006), we refer to this as the "labor pull" hypothesis.[3] Gary D. Hansen and Edward C. Prescott (2002) model a similar mechanism and conclude that "the (modern) technology must improve sufficiently so that it ultimately becomes profitable to shift resources into this sector."

On the other hand, some scholars consider agricultural productivity the main driver of structural change. Ragnar Nurkse (1953) argues that "everyone knows that the spectacular industrial revolution would not have been possible without the

[2] In this paper, we use the term "structural change" in a narrow sense to refer exclusively to movements of resources out of the agricultural sector. Moreover, to keep the prose simple, we will use the terms "modern sector" and "manufacturing sector" to refer to the entire nonagricultural sector.

[3] Additional work in this tradition has been conducted by Valerie R. Bencivenga and Bruce D. Smith (1997), W. Bentley MacLeod and James M. Malcomson (1998), and Mathan Satchi and Jonathan Temple (2009), among others. The first authors present a neoclassical growth model with structural change and urban underemployment, which arises from an adverse selection problem in the urban labor market. As capital accumulates, the real wage rate in formal urban manufacturing rises relative to that in agriculture. As a result, labor is induced to migrate to the city, exacerbating the adverse selection problem and unemployment there. MacLeod and Malcomson (1998) analyze a two-sector model in which workers can be motivated by either efficiency wages or bonus schemes. One sector is relatively labor-intensive, and so can be interpreted as a traditional agricultural sector. In equilibrium, the two sectors may use different reward schemes, and this generates a rural-urban wage differential. Finally, Satchi and Temple (2009) develop a general equilibrium model with matching frictions in the urban labor market, the possibility of self-employment in the informal sector, and scope for rural-urban migration. Matching frictions can lead to a large informal sector when formal sector workers have substantial bargaining power.

agricultural revolution that preceded it." W. W. Rostow (1960) identifies increases in agricultural productivity as a necessary condition for a successful takeoff. These authors suggest that improvements in agricultural technology help to solve the "food problem" (Theodore W. Schultz 1953), so that resources can be released from the agricultural to the manufacturing sector. We refer to this as the "labor push" hypothesis. Recently, Douglas Gollin, Stephen L. Parente, and Richard Rogerson (2002, 2007) provided a modern formalization of these ideas. In their words, "improvements in agricultural productivity can hasten the start of industrialization and, hence, have large effects on a country's relative income. A key implication of the model is that growth in agricultural productivity is central to development." Productivity growth in agriculture also acts as the main driver of the structural transformation in L. Rachel Ngai and Christopher A. Pissarides (2007).

Our objective is to provide empirical evidence on the relative importance of the "push" and "pull" hypotheses. We present a simple model close to Kiminori Matsuyama (1992) and to Piyabha Kongsamut, Sergio Rebelo, and Danyang Xie (2001) that is consistent with the two crucial observations associated with the process of structural change: a secular decline in the share of the labor force devoted to agriculture and a decreasing weight of agricultural output in national product. Our model captures both sources of structural change highlighted in the literature: improvements in agricultural technology combined with Engel's law of demand shift resources to the industrial sector; and improvements in manufacturing technology increase manufacturing wages, pulling labor into that sector. We use this framework to assess the effects of increases in agricultural and manufacturing productivity on key observable variables. Both hypotheses lead to qualitatively similar behavior of labor allocations, the share of agriculture in GDP, and wages. They differ in their predictions for the evolution of the price of manufactured goods relative to agricultural goods. Hence, the relative price helps to identify which sector is the main engine of the structural transformation. In this sense, our exercise follows a long tradition in economics that uses changes in relative prices to infer changes in productivity (see e.g., Jeremy Greenwood, Zvi Hercowitz, and Per Krusell 1997). As in all such exercises, it is important to bear in mind that our conclusions depend on some of the model's assumptions.

We then explore the determinants of structural change using data on relative prices and on agricultural employment shares for the United States since 1800 and for a long panel of 11 industrialized countries starting in the nineteenth century. Since, for the United States, estimates of sectoral productivities are available, the first exercise allows us to confirm the validity of our basic identifying strategy. In line with the model predictions, the relative price is almost a mirror image of relative productivity. For the larger sample, not all of the data required to compute sectoral productivities are available. In these circumstances, our parsimonious approach that relies on the relative price provides important insights that could not be obtained otherwise.

The main findings are as follows. First, there is a lot of heterogeneity. Both channels play a role. For instance, in the case of the United States, it is very clear that the "labor pull" channel dominated before World War I, with the "labor push" channel taking over after World War II. Second, driven by faster productivity growth, structural change accelerated during the twentieth century, even in countries that were relatively advanced in the structural transformation.

Most importantly, the relative price clearly indicates that the main driver of structural change varies both over time and with a country's stage in the structural transformation. On average, the relative price reflects stronger technological progress in manufacturing in countries with relatively large shares of agricultural employment in our sample. These countries tend to be late starters in terms of the structural transformation. Controlling for this effect, our empirical approach also indicates faster technological change in manufacturing from 1800 to 1960 and in countries with an employment share in agriculture above 10 percent. After 1960, or in countries with very small employment shares in agriculture, productivity changes in agriculture gain importance. These results hold no matter whether we assume that the economies in our sample are closed or open to trade. They also coincide with results for the United States. The importance of time periods in our results suggests the presence of common trends in technology, most plausibly in innovation and the diffusion of technology. However, a country's current stage in the structural transformation also matters. In particular, there appears to be a sequence of "first pull, then push."

The main contribution of our paper is to provide insights about the historically important drivers of structural change. As the bulk of structural change in the countries in our sample occurred before 1960, the main driver is productivity growth outside agriculture. This result has important implications for modeling that process. In particular, models of structural change that rely on faster productivity growth in agriculture, such as Ngai and Pissarides (2007), seem to be at odds with most of the the pre-World War II evidence. Moreover, models of structural change that restrict non-homotheticities in preferences to food consumption, such as Gollin, Parente, and Rogerson (2002), seem to miss nonagricultural technological progress as an important driver of structural change. As a consequence, our results cast some doubts on the estimates and policy recommendations derived using modeling strategies that neglect the crucial role played by nonagricultural productivity in the process of structural change and economic development. Given the continuing importance of the agricultural sector in today's poor economies and its impact on aggregate productivity differences documented by Francesco Caselli (2005), Jonathan Temple and Ludger Wossmann (2006), and Diego Restuccia, Dennis Tao Yang, and Xiaodong Zhu (2008), among others, it is crucial to have a proper understanding of the historical determinants of structural change.

Finally, our work is complementary to recent work by Fumio Hayashi and Prescott (2008), and by Andrew D. Foster and Mark R. Rosenzweig (2007). The former argue that low growth in Japan before World War II resulted from a barrier to labor mobility that kept a large fraction of the labor force in agriculture, while the latter examine the linkages between agricultural development and rural nonfarm activities.

The paper is organized as follows. Section I sets out the basic model and explores the implications of increases in agricultural and manufacturing productivity. Section II presents data sources, and Section III evaluates the model against the US experience. Section IV explores the determinants of structural change in a long panel of 11 industrialized countries. The conclusions are summarized in Section V, while the Appendices provide some technical details. An online Appendix contains a more detailed description of sources.

I. A Simple Model of Structural Change

We consider a closed economy that consists of two sectors: a traditional sector devoted to the production of agricultural goods and a modern sector that produces industrial commodities and services. For simplicity, we assume that the labor force is constant and normalize its size to unity.[4] Both production technologies exhibit weakly diminishing returns to labor,

$$(1) \qquad Y_t^A = AG(L_t^A), \qquad A > 0,\ G' > 0, \qquad G'' \leq 0,$$

$$(2) \qquad Y_t^M = MF(L_t^M), \qquad M > 0,\ F' > 0, \qquad F'' \leq 0,$$

where L_t^A and $L_t^M = 1 - L_t^A$ are the amounts of labor employed in agriculture and in manufacturing, respectively, and A and M denote the levels of technology in the two sectors. For the moment, we assume that both technology parameters are constant.

Labor can move freely across sectors. Then, competition between firms in both sectors ensures that a nonarbitrage condition holds:[5]

$$(3) \qquad w_t^A = AG'(L_t^A) = p_t MF'(1 - L_t^A) = w_t^M,$$

where w_t^A is the real wage in the traditional sector, and w_t^M is the real wage in the modern sector. p_t is the relative price of the manufacturing good, which can be expressed as

$$(4) \qquad p_t = \frac{AG'(L_t^A)}{MF'(1 - L_t^A)}.$$

Consumers are identical, infinitely lived, and inelastically supply their labor endowment. Their preferences are given by

$$(5) \qquad U(c_t^A, c_t^M) = \alpha \ln(c_t^A - \gamma) + \ln(c_t^M + \mu), \quad \alpha, \gamma, \mu > 0,$$

[4] In online Appendix V, we extend our basic framework to allow for population growth and for capital as an additional input of production. The qualitative results presented in this section are consistent with the steady-state comparative statics of the model with capital and a growing labor force.

[5] The extent of integration of the rural labor market with the rest of the economy is a topic of debate. While some development economists argue that it is low, Thierry Magnac and Gilles Postel-Vinay (1997) provide evidence from nineteenth century France that "migration between industry and agriculture was quite sensitive to relative wages in the two sectors" and that firms took this into account in their decisions. They also find that wages were similar in the two sectors. More recently, Yair Mundlak (2000) reports the percentage of farm operators reporting off-farm work for several industrialized countries in the second half of the twentieth century. In most countries between one-fourth and one-half of the farm operators report off-farm employment, suggesting an important degree of labor market integration. Finally, our qualitative results are robust to the introduction of quadratic migration costs à la Paul Krugman (1991).

where c_t^A and c_t^M denote individual consumption of food and nonagricultural goods, respectively, and α denotes the relative weight of food in preferences. These preferences are nonhomothetic for two reasons. First, we introduce a subsistence level of food consumption, γ. As a result, the income elasticity of food demand is below one, in line with the evidence on the universality of Engel's law known at least since Hendrik S. Houthakker (1957). This feature of preferences has long been emphasized in the literature on sectoral reallocation (Matsuyama 1992; John Laitner 2000; Caselli and Wilbur J. Coleman, II 2001; Gollin, Parente, and Rogerson 2002). Second, we assume that the income elasticity of nonagricultural goods is greater than one. Following Kongsamut, Rebelo, and Xie (2001), we can interpret μ as an exogenous endowment of nonagricultural goods, possibly resulting from home production.[6] Finally, we assume that the level of agricultural productivity is high enough so that if the entire labor force was allocated to food production, the economy would operate above the subsistence level,

$$AG(1) > \gamma. \tag{6}$$

Of course, the subsistence requirement will still constrain the labor allocation at any t.

The representative household chooses his consumption bundle to maximize (5), subject to the budget constraint

$$w_t^A l_t^A + w_t^M(1 - l_t^A) + \pi_t^A + \pi_t^M = c_t^A + p_t c_t^M, \tag{7}$$

where l_t^A represents time spent working in the agricultural sector, and π_t^A and π_t^M are profits from the two sectors distributed to the representative household.[7] Together with (7), the optimality conditions associated with this program are

$$\frac{\alpha}{c_t^A - \gamma} = \lambda \tag{8}$$

$$\frac{1}{c_t^M + \mu} = \lambda p_t, \tag{9}$$

where λ is the shadow value of an additional unit of income. Optimizing households equate the marginal rate of substitution between the two consumption goods to the relative price. Combining these two equations, the individual demand for the agricultural good satisfies $c_t^A = \gamma + \alpha p_t(c_t^M + \mu)$. Since all output from both sectors is consumed ($C_t^A = Y_t^A$ and $C_t^M = Y_t^M$), this equation becomes

$$Y_t^A = \gamma + \alpha p_t\left(Y_t^M + \mu\right), \tag{10}$$

[6] For instance, clothes can be washed using a washing machine (a component of c_M) or by hand (home production). Our specification can thus be interpreted as modeling home production in reduced form, similar to Kongsamut, Rebelo, and Xie (2001) and Margarida Duarte and Restuccia (2010). In online Appendix V, we introduce a generalized CES specification that yields identical results when $\mu = 0$. Nonetheless, we believe that our exposition is clearer under (5).

[7] Since profits are a residual, they do not affect household choices.

using upper case letters for aggregate variables.

Combining the market clearing condition with (4) and (10) yields the following relation for the allocation of labor between sectors:

$$(11) \quad \frac{\gamma}{A} = G(L_t^A) - \alpha \frac{G'(L_t^A)}{F'(1 - L_t^A)}\left(F(1 - L_t^A) + \frac{\mu}{M}\right) = \phi(L_t^A, M),$$

where

$$(12) \qquad \phi(L_t^A, M) < \phi(1, M) = G(1); \quad \phi_{L_t^A} > 0; \quad \phi_M > 0,$$

and where ϕ_x denotes the partial derivative of ϕ with respect to the variable x. Given (6), equation (11) has a unique solution that determines the level of employment in the agricultural sector as a function of sectoral productivities.

To obtain the effect of productivity increases on the sectoral allocation, differentiate (11) with respect to the productivity parameters

$$(13) \qquad \frac{\partial L^{A*}}{\partial A} = -\frac{\gamma}{A^2 \phi_{L^A}^*} < 0$$

$$(14) \qquad \frac{\partial L^{A*}}{\partial M} = -\frac{\phi_M^*}{\phi_{L^A}^*} < 0,$$

where equilibrium choices are denoted by *. Productivity increases in either sector lead to flows of labor out of agriculture. Our model thus captures the two engines behind the large reallocation of labor out of agriculture that were highlighted in the introduction. As in Matsuyama (1992) and Gollin, Parente, and Rogerson (2002), increases in the level of agricultural productivity push labor out of the agricultural sector: this is the "labor push" effect discussed by Nurkse (1953) and Rostow (1960). But additionally, as in Hansen and Prescott (2002), improvements in the level of technology in the industrial sector pull labor out of the traditional sector, increasing manufacturing employment, the "labor pull" effect stressed by Lewis (1954) and Harris and Todaro (1970). The income elasticities of demand for agricultural and nonagricultural commodities lie behind these two effects. Notice that if $\gamma = 0$, the labor allocation is independent of the level of agricultural technology; and if $\mu = 0$, the labor allocation is independent of the level of technology in the nonagricultural sector.[8]

Our model is also consistent with the second stylized fact of structural change, the secular decline of the share of agriculture in GDP. Consider the ratio of nonagricultural to agricultural output,

$$(15) \qquad \frac{p_t Y_t^M}{Y_t^A} = \frac{G'(L_t^A)}{F'(1 - L_t^A)} \frac{F(1 - L_t^A)}{G(L_t^A)}.$$

[8] When $\gamma = \mu = 0$, the income elasticities of demand for both goods are 1. Then, income and substitution effects induced by productivity changes in either sector cancel out, and the labor allocation does not depend on A or M. When $\gamma > 0$ ($\mu > 0$), the income elasticity of demand for agricultural (manufacturing) goods is below (above) 1. Then the income effect resulting from an increase in A (M) is weaker (stronger) than the substitution effect, leading to a reduction in L^A.

This expression is decreasing in L_t^A, the share of labor employed in agricultural production. Hence, increases in productivity in either sector reduce the share of agriculture not only in employment but also in output.

Finally, we can evaluate the effects of technological change on the relative price of manufactures. Using (4), (10), (13), and (14), we find the following comparative statics results for the relative price:

$$(16)\quad \frac{\partial p^*}{\partial A} = \frac{\left[G'(\cdot) + AG''(\cdot)\frac{\partial L^{A*}}{\partial A}\right]F'(\cdot) + AG'(\cdot)F''(\cdot)\frac{\partial L^{A*}}{\partial A}}{M[F'(\cdot)]^2} > 0 \quad \text{and}$$

$$(17)\quad \frac{\partial p^*}{\partial M} = \frac{AG'(\cdot)\frac{\partial L^{A*}}{\partial M}}{\alpha[MF(\cdot) + \mu]} - \frac{(AG'(\cdot) - \gamma)\left(F(\cdot) - MF'(\cdot)\frac{\partial L^{A*}}{\partial M}\right)}{\alpha[MF(\cdot) + \mu]^2} < 0.$$

We can use this simple framework with only labor and costless reallocation between sectors to explore the empirical implications of the labor-push and labor-pull hypotheses. Both hypotheses are associated with migrations from the countryside to the manufacturing centers and with a declining weight of agriculture in national product. Furthermore, both hypotheses are associated with increases in rural and urban wages. But while increases in agricultural productivity, A, are associated with increases in the relative price of the nonagricultural good, increases in the level of productivity in the modern sector, M, reduce the relative price of nonagricultural goods. Thus, while the evolution of wages, labor allocations, or sectoral output shares provide little information to discriminate between the two hypotheses, the behavior of relative prices gives crucial insights about the relative roles of the agricultural revolution and the industrial revolution in the process of structural change that started in Britain more than two centuries ago. In this sense, our exercise follows a long tradition in economics that uses changes in relative prices to infer changes in productivity. A recent example is Greenwood, Hercowitz, and Krusell (1997).

Finally, we turn to explore the implications of our model in the presence of continuous technological change in both sectors, most likely the empirically relevant case. Denoting the instantaneous growth rates of agricultural and nonagricultural productivity by $\hat{A} > 0$ and $\hat{M} > 0$, respectively, and denoting the change in the share of employment in agriculture by $\dot{L}^A$, we use (4) to reach the following expression for the growth rate of the relative price,

$$(18)\qquad \hat{p} = \hat{A} - \hat{M} + \dot{L}^A\left[\frac{G''(L_t^A)}{G'(L_t^A)} + \frac{F''(1 - L_t^A)}{F'(1 - L_t^A)}\right] > \hat{A} - \hat{M}.$$

As long as there is no technological regress, the last inequality holds. This inequality implies that decreases in the relative price of manufactures are unambiguously associated with faster technological change in the nonagricultural sector, i.e., they indicate that the labor pull effect dominates. If the relative price rises, the situation is less clear. An equal proportionate increase in the productivity of both sectors induces an increase in the relative price of manufactures, resulting from the low-income elasticity of demand for food and the high-income elasticity of demand for manufactures. So only a strong increase in the relative price is an unambiguous sign of stronger growth in agricultural productivity, or "labor push." A weak increase in the relative price can well occur in a situation where the productivity in manufacturing has increased by a slightly higher proportion.[9]

In the remainder of the paper, we explore the importance of the "push" and "pull" channels in the United States and in a long panel of 11 other countries that already completed the process of structural transformation, using the model as a guiding line for identification. The fundamental step in this is to draw on equation (18) to infer information on productivity changes from the observed evolution of the relative price. Next, we briefly present the data we use, and then turn to interpreting the United States and other countries' experience in the light of the model.

II. Historical Data

Structural change out of agriculture is a long-run phenomenon that in some countries started as early as the seventeenth century. Our data selection is then driven by two criteria: to enter our sample, countries should have completed the process of structural change (defined as a current employment share in agriculture of less than 10 percent);[10] and a sufficiently long series of data should be available. In particular, we require series on the employment share in agriculture to document structural change and on the relative price to assess its main drivers.

Drawing on a variety of sources, we managed to compile series for the United States and for 11 other countries. While the number of countries in our sample is not large, it corresponds to a large fraction of countries that have completed their structural transformation out of agriculture. Moreover, the series cover a long span of time (on average substantially more than 100 years), giving a reasonably complete picture for these countries. We benefit from the fact that agriculture was an early object of attention for statisticians and therefore is a particularly well-documented sector.

Our main sources of data are Brian R. Mitchell (1988, 2003a, 2003b) and the Groningen Growth and Development Centre (GGDC) 10-sector and Historical National Accounts databases (for documentation, see Bart van Ark 1996; Marcel Timmer and Gaaitzen J. de Vries 2007; Jan-Pieter Smits, Pieter Woltjer, and Debin Ma 2009).[11] The volumes by Mitchell contain series on sectoral employment shares in many countries, sometimes going back until 1800. They mainly draw on national censuses (via Paul Bairoch 1968) up to 1960 and then on national statistical yearbooks. The GGDC databases are intended "to bring together the available,

[9] The interpretation is different in a small open economy (see e.g., Matsuyama 1992, 2009), which is discussed in Section IVC.

[10] This threshold was reached by the United Kingdom as soon as 1891, by Canada in 1951, and by the United States in 1955.

[11] Data is available at http://www.ggdc.net.

but fragmented, data on GDP at the industry level for all major economies and to standardize these series to make a consistent long-run international comparison of output and productivity feasible" (Smits, Woltjer, and Ma 2009). These sectoral national accounts use price indices for sectoral value added, which are either reported directly or can easily be backed out from constant and current price sectoral value added series. We then use the price indices for aggregate value added and for value added in agriculture to compute the relative price p_y/p_a that we use in the empirical analysis.[12] For more detail on these and additional sources, see the online Appendix.

Unfortunately, the price index for value added in agriculture is not available for the United States. In Angus Maddison's (1995, Appendix B) words, "we have the paradox that the USA is one of the few countries where the construction of historical accounts by industry of origin has been neglected, though the statistical basis for such estimates is better than elsewhere." We therefore use producer prices and wholesale prices of all commodities versus farm products for the United States. In principle, however, value added prices are preferable for our purpose, as they net out the contribution of intermediate goods.[13]

The fact that the type of price index differs between the United States and the remaining countries forces us to analyze them separately. Indeed, Berthold Herrendorf, Rogerson, and Ákos Valentinyi (2009) show, for their quantitative exercises, the choice of measure matters. Results will still be comparable qualitatively, however, as the predictions of the model are the same no matter whether we interpret prices and quantities as referring to final expenditure or to value added. Considering the United States separately has the further advantage that for the United States, historical sectoral TFP series are available and can be used as a check on our model's predictions before taking them to a broader dataset.

By their nature, long series of historical data are less reliable than statistics for more recent times. Survey and measurement methods change over time. For instance, in the nineteenth and early twentieth century, several countries (e.g., the United States and Canada) counted "gainful workers" and not employment. This does not take into account unemployment. Price indices in earlier times were based on fewer goods, sometimes practically excluded services (e.g., the US PPI in the nineteenth century), and did not use theoretically well-founded aggregation procedures. On top of this comes a problem that still poses a challenge to contemporary price indices, namely ongoing change in the set of available goods and in their quality. This makes past series noisy and potentially (though not always perceptibly) incomplete.

To obtain results that are reliable despite these issues, we take an empirical approach that makes few assumptions and mainly relies on robust first-order features of the data. To reduce data requirements and the need for assumptions on functional forms, we make inference based only on the relative price and do not rely on

[12] While this is not exactly the same as the relative price p_m/p_a used in the model, online Appendix V shows that these two ratios move in a similar way in the model, so that we refer to both of them interchangeably as the relative price of nonagricultural goods. (This would of course be obvious with homothetic preferences.)

[13] Whereas in the United States, prices for farm products and not just for food expenditure (which would include e.g., manufactured processed foods!) are available, the main difference is that the producer price index only indexes the price of agricultural output, while the value-added price index also adjusts for changes in prices of intermediate inputs. The wholesale price index contains a distribution markup on top of the producer price. Historians argue that these markups are rather stable (see e.g., John W. Kendrick 1961).

sectoral TFP series. This strategy is less demanding in terms of data, giving us more and longer series to work with. Computing TFP is a data intensive exercise that, besides the data on labor allocations and prices that we use, requires data on output, other inputs, and factor shares. In most cases, these other series are not available. Where they are, they are harder to measure and therefore likely less reliable than the data we use. By using relative prices, we also avoid imposing the stronger restrictions on the production function required to obtain TFP estimates.[14]

To make our results more flexible and more robust, we also focus on trends in different subperiods and stages of the structural transformation rather than using precise levels. For instance, as shown below, the general evolution of the employment share in agriculture has such a clear trend and varies so much across countries that potential differences in the treatment of unemployment across countries or in a country over time should not affect the broader picture. Analyzing stages of the structural transformation also helps since broad stages, as opposed to precise levels, are almost certainly measured correctly. This essentially rules out measurement error in the independent variables in the regressions in Section IV. Remaining (classical) measurement error in the relative price then does not affect point estimates.

Concerning prices and price changes, the use of ratios (the relative price) and their rates of change makes our results more robust to biases in levels. We also use five-year moving averages, where data are available at a higher frequency to abstract from short-run fluctuations and to make figures comparable across data sources. Two remaining issues are measurement error and quality changes. Generally, measurement error could evolve differently over time for the two sectors. Given the importance of agriculture and the relative ease of price and output measurement in that sector (e.g., compared to services or multistage manufacturing), figures on agriculture are likely to be more reliable, particularly in early data. Measurement error in aggregate prices, in contrast, probably declined more strongly over time. This could induce heteroskedasticity in the regression specifications in Section IV. Properties of the error could also vary across countries. To deal with these two issues, we use robust standard errors clustered at the country level.

The failure of price indices to adjust for new goods and quality changes, which arguably matter more for nonagricultural goods, could imply that increases in the relative price of manufacturing goods are overstated, and the trends we find have to be corrected downward. Without this correction, there is a bias against finding a "pull" channel. Quantitatively, the Boskin Commission report argues that the US CPI overstated inflation by around 1.1 percentage points in 1995–1996 (see e.g., Michael J. Boskin et al. 1998). The bias most likely was not constant over time and probably was lower before the 1990s, which makes it difficult to judge its size. While the issue is not resolved with precision, we can still conclude that observing a period of falling nonagricultural goods prices robustly indicates a dominant pull channel, while this is not so clear for the opposite case. Finally, while in theory

[14] While the data requirements for computing value added prices are also nontrivial (for instance, intermediate goods prices are required), they are still much more modest than those for computing TFP, which requires several assumptions and data series beyond value added. The fact that agriculture used to be the dominant sector and therefore was the object of a lot of scrutiny by statisticians acts in our favor.

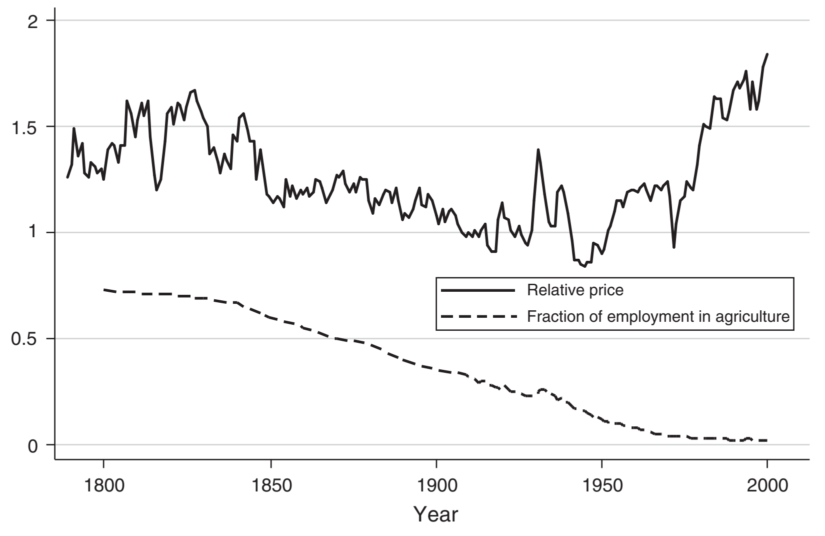

Figure 1. The Share of Employment in Agriculture and the Relative Price of Manufactures to Agricultural Goods, US, 1790/1800–2000

Note: See Section II.

changes in the composition of baskets used for the price indices could lead to spurious trends, this does not appear to be too much of a concern, as price indices relying on broader baskets (though with more sparse observations) exhibit similar trends, at least in the United States (Benjamin N. Dennis and Talan B. İşcan 2009). We thus believe our results to be robust, though it is, of course, impossible to be absolutely certain that they do not reflect some imperfections of the data.

III. A Long-Term View of Structural Change in the United States

Although large migrations out of the agriculture began in the United Kingdom more than two centuries ago, the United States was one of the first countries to complete this process of structural transformation. Furthermore, the wealth and quality of the US data, which besides relative prices includes data on sectoral productivities, makes this country an ideal candidate to evaluate the basic prediction of our model: that changes in the relative price reflect changes in relative productivity. In particular, equation (18) implies that if the relative price falls, it must be that productivity in the nonagricultural sector has increased at a faster pace than agricultural productivity.

Figure 1 presents the evolution of the share of employment in agriculture L^A and the relative price of manufactures to agricultural goods p for the United States from 1790 (for p) and 1800 (for L^A) to 2000. Over these two centuries, the share of labor employed in agriculture declined from 73 percent to barely 2.5 percent. This decline was monotonic, except for the period of the Great Depression.[15] In contrast, there

[15] Only recently have real business cycles scholars made an attempt to explain the Great Depression in terms of fully specified stochastic general equilibrium models, see Prescott (1999) and Harold L. Cole and Lee E. Ohanian

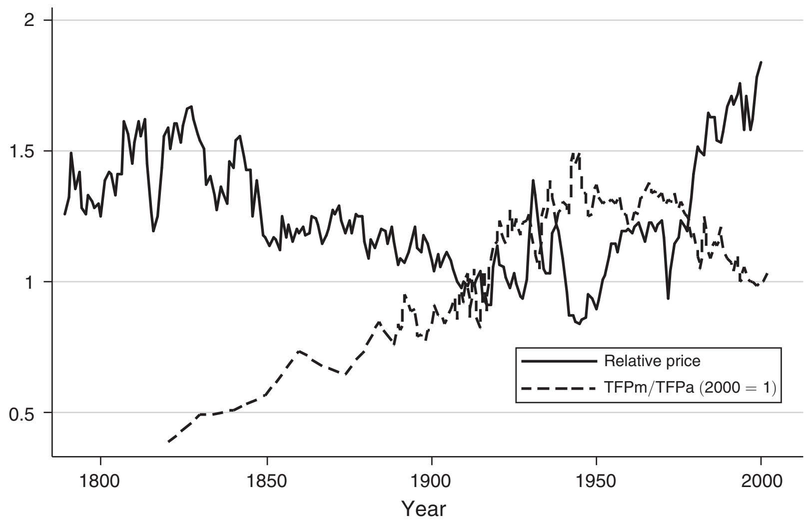

FIGURE 2. RELATIVE PRODUCTIVITY (2000 = 1) AND RELATIVE PRICE OF NONFARM AND FARM GOODS, US, 1820–2000

Sources: US farm productivity is from Robert E. Gallman (1972, table 7) for 1800–1840, from Lee A. Craig and Thomas J. Weiss (2000, table 3) for 1840–1870 (both cited in Dennis and İşcan 2009), from Kendrick (1961, table B-I) for 1869–1948, and from the United States Department of Agriculture (USDA) Economic Research Service, Agricultural Productivity Dataset, http://www.ers.usda.gov/Data/AgProductivity/, for 1948–2000. Nonfarm productivity is from Kenneth L. Sokoloff (1986, Table 13.9) for 1820–1860 (again cited in Dennis and İşcan 2009), from Kendrick (1961, table A-XXIII) for 1870–1948, and from the Bureau of Labor Statistics (BLS) Multifactor Productivity Trends—Historical SIC Measures 1948–2002, http://www.bls.gov/mfp/historicalsic.htm, for 1948–2000.

is no clear trend in the relative price until about 1840. After this date, p declined steadily until 1918, then became more volatile until the end of World War II, after which it went on an upward trend. Our model then identifies a change in the main driver behind the process of structural transformation after World War II: the labor pull effect dominates before the war, with the labor push effect taking over later on. This suggests that nonagricultural productivity growth outpaced its agricultural counterpart from the beginning of our sample period to World War I, with roles reversing after World War II. Because equation (18) implies a positive trend in p even if A and M increase at equal rates, our identification of the main driver of sectoral reallocation is very robust for the first period, in which the bulk of structural change occurred, and more tentative for the second one.

This prediction is consistent with existing estimates of farm and nonfarm productivity in the United States.[16] Figure 2 plots the relative price of manufactures to agricultural goods and the relative productivity in the two sectors. Productivity is almost a mirror image of the price. In particular, it is striking to see that while the average

(1999, 2002). Their estimates suggest a 14 percent drop in TFP between 1929 and 1934. In the context of the model outlined in the previous section, a drop in TFP in any sector will trigger a process of reverse migration similar to the one observed in the data.

[16] See notes to Figure 2 for sources.

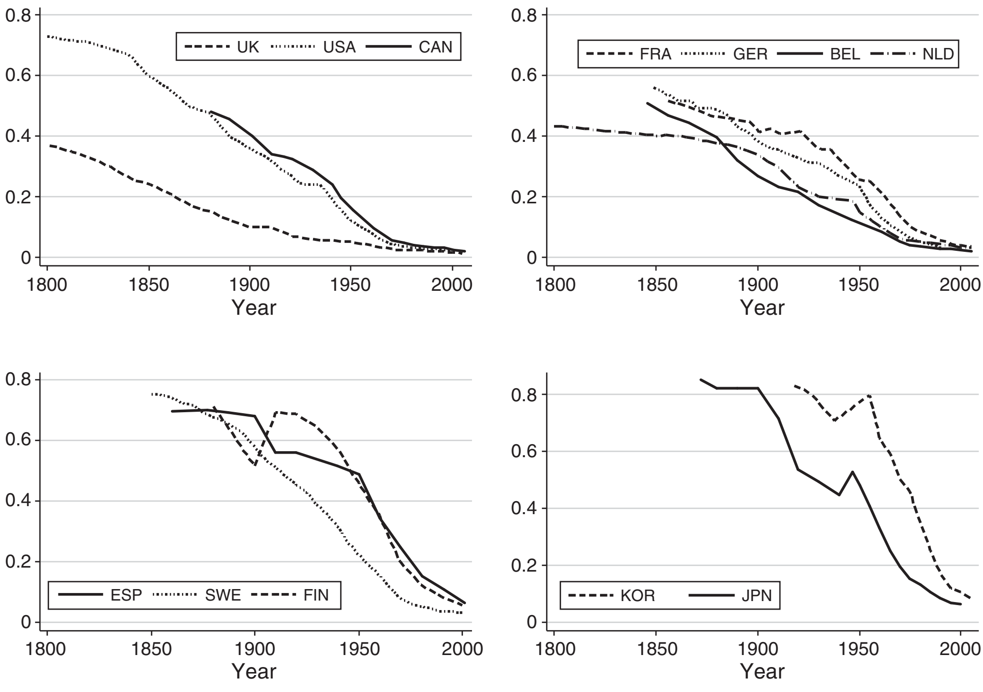

Figure 3. The Employment Share of Agriculture

growth rate in the nonfarm sector outstrips that in the farm sector by 1.7 percent versus 0.8 percent over the period from 1820 to 1948, the trend strongly reverses for the 1948 to 2002 period. In the second half of the twentieth century, average yearly TFP growth in the nonfarm sector is 1.4 percent, compared to 1.7 percent in the farm sector. The rapidly increasing adoption rates of tractors and of hybrid corn (Zvi Griliches 1957; Alan L. Olmstead and Paul W. Rhode 2001), to name some examples, contributed to boosting productivity growth in agriculture. More importantly, the results of this comparison are consistent with the basic prediction of our model and give us confidence to extend our identification strategy based on relative price data to a larger sample of countries where data on sectoral productivity are not readily available.

IV. Historical Evidence from Some Successful Transformers

Is the United States experience representative? To answer this question, we analyze data on labor allocations and relative prices for another 11 countries that completed their process of structural transformation by the end of the twentieth century.

A. *Structural Change across Countries*

Figure 3 reproduces the time paths of the employment share in agriculture for the countries in our sample. The panels group countries with similar experiences. For half the countries in our sample (Finland, Japan, South Korea, Spain, Sweden, and the United States), our data cover essentially the whole process of structural change, with initial agricultural employment shares in the neighborhood of 80 percent. For the remaining ones (Belgium, Canada, France, Germany, the Netherlands, and the United Kingdom), the period or change in labor allocation covered is somewhat shorter. On average, our data capture reallocations that involve a change in the employment share in agriculture of more than 50 percentage points. Also note that the assumption imposed in the model that guarantees that both sectors are active (equation 6) is borne out for our period of analysis.

As emphasized by the model, the historical evidence shows that structural change is a one-way street. Increases in the employment share in agriculture are extremely rare events. Clearly, the United Kingdom (top left panel) was the first country to experience substantial structural change, with an employment share in agriculture below 50 percent as early as 1800. At that time, the US agricultural share was still above 75 percent. Countries that started the process of structural change later tended to experience a faster pace of migration. The difference in the speed of change is particularly clear when comparing the European early starters in the top right panel to the European late starters in the bottom left panel. When the latter started their transformations, the former already had very low employment shares in agriculture. Nonetheless, the late starters experienced much faster reallocations and nowadays their agricultural employment shares are not far from those of the earlier starters. The fastest change was experienced by South Korea and Japan.

Similar patterns emerge from the descriptive statistics summarized in Table 1. The table presents the average annual absolute change of the employment share in agriculture by country. It is clear that the variation across countries is substantial. While part of this is due to differences in data coverage across countries, most of it remains when computing the same statistics for smaller, balanced panels, as is evident from the numbers on structural change in shorter 40-year subperiods. As was already evident in Figure 1, the late starters experienced the fastest rates of structural change while France, Germany, the Netherlands, and the United Kingdom underwent a much slower, drawn-out process.

The median rate of decline of the agricultural employment share across countries is 0.37 percentage points per year. At this rate it takes about 108 years to reduce the agricultural employment share from 60 percent, the average employment share at the beginning of our sample, to 20 percent.

In addition, Table 1 reveals that, on average, structural change was faster in recent periods.[17] Given that growth in output per capita in the countries in our sample was also faster in more recent periods (with few exceptions; see Table 2), the acceleration of structural change is not surprising. As the periods under consideration are long, faster output growth in more recent periods must be at least in part due to higher productivity growth in those periods. But no matter how this is distributed across sectors, the model predicts that it should lead to faster structural change. Faster technological change thus drives faster structural change.

[17] Note that this acceleration is all the more remarkable as levels of L^A fall over time toward zero, reducing the scope for further reductions. Within a given country, the acceleration thus has to stop at some point, as indeed is visible e.g., for the United Kingdom and the United States. Still, the trend is not purely due to sample selection.

Table 1—Structural Change across Countries

Country	Average annual change in the employment share in agriculture L^A (percentage points)						Years covered
	All years	1800–1839	1840–1879	1880–1919	1920–1959	1960–	
Belgium	−0.31		−0.33	−0.45	−0.32	−0.15	1846–2005
Canada	−0.37			−0.39	−0.57	−0.18	1881–2006
Finland	−0.55			−0.06	−0.83	−0.75	1880–2000
France	−0.32		−0.24	−0.12	−0.50	−0.41	1856–2005
Germany	−0.37		−0.23	−0.38	−0.51	−0.34	1849–1990
Japan	−0.61			−0.72	−0.51	−0.67	1872–2000
Netherlands	−0.20	−0.07	−0.08	−0.36	−0.33	−0.16	1800–2005
South Korea	−0.86				−0.09	−1.43	1918–2005
Spain	−0.45		0.02	−0.33	−0.54	−0.69	1860–2001
Sweden	−0.51		−0.32	−0.56	−0.75	−0.31	1860–2000
UK	−0.17	−0.28	−0.28	−0.20	−0.07	−0.06	1801–2005
USA	−0.35	−0.15	−0.48	−0.52	−0.48	−0.15	1800–1999
Average	−0.42	−0.16	−0.24	−0.37	−0.46	−0.44	

Notes: Computed using five-year moving averages where observations are more frequent. The figures for subperiods are for the indicated periods or very close ones, depending on data availability. The average is unweighted across countries. For sources, see Section II.

Table 2—Average Annual Growth Rate of Output per capita in Percent, 1820–2000

Country	All years	1820–1840	1840–1880	1880–1920	1920–1960	1960–2000
Belgium	1.5	0.8	1.7	0.6	1.4	2.8
Canada	1.8	1.3	1.1	1.9	2.1	2.4
Finland	1.8	0.5	0.7	1.2	3.1	2.9
France	1.6	1.2	1.0	1.1	2.1	2.6
Germany	1.6	1.5	0.8	0.9	2.6	2.3
Japan	1.9	0.1	0.6	1.7	2.2	4.2
Netherlands	1.4	1.1	0.7	0.8	1.7	2.5
South Korea	1.8	0.0	0.2	1.3	0.3	6.3
Spain	1.5	0.2	1.1	0.7	0.9	4.1
Sweden	1.8	0.6	1.2	1.8	2.6	2.2
UK	1.4	0.8	1.4	0.7	1.6	2.2
USA	1.7	1.2	1.8	1.4	1.8	2.3
Average	1.7	0.8	1.0	1.2	1.9	3.1

Note: The average is unweighted across countries.

Source: Angus Maddison (2009) http://www.ggdc.net/maddison/.

B. *The Relative Price and Structural Change*

To infer which of the two sectors was the main driver of structural change, we turn to the evolution of the price of nonagricultural relative to agricultural goods, $p \equiv p_m/p_a$. In our dataset, the relative price rises slightly, on average, across countries and over the entire period. Sixty percent of price changes over five-year intervals are increases. The fact that price changes in both directions are common indicates that both the push and the pull channels matter.

To obtain a more detailed picture of the importance of each channel in different situations, in Figure 4, the relative price is plotted against time (left panel) and against a country's employment share in agriculture (right panel). The latter measures the country's stage in the structural transformation. In the graphs, the relative price is standardized to be one at the date of the first observation in each country.

FIGURE 4. THE EVOLUTION OF THE RELATIVE PRICE p_m/p_a ACROSS COUNTRIES

Note also that in some countries, there are two disjoint series for the relative price.[18] The level of the relative price thus is not comparable across countries or disjoint series within a country. Trends or growth rates are comparable, though, except at the point where two series for a single country are disjoint.

The existence of two distinct subperiods is visible to the naked eye. Up to about 1920, the relative price fell in all countries except for the United Kingdom. After World War II, it increased in all countries, in some by a lot. This overall picture remains when breaking down the series into shorter periods of about 40 years, as shown in Table 3.[19] In the earliest period before 1840, data are available for only three countries: the relative price declined in France and was basically flat in the Netherlands and in Sweden. In the following 80 years up to 1920, the relative price declined everywhere except for the United Kingdom and Japan. In the period 1920–1959 covering the Great Depression and World War II, there is a lot of variation across countries, with an average change close to zero. In the most recent period starting in 1960, the relative price has increased in all countries. Note that while the price changes after 1960 are particularly rapid, most of the structural transformation in our sample took place in the earlier period. On average, across countries, slightly less than a quarter of the absolute change in L^A in the sample occurs after 1960. Overall, the relative price was close to flat up to 1840, then declined for 80 years, was close to flat up to 1960, and then increased. With very few exceptions, this pattern holds not only on average, but also within each country.

Given the almost monotonic relationship between time and the employment share in agriculture, it is no surprise that the plot of p against L^A is almost a mirror image of the time series. The relative price tends to fall as the employment share in agriculture falls until that share reaches about 15–20 percent. Then, as the employment share in agriculture falls further, the price rises precipitously.

The lower panel of Table 3 shows the growth rate of the relative price for more detailed stages of development, as defined by brackets of the employment share in

[18] This is the case for Belgium, France, Germany, Japan, the Netherlands, South Korea, Spain, and the United Kingdom.

[19] Results are robust to changing the period cutoffs.

Table 3—The Relative Price: Average Annualized Percentage Change

		By time period					
Country	All years	1789–1839	1840–1879	1880–1919	1920–1959	1960–	Years covered
Belgium	0.57		−0.22	−0.71	0.86	3.21	1836–2005
Canada	0.01				−0.99	2.38	1936–1960
Finland	−0.21		−0.95	−0.58	−0.99	0.87	1860–2000
France	0.49	−0.49	−0.43	−0.31	1.14	2.07	1815–1995
Germany	0.31		−0.42	−0.22	0.04	3.32	1852–1990
Japan	−0.12			0.15	−0.84	0.04	1885–2000
Netherlands	0.72	−0.03	−1.17	−0.44	2.56	3.43	1808–2005
South Korea	0.22			−0.72	−0.35	0.65	1913–2005
Spain	0.52		−0.67	0.08	−0.25	2.80	1850–2001
Sweden	0.08	0.09	−0.07	−0.41	−0.98	1.50	1800–2000
UK	1.18		0.32	0.43	0.58	2.64	1861–2005
Average	0.34	−0.14	−0.45	−0.27	0.07	2.08	

		By stage in the process of structural change				
	L^A:	< 10 percent	10–20 percent	20–40 percent	40–60 percent	> 60 percent
Belgium		3.27	1.15	−1.24	−0.74	
Canada			−4.49	−1.85		
Finland		0.28	−0.32	1.62	−0.08	−0.72
France		3.74	0.18	1.18	−0.54	
Germany		3.37	−1.78	−0.12	−0.20	
Japan		−0.43	0.05	0.73	−1.05	−0.26
Netherlands		3.49		0.10	−0.75	
South Korea		1.98	0.89	1.20	−2.43	−0.42
Spain		2.91	5.19		−0.32	−0.28
Sweden		1.58	0.49	−2.48	0.07	0.27
UK		2.05	0.41			
Average		2.21	0.15	−0.11	−0.67	−0.28

Notes: Computed using five-year moving averages where observations are more frequent. The figures for subperiods are for the indicated periods or very close ones, depending on data availability. The average is unweighted across countries. For sources, see Section II.

agriculture. Again, on average, across countries, the relative price falls while L^A is above 20 percent, rises slightly while it is between 10 and 20 percent, and rises strongly when it is below 10 percent. While this mirrors the pattern in terms of time periods shown in the top panel of the table, there is more heterogeneity across countries.

The fact that relative price changes are so similar whether plotted against time or against the stage of development raises the question which of the two factors drives relative price changes: developments in a certain time period (e.g., the nature of technological progress in the nineteenth versus the late twentieth century) or features specific to a certain stage of development (e.g., technological developments in nonagriculture necessarily preceding those in agriculture because maybe the former are instrumental to the latter).

To answer this question, we regress the growth rate of the relative price on dummies for time periods and for stages of the structural transformation. Results on the pooled sample of 11 countries are shown in the first column of Table 4. They reveal that even controlling for the stage of development, the growth rate of p is significantly lower in the three periods 1840–1879, 1880–1919, and 1920–1959, corroborating the results shown in Table 3. The coefficient on the period 1800–1839

Table 4—Changes in the Relative Price: The Role of Time versus the Stage of Structural Change

	Dependent variable: growth rate of p					
	OLS on pooled data		OLS using country averages		Country fixed effects	
L^A:						
Country average stages: L^A			−0.0248	(0.0093)**		
$<$ 10 percent	0.0098	(0.0071)			−0.0178	(0.0134)
10–20 percent	−0.0061	(0.0061)			−0.0222	(0.0095)**
20–40 percent	−0.0047	(0.0048)			−0.0209	(0.0080)**
40–60 percent	−0.0064	(0.0024)**			−0.0166	(0.0025)***
Time periods:						
1800–1839	−0.0096	(0.0065)			−0.0330	(0.0135)**
1840–1879	−0.0162	(0.0062)**			−0.0376	(0.0112)***
1880–1919	−0.0144	(0.0052)**			−0.0310	(0.0090)***
1920–1959	−0.0158	(0.0068)**			−0.0251	(0.0082)**
Constant	0.0159	(0.0065)***	0.0125	(0.0029)***	0.0410	(0.0121)**
Observations	189		11		189	
Countries	11		11		11	
R^2	0.271		0.503		0.302	

Notes: The dependent variable is the annualized growth rate of the relative price $p \equiv p_m/p_a$ between two subsequent observations of L^A in the first and third column and a country's mean growth rate of the relative price over the whole sample where both p and L^A are observed in the second column. Independent variables are indicator variables for the time period and the stage in structural change as indicated by the intervals in the table in the first and third columns (omitted: the stage where $L^A > 60$ percent and the period from 1960 on) and a country's average L^A in the sample in the second column. Regression is by OLS in the first two columns and includes country fixed effects in the last one. Robust standard errors in parentheses; in the first and third column clustered at the country level.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

is negative but not significant. Among the stage dummies, only the one for the stage with L^A between 40 and 60 percent is individually significant. However, the stage dummies are jointly significant at the 1 percent level. (The year dummies jointly are so at the 5 percent level.)

To further dissect the role of stages, we compute the overall annualized growth rate of p in each country and regress this on a country's average employment share in agriculture in the sample (second column). The resulting coefficient is negative and strongly significant despite the small sample. In countries that in our sample have a high average L^A (those are late starters such as Spain or South Korea), the relative price thus declined more strongly (or grew less) than in early starters like the United Kingdom. This suggests that across countries, the pull channel is more important in countries that are less advanced in their structural transformation. This result is all the more important as the late starters are present in the sample at a time when the relative price increases in many countries. Just from Figure 4, this timing would lead one to expect a positive relationship between average L^A and the average price change. The significantly negative regression coefficient shows that instead, even in the period where p grows in many countries, there are substantial cross-country differences, and p tends to grow less in countries where the structural transformation is less advanced.

To exploit information from within country histories, we include country fixed effects in the regression of the growth rate of the relative price on stage and period dummies. Results are shown in the third column. They are similar to those in the pooled sample; the growth rate of the relative price is significantly lower in all periods up to 1960 and while the employment share in agriculture is above 10 percent. Both sets of dummies are jointly significant at the 1 percent level. This result is in line with the consistent pattern of price changes in the different periods across countries documented in Table 3, compared to the more varied pattern for stages.[20]

To summarize, there is evidence that time and stages are related to changes in the relative price in similar ways even after disentangling them. First, growth in the relative price is significantly lower in countries that are less advanced in their structural change in our sample. Second, controlling for these cross-country differences in the growth rate of p, growth in the relative price is significantly lower between 1840 and 1960, just as it is significantly lower in the early and intermediate stages of structural change (L^A between 10 and 60 percent). Overall, stage effects have slightly higher explanatory power, as they are related to differences in the evolution of the relative price both within and across countries. Time and stage effects point in the same direction. The early time and stage of the structural transformation were dominated by the pull channel, with the push channel taking over later on and as structural change was already more advanced. The only exception to this is the very early time (before 1840) and stage ($L^A > 60$ percent) where data availability is an issue.[21]

The existence of a pattern both with respect to time and with respect to the stage in the structural transformation suggests that the sequence of events in the structural transformation is a function of both country-specific (the stage) and broader (time) elements. The consistency of the time pattern across countries points to the importance of either the diffusion of technology or trade. Prices can be expected to evolve in similar ways if technological advances are shared across countries, or if they occur in an important producer and are then mediated through world prices. At the same time, the stage of development matters. Although late starters share the overall time pattern in the relative price of early starters, they go through it at a different level. The pattern of price changes is similar, but they are, on average, more negative. This suggests that despite time effects, countries go through the structural transformation in a certain order. Consider, for instance, South Korea after World War II. While overall the push channel dominates in South Korea in this period, it is much weaker than in other countries at this time, suggesting that the country absorbs not only recent technological advances in agriculture but on top of that previous advances in nonagriculture that other countries already absorbed before, suggesting that the sequence of "first pull, then push" is respected.

C. *The Role of Trade and Technology Transfer*

The broadly similar trend in the relative price across countries, in particular countries at different stages of the structural transformation, suggests that there could be

[20] In all the regressions, sign patterns among dummies of one type are not sensitive to excluding the other set of dummies.

[21] Before 1840, results are similar to the following periods but not significant as there are data on only three countries. While L^A was above 60 percent, the growth rate of p was significantly larger than at the next stages in the structural transformation. Nonetheless, as shown above using equation (18), it is difficult to draw conclusions on the source of technological change from small increases in the relative price.

a common driver of the relative price. For this, technology transfer and trade are the more likely candidates. A technological improvement in one country will likely sooner or later be transmitted to other countries. Then, all countries benefiting from the new technology should experience similar relative price changes. Alternatively, if there is trade, a technology improvement in one country could influence the world relative price and domestic labor allocations. Along these lines, Mundlak and Donald F. Larson (1992) and Mundlak (2000) present evidence on the pass-through from world agricultural prices to domestic prices. Using a sample of 58 countries for the period 1968–1978, they find that most changes in world prices are transmitted to domestic prices, and that world prices constitute the dominant driver of changes in domestic prices in this period.

Most countries in our sample had substantial trade shares at least in the decades leading up to World War I and in the time after World War II (Maddison 2001, tables A1-c, A3-b, F2, and F3), and agriculture accounted for a substantial part of trade (Giovanni Federico 2005, 28). For most of the period under consideration, the countries in our sample accounted for more than half of world output and trade (Maddison 2001) and for up to one-third of world agricultural output (Federico 2004, table A.6). How does the presence of trade affect our conclusions?[22]

If the countries in our sample were small open economies that take the world relative price as given, Matsuyama's (1992, 2009) results would apply. In terms of our model, this implies that trade breaks the link between domestic consumption and production, so that the resource allocation is uniquely determined by equation (4), restated here for convenience:

$$p = \frac{A}{M}\frac{G'(L^A)}{F'(1 - L^A)}.$$

A decrease in the relative price, as observed in the data prior to 1920 in all countries except for the United Kingdom, then should lead to a movement of labor *toward* agriculture. Of course, this almost never occurred, as is clear from Figures 1 and 3. To the contrary, the large movement of labor out of agriculture in that period implies an increase of the last term in the equation. The observed movements in prices and allocations before 1920 then are consistent only if the first term on the right-hand side declined a lot, i.e., if productivity in nonagriculture grew strongly relative to that in agriculture.[23] For the period after 1960, no clear conclusions about the evolution of relative productivities can be made under the assumption of small open economies.

[22] Note though that while the relative price moves in similar ways at low frequencies, this is not the case at high frequencies. For instance, in a regression of the growth rate of the relative price on country and time dummies, only two time dummies before 1960 (1930, 1945) and two recent ones (1980, 1981) are statistically significant at conventional levels.

[23] While our sample consists of currently developed countries that probably had a comparative advantage in manufacturing at the time, the movement out of agriculture in this period also occurred in other countries, suggesting that the result is not driven by sample selection. The largest grain exporters in 1900 were Russia, Argentina, Romania, and the United States (Mitchell 2003a, 2003b, 2003c). By 1913, Canada had joined this group. (Other large producers like China, India, or Germany either did not export much or were net importers. For cross-country output data in 1913 in wheat units, see Federico (2004). As shown above, the share of employment in agriculture declined strongly in the United States and Canada in this period. It fell slightly in Romania (Mitchell 2003b). For Russia, no time series on the employment share is available. However, both the rural population and the share of

Even if taken as exogenous under the small open economy assumption, the observed relative price trends must have some cause. Going to an extreme and interpreting our sample as a fully integrated world economy, the relative price trends are informative about some measure of "world technology." They suggest, again, that this first improved more strongly in nonagriculture, and only after 1960 in agriculture. This is consistent with conclusions we obtained at the country level.

To summarize, even with trade overall results go through, structural change from 1840–1920 was mainly driven by "pull," and only after 1960 by "push." This is true for "world technology" and for individual country technologies for the earlier period. Given that even allowing for trade the data suggest that relative technologies evolve broadly similarly across countries, technology and its transfer across countries are the most plausible drivers of the similar patterns in the evolution of the relative price.

Summarizing our findings on the historical evidence, we conclude that the trends in the relative price suggest a very clear common pattern across countries. Structural change is mainly driven by technological progress outside agriculture before World War II and by increases in agricultural productivity after the war. This is exactly the same pattern found using US time series data.

The similarity of results across countries is comforting. It appears that over the long horizon that we are considering here, long-run movements in technology are similar across countries, despite potentially substantial delays in technology diffusion in the short run. The results are also consistent with more direct evidence on the introduction of improvements in agricultural technology in the postwar period, for instance hybrid corn. Nonetheless, the most surprising result is the robust dominance of the pull channel for the period before 1940.

V. Conclusions

Recent years have seen a renewed interest in the role of agriculture in the process of development and structural change, motivated by the large role agriculture still plays in today's poor economies and by its importance for their aggregate productivity. Yet, there has been (and still is) a substantial debate about the relative roles played by agricultural and nonagricultural productivity in this process of structural change. The goal of this paper was to shed some light on this debate by examining the experience of countries that completed this transformation.

We presented a simple model consistent with the two crucial observations associated with the process of structural change: a secular decline in the share of the labor force devoted to agriculture and a decreasing weight of agricultural output in national product. We used this framework to explore the testable implications of the "labor push" and "labor pull" hypotheses that point to technological progress in agriculture and manufacturing, respectively, as the main driver of structural change. Then, using data covering the structural transformation of 12 countries that completed that process, we explored the relative contribution of the two channels to the process of structural change.

agriculture in GDP fell between the late nineteenth century and the years before World War I, while employment in industry strongly increased in this period (Nicolas Spulber 2003). The share of employment in agriculture increased only in Argentina.

This analysis yielded four main results. First, both channels matter. In the case of the United States, for instance, the "labor pull" channel dominated before World War I, with the "labor push" channel taking over after World War II. Second, together with growth in GDP per capita, structural change accelerates in the twentieth century in most countries, even those where the agricultural employment share is already low. Third, the evolution of the relative price suggests that productivity improvements in the nonagricultural sector were the main driver of structural change before 1960. After that, the evidence is somewhat less robust and indicates productivity changes in agriculture as the driver of change. This time pattern coincides exactly with the evidence for the United States. It also fits well with available evidence on the timing of technology adoption in agriculture and holds independently of whether we treat the countries in our sample as closed or open economies. Finally, advances in non-agricultural productivity are more important in countries that are less advanced in their structural transformation. This suggests that, despite the common time effects, it follows a sequence of "first pull, then push."

Whereas there was previous evidence on the recent importance of the "labor push" channel, the clear evidence for the importance of the pull channel during most of the structural transformation is new and important. The dominance of the pull channel before World War II is of particular importance given the emphasis placed on agricultural productivity, the push channel, by most of the recent literature on structural change. (A notable exception is Gollin, Parente, and Rogerson (2007). These results suggest that models of structural change that rely on faster productivity growth in agriculture, such as Ngai and Pissarides (2007), are at odds with most of the pre-World War II evidence—the period in which most of the structural change out of agriculture took place. Similarly, models of structural change that restrict non-homotheticities in preferences to food consumption, such as Gollin, Parente, and Rogerson (2002), miss nonagricultural technological progress as an important driver of structural change. Our empirical evidence thus indicates that quantitative models of structural change should feature both a push and a pull channel. Policy recommendations derived using modeling strategies that neglect the crucial role played by nonagricultural productivity in the process of structural change and economic development may well miss a large part of the story.

Appendix

A. *A Model with Capital*

Here, we explore the robustness of the predictions of our model to the inclusion of a second input in production, capital. One may think that the asymmetry introduced by capital, which is mainly produced in the nonagricultural sector but used in both sectors, may affect some of the results of the basic model that we use to identify changes in the levels of sector-specific productivities.

The introduction of capital accumulation in our basic framework is not a straightforward task. Ngai and Pissarides (2007) present a multi-sector model of capital accumulation under homothetic preferences. Although a balanced growth path for their model exists under quite general conditions, their model predicts that the relative price moves in the same direction as labor allocations. This implication seems at odds with basic features of the empirical evidence presented in our paper. Non-homothetic preferences can resolve this problem. Kongsamut, Rebelo, and Xie (2001) derive a restriction for the existence of a "generalized balanced growth path" in a multi-sector model with capital accumulation and non-homothetic preferences. However, since this restriction implies equal growth rates of agricultural and nonagricultural productivity, it cannot be imposed when analyzing the response of prices and allocations to potentially differing sectoral productivity growth rates. As a way out, we assume constant productivity levels in each sector and study the effects of changes in these levels. This assumption of course is restrictive too, in particular when studying economic phenomena that span long periods of time over which productivity increases may not be unanticipated. Yet, it balances our two goals. First, it allows combining capital accumulation and non-homothetic preferences. Second, it provides a framework with a well-defined steady state where one can explore the response of the relative price and of factor allocations to changes in the levels of sectoral productivity.

Let us thus assume that production takes place according to the following Cobb-Douglas technologies:

$$(\text{A1}) \qquad \begin{aligned} Y_t^A &= AG(K_t^A, L_t^A) = A(K_t^A)^{\theta_A}(L_t^A)^{1-\theta_A} \\ Y_t^M &= MF(K_t^M, L_t^M) = M(K_t^M)^{\theta_M}(L_t^M)^{1-\theta_M}, \end{aligned}$$

where K_t^A, $K_t^M = K_t - K_t^A, \theta_A$ and θ_M are the levels of capital and the elasticities of output with respect to capital in the agricultural and nonagricultural sectors, respectively. The presence of capital introduces an asymmetry in the uses of the output produced by our two sectors. While agricultural production can be used only for consumption purposes, the production of the nonagricultural sector could be either consumed or costlessly transformed into capital. As a result, the law of motion of the capital stock is given by

$$(\text{A2}) \qquad \dot{K}_t = M(K_t^M)^{\theta_M}(L_t^M)^{1-\theta_M} - C_t^M,$$

where we abstract from capital depreciation. Finally, we allow population to grow at the exogenous rate n.

Since both factors are freely mobile, productive efficiency requires the marginal rates of transformation to be, at all times, equal across sectors:

$$(\text{A3}) \qquad \frac{(1-\theta_A)}{\theta_A}\frac{K_t^A}{L_t^A} = \frac{(1-\theta_M)}{\theta_M}\frac{K_t^M}{L_t^M}.$$

As in the model without capital, a nonarbitrage condition in the labor market requires wages (and returns to capital) to be equated across sectors:

$$w_t^A = (1-\theta_A)A\left(\frac{K_t^A}{L_t^A}\right)^{\theta_A} = p_t(1-\theta_M)M\left(\frac{K_t^M}{L_t^M}\right)^{\theta_M} = w_t^M.$$

This implies

$$\text{(A4)} \qquad p_t = \frac{(1-\theta_A)}{(1-\theta_M)}\frac{A}{M}\frac{\left(\frac{K_t^A}{L_t^A}\right)^{\theta_A}}{\left(\frac{K_t^M}{L_t^M}\right)^{\theta_M}} = \frac{(1-\theta_A)}{(1-\theta_M)}\frac{A}{M}\frac{\left(\frac{\theta_A(1-\theta_M)}{\theta_M(1-\theta_A)}\frac{K_t^M}{L_t^M}\right)^{\theta_A}}{\left(\frac{K_t^M}{L_t^M}\right)^{\theta_M}}$$

$$= \xi\frac{A}{M}\left(\frac{K_t^M}{L_t^M}\right)^{\theta_A-\theta_M} = \xi\frac{A}{M}\left(\frac{K_t - K_t^A}{L_t - L_t^A}\right)^{\theta_A-\theta_M},$$

where $\xi \equiv (1-\theta_A)^{1-\theta_A}(\theta_A)^{\theta_A}/(1-\theta_M)^{1-\theta_M}(\theta_M)^{\theta_M}$, and we impose the production efficiency condition (A3).

Using US evidence from the second half of the twentieth century, Jorgenson, Frank Gallop, and Barbara Fraumeni (1987, tables 7.3, 9.8) report a share of capital in value added of 30 percent in the agricultural sector and of close to 40 percent in the nonagricultural sector. Measures of capital intensity in agriculture in earlier times or in less developed countries suggest even lower values. See, for instance, Kendrick (1961), Robert E. Gallman (1972), and Yujiro Hayami and Vernon W. Ruttan (1985, chapter 6). Capital intensity in nonagriculture, in contrast, varies less over time or across countries (Gollin 2002). This evidence suggests that the empirically relevant case is one where capital intensity in the nonagricultural sector exceeds that of the agricultural sector. As a consequence, we will assume $\theta_M \geq \theta_A$ in the remaining analysis. Furthermore, we will concentrate on the two limiting cases that are analytically tractable: $\theta_M = \theta_A = \theta > 0$ and $\theta_M = \theta > \theta_A = 0$.

When $\theta_M = \theta_A = \theta > 0$, equation (A3) implies that the capital-labor ratio is equated across sectors and, as a result, we can write the production technologies as a function of this ratio as follows,

$$\text{(A5)} \qquad Y_t^A = A\left(\frac{K_t^A}{L_t^A}\right)^{\theta} L_t^A = A(K_t)^{\theta} L_t^A$$

$$Y_t^M = M\left(\frac{K_t^M}{L_t^M}\right)^{\theta} L_t^M = M(K_t)^{\theta}(L_t - L_t^A).$$

Furthermore, the relative price reduces to

$$\text{(A6)} \qquad p_t = \frac{A}{M}.$$

Using (A2) yields the aggregate budget constraint

$$\text{(A7)} \qquad \left(\dot{K}_t + C_t^M\right)p_t + C_t^A = A(K_t)^{\theta}(L_t)^{1-\theta}.$$

Maximizing welfare, given by the present value of (5) discounted using a rate of time preference ρ, subject to (A7), yields (apart from (10) and the transversality condition) an additional intertemporal allocation condition that governs the evolution of consumption through time.

$$\text{(A8)} \qquad \frac{\dot{\lambda}_t}{\lambda_t} = \rho + n - r_t - \frac{\dot{p}_t}{p_t},$$

where $r_t \equiv MF_k(k_t, 1)$, is the marginal physical product of capital, and k_t is the capital-labor ratio. Restricting our analysis to steady states in per capita terms (so $\dot{\lambda}_t = \dot{p}_t = 0$), the Euler equation implicitly defines the capital-labor ratio as a function of the level of technology in the nonagricultural sector as

$$\text{(A9)} \qquad k^*(M), \text{ with } \frac{dk^*}{dM} = -\frac{F_k}{MF_{kk}} > 0.$$

Combining (10), (A5), (A6), and (A9), we reach the counterpart of (11) that determines the steady-state allocation of labor across sectors,

$$\text{(A10)} \quad \frac{\gamma}{A} = (k^*(M))^{\theta} l^A - \alpha\left[(k^*(M))^{\theta}(1 - l^A) + \frac{\mu}{M}\right] = \phi(l^A, M),$$

where $l^A \equiv \frac{L^A}{L}$ is the share of labor employed in agriculture. Since[24]

$$\text{(A11)} \qquad \phi_{l^A} = (1 + \alpha)(k^*(M))^{\theta} > 0$$

$$\phi_M = a(k^*(M))^{\theta-1}\left[l^A - \alpha(1 - l^A)\right]\frac{dk^*}{dM} + \alpha\frac{\mu}{M^2} > 0,$$

$\partial l^A/\partial M < 0$ and $\partial l^A/\partial A < 0$.

Finally, differentiating (A6) gives the responses of the steady-state relative price to changes in the level of technology in each sector as

$$\text{(A12)} \qquad \frac{\partial p^*}{\partial A} = \frac{1}{M} > 0 \text{ and } \frac{\partial p^*}{\partial M} = -\frac{A}{M^2} < 0.$$

Now, let us turn to the other limiting case, where $\theta_M = \theta > \theta_A = 0$. Using (A2), we obtain the following aggregate budget constraint:

$$\text{(A13)} \qquad \left(\dot{K}_t + C_t^M\right)p_t + C_t^A = p_t M(K_t)^{\theta}\left(L_t^M\right)^{1-\theta} + AL_t^A.$$

The counterpart of (A8) implies that the steady-state level of capital is implicitly defined by $MF_k(k^*, 1 - l^A) = \rho + n$, with the following comparative statics:

$$\text{(A14)} \quad k^*\left(M, l^A\right), \text{ with } \frac{\partial k^*}{\partial M} = -\frac{F_k}{MF_{kk}} > 0 \text{ and } \frac{\partial k^*}{\partial l^A} = \frac{F_{kl}}{F_{kk}} < 0.$$

As in the previous case, the steady-state labor allocation is implicitly defined by

$$\text{(A15)} \quad \frac{\gamma}{A} = l^A - \alpha\frac{(1 - l^A)^{\theta}}{(1 - \theta)(k^*(M, l^A))^{\theta}}\left[(k^*(M, l^A))^{\theta}(1 - l^A)^{1-\theta} + \frac{\mu}{M}\right] = \phi(l^A, M),$$

[24] The sign of the last partial derivative results from the fact that $\gamma/A > 0$ and $\mu/M > 0$, implying that $(k^*(M))^{\theta} l^A > \alpha(k^*(M))^{\theta}(1 - l^A)$, and therefore $l^A > \alpha(1 - l^A)$.

where[25]

$$\text{(A16)} \qquad \phi_{l^A} = 1 + \frac{\alpha}{(1 - \theta)} > 0$$

$$\phi_M = \frac{a\mu(1 - l^A)^\theta}{(1 - \theta)\left(M(k^*)^\theta\right)^2}\left((k^*)^\theta + \theta M (k^*)^{\theta-1}\frac{\partial k^*}{\partial M}\right) > 0.$$

As a result, $\partial l^A/\partial M < 0$ and $\partial l^A/\partial A < 0$, as in the model that abstracts from capital.

Combining (A4) with (A14), we reach the following expression for the steady-state relative price:

$$\text{(A17)} \quad p^* = \frac{A}{(1 - \theta) M(k^*(M,l^A))^\theta (1 - l^A)^{-\theta}} = \frac{A}{MF_L[k^*(M,l^A),(1 - l^A)]},$$

with the following comparative statics[26]

$$\text{(A18)} \qquad \frac{\partial p^*}{\partial A} = \frac{1}{(1 - \theta) M (k^*)^\theta (1 - l^A)^{-\theta}} > 0$$

$$\frac{\partial p^*}{\partial M} = -\frac{A(1 - \theta) M (1 - l^A)^{-\theta}}{((1 - \theta) M (k^*)^\theta (1 - l^A)^{-\theta})^2}\left((k^*)^\theta + \theta (k^*)^{\theta-1}\frac{\partial k^*}{\partial M}\right) < 0.$$

Given (A11), (A16), (A12), and (A18), the sign of the response of the steady-state labor allocation and the relative price to changes in the productivity parameters are consistent with the ones we obtained in the model that abstracts from capital accumulation.

[25] Notice that we can write the last term of (A15) as $\Psi(M,l^A) \equiv \alpha\mu/[MF_l(k^*(M,l^A),1 - l_A)]$, with $\partial\Psi/\partial l^A = -\alpha\mu M(F_l)^{-2}(F_{lk}\,\partial k^*/\partial l^A - F_{ll}) = 0$. This last equality uses (A14) and the fact that any function of two variables that is homogeneous of degree one satisfies $F_{kk}F_{ll} - (F_{lk})^2 = 0$.

[26] Since $p^* = A/[MF_l(k^*(M,l^A),(1 - l^A))]$, the first expression is

$$\frac{\partial p^*}{\partial A} = \left[MF_l - AM\left(F_{lk}\frac{\partial k^*}{\partial l^A}\frac{\partial l^A}{\partial A} - F_{ll}\frac{\partial l^A}{\partial A}\right)\right]\Big/(MF_l)^2 = \frac{1}{MF_l}$$

since

$$F_{lk}\frac{\partial k^*}{\partial l^A}\frac{\partial l^A}{\partial A} - F_{ll}\frac{\partial l^A}{\partial A} = \frac{\partial l^A}{\partial A}\left(F_{lk}\frac{\partial k^*}{\partial l^A} - F_{ll}\right) = \frac{\partial l^A}{\partial A}\left(F_{lk}\frac{F_{lk}}{F_{kk}} - F_{ll}\right) = 0,$$

and the second expression is

$$\frac{\partial p^*}{\partial M} = -\frac{A}{(MF_l)^2}\left(F_l + M\left[F_{lk}\left(\frac{\partial k^*}{\partial M} + \frac{\partial k^*}{\partial l^A}\frac{\partial l^A}{\partial M}\right) - F_{ll}\frac{\partial l^A}{\partial M}\right]\right) = -\frac{A}{(MF_l)^2}\left(F_l + MF_{lk}\frac{\partial k^*}{\partial M}\right)$$

since

$$F_{lk}\left(\frac{\partial k^*}{\partial M} + \frac{\partial k^*}{\partial l^A}\frac{\partial l^A}{\partial M}\right) - F_{ll}\frac{\partial l^A}{\partial M} = F_{lk}\frac{\partial k^*}{\partial M} + \frac{\partial l^A}{\partial M}\left[F_{lk}\frac{\partial k^*}{\partial l^A} - F_{ll}\right] = F_{lk}\frac{\partial k^*}{\partial M}.$$

B. *Basic Results under CES Preferences*

The empirical evidence on the income elasticity of food demand uncontroversially implies that $\gamma > 0$. Using a general CES utility function, this Appendix shows that our results do not rely on the assumption that $\mu > 0$, which is used to simplify the exposition in the main text.

Assume that preferences of our representative household are given by

$$U\left(c_t^A, c_t^M\right) = \left[\left(1 - \eta\right)^{\frac{1}{\nu}}\left(c_t^A - \gamma\right)^{\frac{\nu-1}{\nu}} + \eta^{\frac{1}{\nu}}\left(c_t^M\right)^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{1-\nu}}, \quad \alpha > 0; \nu > 0,$$

where c_t^A and c_t^M denote individual consumption of food and nonagricultural goods, respectively; η is the relative weight of nonagricultural goods in preferences; and ν is the elasticity of substitution between the two types of good. Under this preference, specification (11) becomes

$$\frac{\gamma}{A} = G(L_t^A) - \frac{1 - \eta}{\eta}\left(\frac{A}{M}\right)^{\nu-1}\left[\frac{G'(L_t^A)}{F'(1 - L_t^A)}\right]^{\nu} F(1 - L_t^A) \equiv \phi^{CES}(L_t^A, M, A),$$

with

$$\phi^{CES}\left(L_t^A, M, A\right) < \phi^{CES}(1, M, A) = G(1); \quad \phi_{L_t^A} > 0.$$

On the one hand, the labor pull hypothesis requires $\phi_M^{CES} > 0$, which implies that the elasticity of substitution has to exceed unity, $\nu > 1$.[27] On the other hand, since $\text{sign}\,(\phi_M^{CES}) = -\text{sign}\,(\phi_A^{CES})$, the labor push hypothesis requires that $\nu > 1$ is not too large.[28] If these two restrictions on the degree of substitutability between agricultural and nonagricultural goods hold, then all the results presented in Section I are valid under this preference specification that abstracts from μ. In addition, as in Ngai and Pissarides (2007) differential productivity growth across sectors results in structural change even when the last source of non-homotheticity, $\gamma = 0$, is removed.[29] The intuition for this result is as follows. If the elasticity of substitution ν is above 1, an increase in M reduces the price of the nonagricultural good, and since both goods are good substitutes, induces a more than proportional increase in its demand that leads to a reallocation of labor to the nonagricultural sector. An increase in agricultural productivity reduces the price of food, causing opposing income and substitution effects. The substitution effect tends to raise food demand, while the income effect implies a reduced food expenditure share because the income elasticity of food is less than one. Our second restriction on the size of ν ensures that the income effect dominates the substitution effect, and, therefore, an increase in A is associated with a reduction in the agricultural labor force.

[27] Moreover, an elasticity of substitution below 1, as in Ngai and Pissarides (2007), allows for structural change out of agriculture only by faster productivity growth in agriculture compared to manufacturing. But this clashes with the evidence for the period before World War II, in which most structural change took place.

[28] Specifically, we need $\gamma - \left((1 - \eta)/\eta\right)\,(\nu - 1)\,[AG'\,(L_t^A)/MF'\,(1 - L_t^A)]^{\nu}\,MF\,(1 - L_t^A) > 0$. This inequality holds for sufficiently small values of $\nu > 1$.

[29] Nonetheless, when $\gamma = 0$, only the labor pull hypothesis would be consistent with the path of migrations observed in the data. This is because our restrictions on ν imply that an increase in agricultural productivity leads to an increase in the share of labor employed in this sector.

C. *The Measure of the Manufacturing Price*

This Appendix shows that p_y/p_a changes with changes in relative productivity of the two sectors in the same way as p_m/p_a does, even with non-homothetic utility. For this, first derive the correct consumption-based aggregate price index. With non-homothetic preferences, this requires some precision because the marginal expenditure needed to raise utility by one unit is not constant and, therefore, does not coincide with the average expenditure per unit of utility. (This distinguishes this setup from e.g., a setup with Dixit-Stiglitz preferences, where such a consumption-based price index is often used, and where the two concepts coincide.)

Let P be the marginal expenditure needed to raise utility by one unit beyond $\overline{u}$ and $\overline{P}$ the minimum expenditure needed to reach utility $\overline{u}$. $\overline{P}$ solves the problem

$$\min_{c_a, c_m} p_a c_a + p_m c_m$$
$$\text{s.t. } \beta \ln(c_a - \gamma) + \ln(c_m + \mu) = \overline{u}.$$

P is the multiplier on the constraint. The first-order conditions are

$$p_m = \frac{P}{c_m + \mu} \qquad \text{(C1)}$$
$$p_a = \frac{\beta P}{c_a - \gamma}.$$

Plugging this into the constraint and solving for P yields

$$P = \beta^{-\frac{\beta}{1+\beta}} \left[\exp(\overline{u})\right]^{\frac{1}{1+\beta}} p_m^{\frac{1}{1+\beta}} p_a^{\frac{\beta}{1+\beta}}.$$

Using this,

$$\frac{P}{p_a} = \beta^{-\frac{\beta}{1+\beta}} \left[\exp(\overline{u})\right]^{\frac{1}{1+\beta}} \left(\frac{p_m}{p_a}\right)^{\frac{1}{1+\beta}}. \qquad \text{(C2)}$$

Clearly, $\ln(P/p_a)$ varies proportionally with $\ln(p_m/p_a)$.

Obtain $\overline{P}$ by evaluating the objective function at the optimum:

$$\text{(C3)} \qquad \overline{P} = p_m c_m + p_a c_a = (1 + \beta) P - p_m \mu + p_a \gamma$$
$$= (1 + \beta) \beta^{-\frac{\beta}{1+\beta}} \left[\exp(\overline{u})\right]^{\frac{1}{1+\beta}} p_m^{\frac{1}{1+\beta}} p_a^{\frac{\beta}{1+\beta}} - p_m \mu + p_a \gamma$$
$$\frac{\overline{P}}{p_a} = (1 + \beta) \beta^{-\frac{\beta}{1+\beta}} \left[\exp(\overline{u})\right]^{\frac{1}{1+\beta}} \left(\frac{p_m}{p_a}\right)^{\frac{1}{1+\beta}} - \frac{p_m}{p_a}\mu + \gamma .$$

Then,

$$\frac{\partial(\overline{P}/p_a)}{\partial(p_m/p_a)} = \beta^{-\frac{\beta}{1+\beta}} \left[\left(\frac{\beta P}{p_a}\right)^{\beta} \frac{P}{p_m}\right]^{\frac{1}{1+\beta}} \left(\frac{p_m}{p_a}\right)^{\frac{1}{1+\beta}-1} - \mu = \frac{P}{p_m} - \mu = c_m > 0.$$

Hence, p_y/p_a moves in the same direction as p_m/p_a no matter whether the historical price indices we use measure average or marginal expenditure.

REFERENCES

Alvarez-Cuadrado, and Markus Poschke. 2011. "Structural Change out of Agriculture: Labor Push versus Labor Pull: Dataset." *American Economic Journal: Macroeconomics*. http://www.aeaweb.org/articles.php?doi=10.1257/mac.3.3.127.

Bairoch, Paul. 1968. *The Working Population and Its Structure.* Brussels: Universite Libre de Bruxelles, Editions de l'Institut de Sociologie.

Bencivenga, Valerie R., and Bruce D. Smith. 1997. "Unemployment, Migration, and Growth." *Journal of Political Economy*, 105(3): 582–608.

Boskin, Michael J., Ellen R. Dulberger, Robert J. Gordon, Zvi Griliches, and Dale W. Jorgenson. 1998. "Consumer Prices, the Consumer Price Index, and the Cost of Living." *Journal of Economic Perspectives*, 12(1): 3–26.

Caselli, Francesco. 2005. "Accounting for Cross-Country Income Differences." In *Handbook of Economic Growth*, Vol 1A, ed. Philippe Aghion and Steven N. Durlauf, 679–724. Amsterdam: Elsevier B.V.

Caselli, Francesco, and Wilbur John Coleman II. 2001. "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation." *Journal of Political Economy*, 109(3): 584–616.

Chenery, Hollis B., and Moises Syrquin. 1975. *Patterns of Development, 1950–1970.* London: Oxford University Press.

Clark, Colin. 1940. *The Conditions of Economic Progress.* 3rd ed. London: Macmillan.

Cole, Harold L., and Lee E. Ohanian. 1999. "The Great Depression in the United States from a Neoclassical Perspective." *Federal Reserve Bank of Minneapolis Quarterly Review*, 23(1): 2–24.

Cole, Harold L., and Lee E. Ohanian. 2002. "The U.S. and U.K. Great Depressions through the Lens of Neoclassical Growth Theory." *American Economic Review*, 92(2): 28–32.

Craig, Lee A., and Thomas Weiss. 2000. "Hours at Work and Total Factor Productivity Growth in Nineteenth-Century U.S. Agriculture." In *New Frontiers in Agricultural History*, ed. Kyle D. Kauffman, 1–30. Advances in Agricultural Economic History, Vol. 1. Stamford, CT: JAI Press.

Dennis, Benjamin N., and Talan B. İşcan. 2009. "Engel versus Baumol: Accounting for Structural Change Using Two Centuries of U.S. Data." *Explorations in Economic History*, 46(2): 186–202.

Duarte, Margarida, and Diego Restuccia. 2010. "The Role of the Structural Transformation in Aggregate Productivity." *Quarterly Journal of Economics*, 125(1): 129–73.

Federico, Giovanni. 2004. "The Growth of World Agricultural Production, 1800–1938." In *Research in Economic History*. Vol. 22, ed. Alexander J. Field, 125–81. Oxford, UK: Elsevier.

Federico, Giovanni. 2005. *Feeding the World: An Economic History of Agriculture, 1800–2000*, Princeton Economic History of the Western World. Princeton, NJ: Princeton University Press.

Foster, Andrew D., and Mark R. Rosenzweig. 2007. "Economic Development and the Decline of Agricultural Employment." In *Handbook of Development Economics*, Vol. 4, ed. T. Paul Schultz and John Strauss, 3051–83. Amsterdam: Elsevier B.V.

Gallman, Robert E. 1972. "Changes in Total U.S. Agricultural Factor Productivity in the Nineteenth Century." In *Farming in the New Nation: Interpreting American Agriculture, 1790–1840*, ed. Darwin P. Kelsey, 191–210. Washington, DC: Agricultural History Society.

Gollin, Douglas. 2002. "Getting Income Shares Right." *Journal of Political Economy*, 110(2): 458–74.

Gollin, Douglas, Stephen Parente, and Richard Rogerson. 2002. "The Role of Agriculture in Development." *American Economic Review*, 92(2): 160–64.

Gollin, Douglas, Stephen L. Parente, and Richard Rogerson. 2007. "The Food Problem and the Evolution of International Income Levels." *Journal of Monetary Economics*, 54(4): 1230–55.

Greenwood, Jeremy, Zvi Hercowitz, and Per Krusell. 1997. "Long-Run Implications of Investment-Specific Technological Change." *American Economic Review*, 87(3): 342–62.

Griliches, Zvi. 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica*, 25(4): 501–22.

Gylfason, Thorvaldur, and Gylfi Zoega. 2006. "The Road from Agriculture." In *Institutions, Development, and Economic Growth*, ed. Theo S. Eicher and Cecilia Garcia-Penalosa, 249–79. CESifo Seminar. Cambridge, MA: Cambridge University Press.

Hansen, Gary D., and Edward C. Prescott. 2002. "Malthus to Solow." *American Economic Review*, 92(4): 1205–17.

Harris, John R., and Michael P. Todaro. 1970. "Migration, Unemployment and Development: A Two-Sector Analysis." *American Economic Review*, 60(1): 126–42.

Hayami, Yujiro, and Vernon W. Ruttan. 1985. *Agricultural Development: An International Perspective*. Baltimore: Johns Hopkins University Press.

Hayashi, Fumio, and Edward C. Prescott. 2008. "The Depressing Effect of Agricultural Institutions on the Prewar Japanese Economy." *Journal of Political Economy*, 116(4): 573–632.

Heisenberg, Werner. 1972. *Physics and Beyond: Encounters and Conversations*. New York: Harper & Row.

Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi. 2009. "Two Perspectives on Preferences and Structural Transformation." National Bureau of Economic Research Working Paper 15416.

Houthakker, H. S. 1957. "An International Comparison of Household Expenditure Patterns, Commemorating the Centenary of Engel's Law." *Econometrica*, 25(4): 532–51.

Jorgenson, Dale W., Frank M. Gallop, and Barbara M. Fraumeni. 1987. *Productivity and U.S. Economic Growth*. Cambridge, MA: Harvard University Press.

Kendrick, John W. 1961. *Productivity Trends in the United States*. Princeton, NJ: Princeton University Press.

Kongsamut, Piyabha, Sergio Rebelo, and Danyang Xie. 2001. "Beyond Balanced Growth." *Review of Economic Studies*, 68(4): 869–82.

Krugman, Paul. 1991. "History versus Expectations." *Quarterly Journal of Economics*, 106(2): 651–67.

Kuznets, Simon S. 1966. *Modern Economic Growth: Rate, Structure and Spread*. New Haven, CT: Yale University Press.

Laitner, John. 2000. "Structural Change and Economic Growth." *Review of Economic Studies*, 67(3): 545–61.

Lewis, W. Arthur. 1954. "Economic Development with Unlimited Supplies of Labour." *Manchester School*, 22(2): 139–91.

MacLeod, W. Bentley, and James M. Malcomson. 1998. "Motivation and Markets." *American Economic Review*, 88(3): 388–411.

Maddison, Angus. 1995. *Monitoring the World Economy: 1820–1992*. Paris: OECD Development Centre.

Maddison, Angus. 2001. *The World Economy: A Millennial Perspective*. Paris: OECD Development Centre.

Maddison, Angus. 2009. *Statistics on World Population, GDP and Per Capita GDP, 1–2006 AD*. Unpublished.

Magnac, Thierry, and Gilles Postel-Vinay. 1997. "Wage Competition between Agriculture and Industry in Mid-Nineteenth Century France." *Explorations in Economic History*, 34(1): 1–26.

Matsuyama, Kiminori. 1992. "Agricultural Productivity, Comparative Advantage, and Economic Growth." *Journal of Economic Theory*, 58(2): 317–34.

Matsuyama, Kiminori. 2009. "Structural Change in an Interdependent World: A Global View of Manufacturing Decline." *Journal of the European Economic Association*, 7(2–3): 478–86.

Mitchell, Brian R. 1988. *British Historical Statistics*. Cambridge, MA: Cambridge University Press.

Mitchell, B. R. 2003a. *International Historical Statistics: Africa, Asia & Oceania, 1750–2000.* 4th ed. New York: Palgrave Macmillan.

Mitchell, B. R. 2003b. *International Historical Statistics: Europe, 1750–2000.* 5th ed. New York: Palgrave Macmillan.

Mitchell, B. R. 2003c. *International Historical Statistics: The Americas, 1750–2000.* 5th ed. New York: Palgrave Macmillan.

Mundlak, Yair. 2000. *Agriculture and Economic Growth: Theory and Measurement*. Cambridge, MA: Harvard University Press.

Mundlak, Yair, and Donald F. Larson. 1992. "On the Transmission of World Agricultural Prices." *World Bank Economic Review*, 6(3): 399–422.

Ngai, L. Rachel, and Christopher A. Pissarides. 2007. "Structural Change in a Multisector Model of Growth." *American Economic Review*, 97(1): 429–43.

Nurkse, Ragnar. 1953. *Problems of Capital Formation in Underdeveloped Countries*. New York: Oxford University Press.

Olmstead, Alan L., and Paul W. Rhode. 2001. "Reshaping the Landscape: The Impact and Diffusion of the Tractor in American Agriculture, 1910–1960." *Journal of Economic History*, 61(3): 663–98.

Prescott, Edward C. 1999. "Some Observations on the Great Depression." *Federal Reserve Bank of Minneapolis Quarterly Review*, 23(1): 25–31.

Restuccia, Diego, Dennis Tao Yang, and Xiaodong Zhu. 2008. "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis." *Journal of Monetary Economics*, 55(2): 234–50.

Rostow, W. W. 1960. *The Stages of Economic Growth: A Non-Communist Manifesto*. Cambridge, UK: Cambridge University Press.

Satchi, Mathan, and Jonathan Temple. 2009. "Labor Markets and Productivity in Developing Countries." *Review of Economic Dynamics*, 12(1): 183–204.

Schultz, Theodore W. 1953. *The Economic Organization of Agriculture*. New York: McGraw-Hill.

Smits, Jan-Pieter, Pieter Woltjer, and Debin Ma. 2009. "A Dataset on Comparative Historical National Accounts, ca. 1870–1950: A Time-Series Perspective." Groningen Growth and Development Centre Research Memorandum GD-107.

Sokoloff, Kenneth L. 1986. "Productivity Growth in Manufacturing during Early Industrialization: Evidence from the American Northeast, 1820–1860." In *Long-Term Factors in American Economic Growth*, ed. Stanley L. Engerman and Robert E. Gallman, 679–729. Studies in Income and Wealth, Vol. 51. Chicago: University of Chicago Press.

Spulber, Nicolas. 2003. *Russia's Economic Transitions: From Late Tsarism to the New Millennium*. Cambridge, UK: Cambridge University Press.

Temple, Jonathan, and Ludger Wossmann. 2006. "Dualism and Cross-Country Growth Regressions." *Journal of Economic Growth*, 11(3): 187–228.

Timmer, Marcel, and Gaaitzen de Vries. 2007. "A Cross-Country Database For Sectoral Employment and Productivity in Asia and Latin America, 1950–2005." Groningen Growth and Development Centre Research Memorandum GD-98.

van Ark, Bart. 1996. "Sectoral Growth Accounting and Structural Change in Post-War Europe." In *Quantitative Aspects of Post-war European Economic Growth*, ed. Bart van Ark and Nicholas Crafts, 84–164. Cambridge, UK: Cambridge University Press.

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