Structural change out of Agriculture: Labor Push versus Labor Pull*

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Abstract

A declining employment share of agriculture is a key feature of economic development. Its main drivers are: (i) improvements in agricultural technology combined with Engel's law release resources from agriculture ("labor push"), (ii) improvements in industrial technology attract labor out of agriculture ("labor pull"). We present a model with both channels and evaluate their importance using the U.S. time series since 1800 and a sample of 11 industrialized countries starting in the 19th century. Results suggest that, the "pull" channel dominated until about World War II, with the "push" channel dominating afterwards. In addition, the "pull" channel matters more in countries in early stages of the structural transformation. This contrasts with popular modeling choices in recent literature.

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"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 Heisenberg (1972, p. 63).

1 Introduction

The process of economic development is always and everywhere characterized by substantial reallocations of resources out of agriculture. 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 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 19th century onwards.[1]

Already Clark (1940), Kuznets (1966) and Chenery and 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 U.S. 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% of the labor force remained in the agricultural sector and the share of agricultural production in GDP was close to 1%. Over these two centuries, U.S. 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 roles 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. Lewis (1954) presents a model where capital accumulation in the modern sector raises urban wages and attracts surplus labor

[1] 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 non-agricultural sector.

from the agricultural sector. Reinvestment of profits keeps the process going. Similarly, Harris and 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 Gylfason and Zoega (2006) we refer to this as the "labor pull" hypothesis.[2] Hansen and 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. Nurkse (1953) argues that "everyone knows that the spectacular industrial revolution would not have been possible without the agricultural revolution that preceded it". Rostow (1960) identifies increases in agricultural productivity as a necessary condition for a successful take-off. These authors suggest that improvements in agricultural technology allow solving the "food problem" (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, Gollin, Parente and Rogerson (2002, 2007) provide 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 Ngai and Pissarides (2007).

Our objective is to provide empirical evidence on the relative importance of the "push"

[2] Additional work in this tradition has been conducted by Bencivenga and Smith (1997), MacLeod and Malcomson (1998) and Satchi and 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-intesive, 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.

and “pull” hypotheses. We present a simple model close to Matsuyama (1992) and to Kongsamut, Rebelo and 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. A recent example is Greenwood, Hercowitz and Krusell (1997).

We then explore the determinants of structural change using data on relative prices and on agricultural employment shares for the U.S. since 1800 and for a long panel of 11 industrialized countries starting in the 19th century. Since for the U.S., 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.

There are four main findings. Firstly, there is a lot of heterogeneity; both channels play a role. For instance, in the case of the U.S. 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. Secondly, driven by faster productivity growth, structural change accelerated during the 20^{th} 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, the relative price also indicates faster technological change in manufacturing from 1800 to 1960 and in countries with an employment share in agriculture above 10%. 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 U.S.. The importance of time periods in our results suggests the presence of common trends in technology, most plausibly 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 hence 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 non-agricultural 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 non-agricultural 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 Caselli (2005), Temple and Woessmann (2006) and Restuccia, Yang and 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 Hayashi and Prescott (2008) and by Foster and 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 non-farm activities.

The paper is organized as follows. Section 2 sets out the basic model and explores the implications of increases in agricultural and manufacturing productivity. Section 3 presents data sources, and Section 4 evaluates the model against the U.S. experience. Section 5 explores the determinants of structural change in a long panel of 11 industrialized countries. The conclusions are summarized in Section 6, while the Appendices provide some technical details and data descriptions.

2 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.[3] Both production technologies exhibit weakly diminishing returns to labor,

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

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

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 non-arbitrage condition holds:[4]

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

[3] In Appendix A 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.

[4] 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, Magnac and Postel-Vinay (1997) provide evidence from 19th 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, 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 Krugman (1991).

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

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

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

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

where c_t^A and c_t^M denote individual consumption of food and non-agricultural goods, respectively, and α the relative weight of food in preferences. These preferences are non-homothetic 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 Houthakker (1957). This feature of preferences has long been emphasized in the literature on sectoral reallocation (Matsuyama 1992, Laitner 2000, Caselli and Coleman 2001, Gollin et al. 2002). Second, we assume that the income elasticity of non-agricultural goods is greater than one. Following Kongsamut et al. (2001) we can interpret μ as an exogenous endowment of non-agricultural goods, possibly resulting from home production.[5] 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.[6] Together with

[5] 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 et al. (2001) and Duarte and Restuccia (2010). In Appendix B, we introduce a generalized CES specification that yields identical results when $\mu = 0$. Nonetheless we believe that our exposition is clearer under (5).

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

(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

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

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.

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

where

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

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:

$$\frac{\partial L^{A*}}{\partial A} = -\frac{\gamma}{A^2 \phi^*_{L^A}} < 0 \tag{13}$$

$$\frac{\partial L^{A*}}{\partial M} = -\frac{\phi^*_M}{\phi^*_{L^A}} < 0, \tag{14}$$

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 et al. (2002), increases in the level of agricultural productivity push labor out of the agricultural sector: 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 non-agricultural 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 non-agricultural sector.[7]

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 non-agricultural to agricultural output,

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

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,

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

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

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

[7] 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.

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 non-agricultural good, increases in the level of productivity in the modern sector, M, reduce the relative price of non-agricultural goods. Thus, while the evolution of wages, labor allocations or sectoral output shares provides 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 et al. (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 non-agricultural 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.

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

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 non-agricultural sector, i.e. they indicate that the "labor pull" effect dominates. If the relative price rises, the situation is less clear. An equal increase in both sectors' productivities 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 a 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 slightly more.[8]

In the remainder of the paper, we explore the importance of the "push" and "pull" channels in the U.S. 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.

[8]The interpretation is different in a small open economy (see e.g. Matsuyama 1992, 2009), which is discussed in Section 5.3.

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 U.S. and other countries' experience in the light of the model.

3 Historical data

Structural change out of agriculture is a long-run phenomenon that in some countries started as early as the 17th 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%),[9] 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 U.S. 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 Mitchell (1988, 1998, 2003) and the Groningen Growth and Development Centre (GGDC) 10-sector and Historical National Accounts databases (for documentation, see van Ark 1996, Timmer and de Vries 2007, Smits, Woltjer and Ma 2009).[10] 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 Bairoch 1968) up to 1960 and then on national statistical yearbooks. The GGDC databases are intended "to bring together the available, but fragmented, data on GDP at the industry level for all major economies and to standardise these series to make a consistent long run international comparison of output and productivity feasible" (Smits et al. 2009). These sectoral national accounts use price indices for sectoral value added,

[9] This threshold was reached by the UK as soon as 1891, by Canada in 1951, and by the U.S. in 1955.
[10] Data is available at `http://www.ggdc.net`.

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, which we use in the empirical analysis.[11] For more detail on these and additional sources, see Appendix D.

Unfortunately, the price index for value added in agriculture is not available for the U.S.. In 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 U.S.. In principle, however, value added prices are preferable for our purpose, as they net out the contribution of intermediate goods.[12]

The fact that the type of price index differs between the U.S. and the remaining countries forces us to analyze them separately. Indeed, Herrendorf, Rogerson and Valentinyi (2009) show that, 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 U.S. separately has the further advantage that for the U.S., historical sectoral TFP series are available and can be used as a check on our model's predictions before taking them to a broader data set.

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 19th and early 20th century, several countries (e.g. the U.S. 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 U.S. PPI in the 19th century), and did not use theoretically well-founded

[11] While this is not exactly the same as the relative price p_m/p_a used in the model, Appendix C 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 non-agricultural goods. (This would of course be obvious with homothetic preferences.)

[12] Where, as in the U.S., 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.

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 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.[13]

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 5. Remaining 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

[13]While the data requirements for computing value added prices are also non-trivial (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.

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 multi-stage 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 5. 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 non-agricultural goods, could imply that increases in the relative price of manufacturing goods are overstated, and the trends we find have to be corrected downwards. Without this correction, there is a bias against finding a "pull" channel. Quantitatively, the Boskin Commission report argues that the U.S. CPI overstated inflation by around 1.1 percentage points in 1995-96 (see e.g. Boskin, Dulberger, Gordon, Griliches and Jorgenson 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 thus is not resolved with precision, we can still conclude that observing a period of falling non-agricultural goods prices robustly indicates a dominant pull channel, while this is not so clear for the opposite case. Finally, while in theory 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 U.S. (Dennis and Iscan 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.

4 A long-term view of structural change in the U.S.

Although large migrations out of the agriculture began in the UK more than two centuries ago, the U.S. was one of the first countries to complete this process of structural transformation. Furthermore, the wealth and quality of the U.S. 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 non-agricultural sector has increased at a faster pace than agricultural productivity.

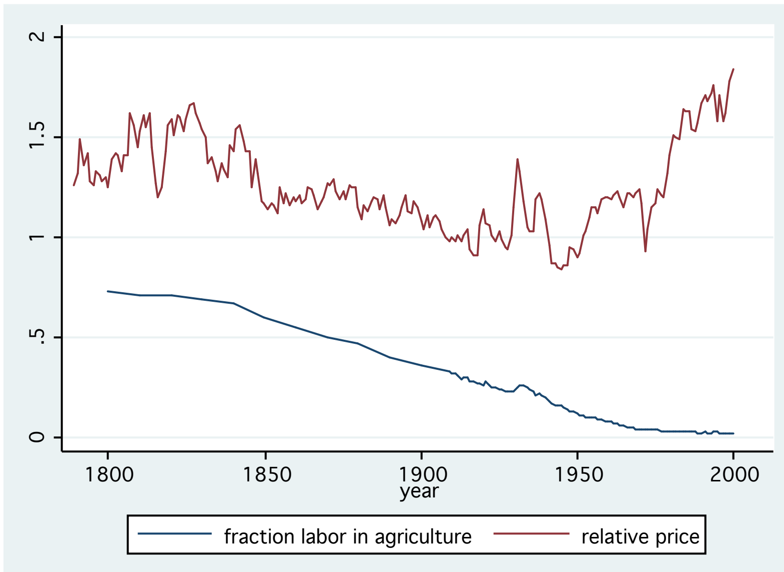
Figure 1 presents the evolution of the share of employment in agriculture L^A and the relative price of manufactures to agricultural goods p for the U.S. from 1790 (for p) and 1800 (for L^A) to 2000. Over these two centuries, the share of labor employed in agriculture declined from 73% to barely 2.5%. This decline was monotonic, except for the period of the Great Depression.[14] In contrast, there 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 implies that non-agricultural 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 non-farm productivity in the U.S..[15] 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 growth rate in the non-farm sector outstrips that in the farm sector by 1.7% versus 0.8% 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 non-farm sector is 1.4%, compared to 1.7% in the farm sector. The rapidly increasing adoption rates of tractors and of hybrid corn (Griliches 1957, Olmstead and 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

[14]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 Cole and Ohanian (1999, 2002). Their estimates suggest a 14% 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.

[15]See notes to Figure 2 for sources.

Figure 1: The share of employment in agricultural and the relative price of manufactures to agricultural goods, U.S., 1790/1800-2000



Sources: See Section 3 and Appendix D.

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.

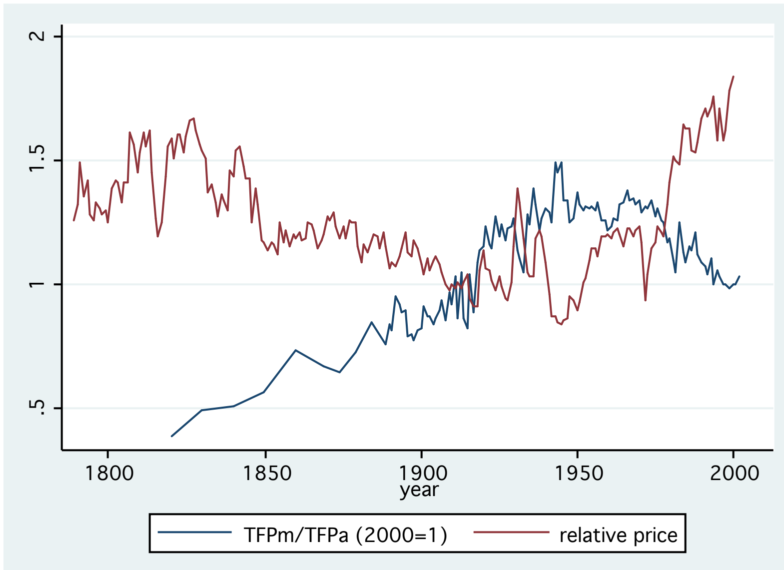
5 Historical evidence from some successful transformers

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

5.1 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 U.S.), our data cover

Figure 2: Relative productivity (2000=1) and relative price of non-farm and farm goods, U.S., 1820-2000



Sources: U.S. farm productivity is from Gallman (1972, Table 7) for 1800-1840, from Craig and Weiss (2000, Table 3) for 1840-1870 (both cited in Dennis and Iscan 2009), from Kendrick (1961, Table B-I) for 1869-1948, and from the United States Department of Agriculture (USDA) Economic Research Service, Agricultural Productivity Data Set, `http://www.ers.usda.gov/Data/AgProductivity/`, for 1948-2000. Non-farm productivity is from Sokoloff (1986, Table 13.9) for 1820-1860 (again cited in Dennis and Iscan 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.

essentially the whole process of structural change, with initial agricultural employment shares in the neighborhood of 80%. For the remaining ones (Belgium, Canada, France, Germany, the Netherlands and the UK), 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

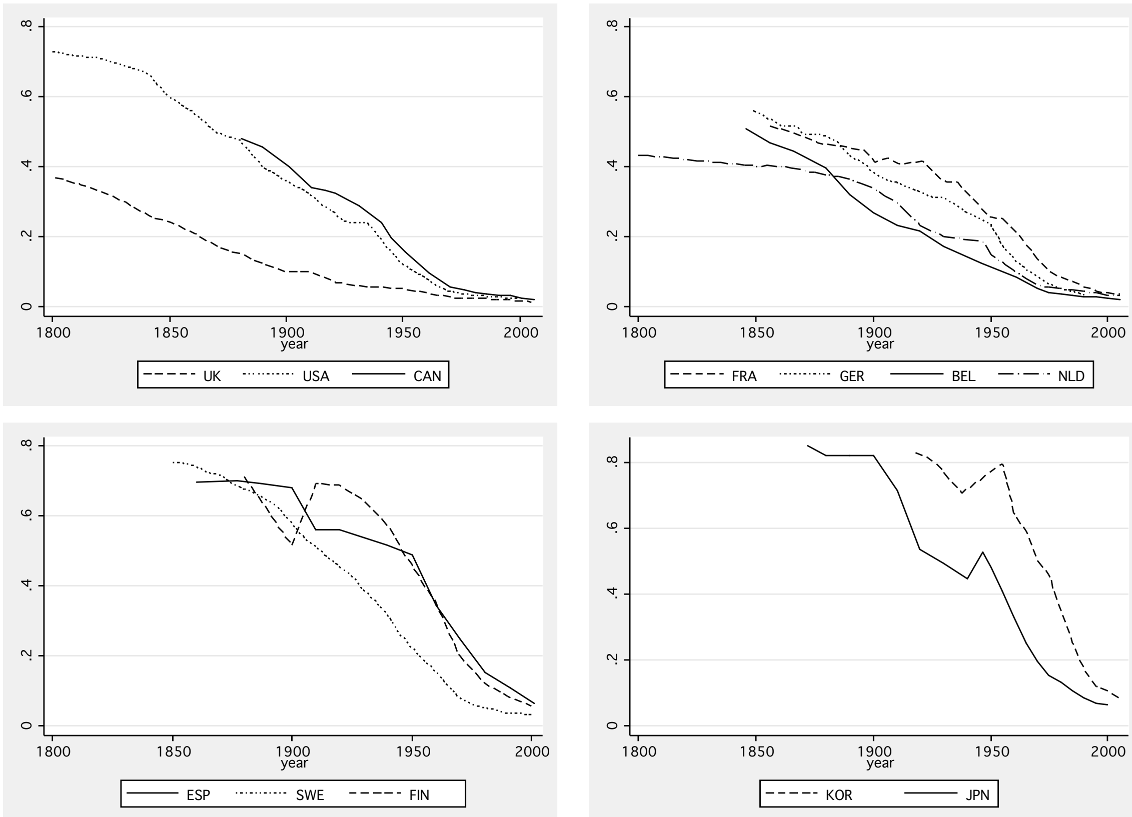


Figure 3: The employment share of agriculture

events. Clearly, the UK (top left panel) was the first country to experience substantial structural change, with an employment share in agriculture below 50% as early as 1800. At that time, the U.S. agricultural share was still above 75%. 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

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 5-year moving averages where observations 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 3 and Appendix D.

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 UK 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 around 108 years to reduce the agricultural employment share from 60%, the average employment share at the beginning of our sample, to 20%.

In addition, Table 1 reveals that on average, structural change was faster in recent periods.[16] Given that growth in output per capita in the countries in our sample was

[16]Note that this acceleration is all the more remarkable as levels of L^A fall over time towards zero,

Table 2: Average annual growth rate of output per capita, 1820-2000

	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%

Notes: Source: Maddison (2009), `http://www.ggdc.net/maddison/`. The average is unweighted across countries.

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 indicate a higher growth rate of aggregate TFP 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.

5.2 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 non-agricultural 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. 60% of price changes over 5-year intervals are increases. The fact that price

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 UK and the U.S.. Still, the trend is not purely due to sample selection.

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, the relative price is plotted in Figure 4 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 1 at the date of the first observation in each country. Note also that in some countries, there are two disjoint series for the relative price.[17] 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.

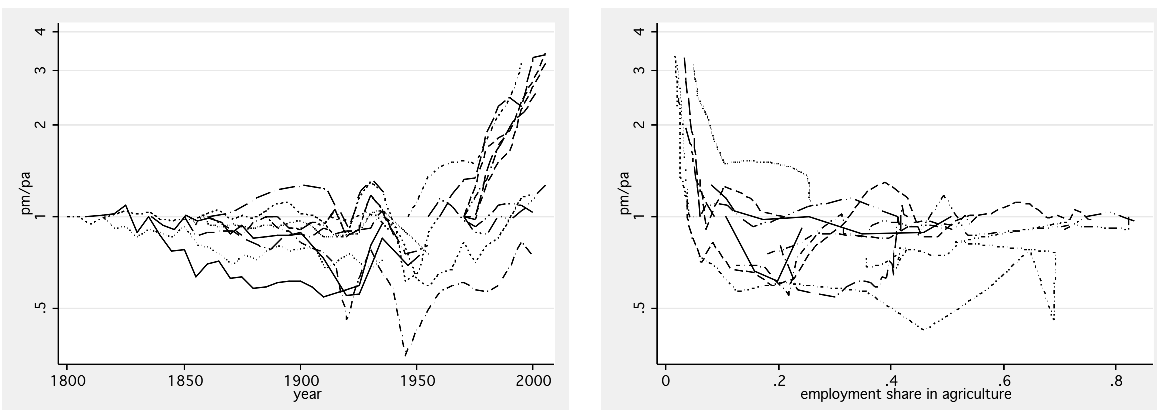


Figure 4: The evolution of the relative price p_m/p_a across countries

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 UK. 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.[18] In the earliest period before 1840, data is available for only 3 countries; the relative price declined in France and was basically flat in the Netherlands and in Sweden. In the following 80 years going up to 1920, the relative price declined everywhere except for the UK and Japan. In the period

[17]This is the case for Belgium, France, Germany, Japan, the Netherlands, South Korea, Spain and the UK.

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

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 thus 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%. 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 agriculture. Again, on average across countries, the relative price falls while L^A is above 20%, rises slightly while it is between 10 and 20%, and rises strongly when it is below 10%. 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 19$^{\text{th}}$ vs the late 20$^{\text{th}}$ century) or features specific to a certain stage of development (e.g. technological developments in non-agriculture 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 is negative but not significant. Among

Table 3: The relative price: average annualized percentage change

country	by time period: 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
cross-country average	0.34	-0.14	-0.45	-0.27	0.07	2.08	
	by stage in the process of structural change: L^A:	<10%	10-20%	20-40%	40-60%	>60%	
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				
cross-country average		2.21	0.15	-0.11	-0.67	-0.28	

Notes: Computed using 5-year moving averages where observations 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 3 and Appendix D.

the stage dummies, only the one for the stage with L^A between 40 and 60% is individually significant. However, the stage dummies are jointly significant at the 1% level. (The year dummies jointly are so at the 5% 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 which 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 UK. 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 demean growth rates of the relative price by the country mean and regress them on stage and period dummies.[19] 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%. The stage dummies are jointly significant at the 5% level, the period dummies at the 1% 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: Firstly, growth in the relative price is significantly lower in countries that are less advanced in their structural change in our sample. Secondly, 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

[19]While using a panel fixed effects specification may appear more obvious, it implies also demeaning the independent variables within each country. With our specification, the dummy variables continue to refer to the same stages and periods across countries.

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

Table 4: Changes in the relative price: the role of time versus the stage of structural change

	dependent variable:								
	growth rate of p (pooled data)			growth rate of p (country average)			demeaned growth rate of p		
L^A:									
country average				-0.025	(0.009)	**			
stages: L^A									
<10%	0.010	(0.007)					0.000	(0.008)	
10-20%	-0.006	(0.006)					-0.013	(0.006)	*
20-40%	-0.005	(0.005)					-0.009	(0.005)	*
40-60%	-0.006	(0.002)	**				-0.009	(0.003)	**
time periods:									
1800-1839	-0.010	(0.007)					-0.018	(0.007)	**
1840-1879	-0.016	(0.006)	**				-0.023	(0.006)	***
1880-1919	-0.014	(0.005)	**				-0.020	(0.005)	***
1920-1959	-0.016	(0.007)	**				-0.020	(0.007)	**
constant	0.016	(0.007)	**	0.012	(0.003)	***	0.020	(0.007)	**
N	189			11			189		
countries	11			11			11		
R^2	0.271			0.503			0.273		

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 column, 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, and the growth rate of p minus its mean growth rate in the country in the third 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 $L^A > 60\%$ and the period from 1960 on) and a country's average L^A in the sample in the second column. Regression is by OLS. Robust standard errors in parentheses; in the first and third column clustered at the country level. Significance levels of the estimates: * 10%, ** 5%, *** 1%.

between 10 and 60%). 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 ($L^A > 60\%$) 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 non-agriculture that other countries already absorbed before, suggesting that the sequence of "first pull, then push" is respected.

5.3 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 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 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

[21] Before 1840, results are similar to the following periods but not significant as there is data on only three countries. While L^A was above 60%, 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.

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 (Federico 2005, p. 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 a 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 UK, then should lead to a movement of labor *towards* 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 non-agriculture grew strongly relative to that in agriculture. For the period after 1960, no clear conclusions about the evolution of relative productivities can be made under the assumption of small open economies.

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 non-agriculture, and only after 1960 in agriculture. This is consistent with conclusions we obtained at the country level.

[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.

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 U.S. 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 post-war period, for instance hybrid corn. Nonetheless, the most surprising result is the robust dominance of the pull channel for the period before 1940.

6 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 non-agricultural 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.

This analysis yielded four main results. Firstly, both channels matter. In the case of the U.S., for instance, the "labor pull" channel dominated before World War I, with the "labor push" channel taking over after World War II. Secondly, together with growth in GDP per capita, structural change accelerates in the 20^{th} century in most countries, even those where the agricultural employment share is already low. Thirdly, the evolution of the relative price clearly points to productivity improvements in the non-agricultural sector as 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 U.S.. 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).) As our data show, 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 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-homotheticicities in preferences to food consumption, such as Gollin et al. (2002), miss non-agricultural technological progress as an important driver of structural change. Our empirical evidence thus suggests 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 non-agricultural 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

In this appendix we explore the robustness of the predictions of our model to the inclusion of a second input in production, capital. Let's assume that production takes place according to the following Cobb-Douglas technologies,

$$\begin{aligned} Y_t^A &= AG\left(K_t^A, L_t^A\right) = A\left(K_t^A\right)^{\theta_A}(L_t^A)^{1-\theta_A} \\ Y_t^M &= MF\left(K_t^M, L_t^M\right) = M\left(K_t^M\right)^{\theta_M}(L_t^M)^{1-\theta_M}, \end{aligned} \tag{19}$$

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 non-agricultural 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 non-agricultural sector could be either consumed or costlessly transformed into capital. As a result the law of motion of the capital stock is given by

$$\dot{K}_t = M\left(K_t^M\right)^{\theta_M}(L_t^M)^{1-\theta_M} - C_t^M, \tag{20}$$

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.

$$\frac{(1-\theta_A)}{\theta_A}\frac{K_t^A}{L_t^A} = \frac{(1-\theta_M)}{\theta_M}\frac{K_t^M}{L_t^M} \tag{21}$$

As in the model without capital, a non-arbitrage 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

$$\begin{aligned} p_t &= \frac{(1-\theta_A)}{(1-\theta_M)}\frac{A}{M}\frac{\left(\frac{K_t^A}{L_t^A}\right)^{\theta_A}}{\left(\frac{K_t^M}{L_t^M}\right)^{\theta_M}} = \frac{(1-\theta_A)}{(1-\theta_M)}\frac{A}{M}\frac{\left(\frac{\theta_A(1-\theta_M)}{\theta_M(1-\theta_A)}\frac{K_t^M}{L_t^M}\right)^{\theta_A}}{\left(\frac{K_t^M}{L_t^M}\right)^{\theta_M}} \\ &= \xi\frac{A}{M}\left(\frac{K_t^M}{L_t^M}\right)^{\theta_A-\theta_M} = \xi\frac{A}{M}\left(\frac{K_t-K_t^A}{L_t-L_t^A}\right)^{\theta_A-\theta_M}, \end{aligned} \tag{22}$$

where $\xi \equiv \frac{(1-\theta_A)^{1-\theta_A}(\theta_A)^{\theta_A}}{(1-\theta_M)^{1-\theta_M}(\theta_M)^{\theta_M}}$ and we impose the production efficiency condition (21).

Using evidence from the second half of the twentieth century, Jorgenson, Gallop and Fraumeni (1987) report a share of capital in value added of 30 percent in the agricultural sector and of close to 40 per cent in the non-agricultural sector. Measures of capital intensity of agriculture in earlier times suggests even lower values (see for instance Gallman (1972) and Kendrick (1961)). This evidence suggests that the empirically relevant case is one where capital intensity in the non-agricultural sector exceeds that of the agricultural sector. As a result, 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 (21) 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,

$$
\begin{aligned}
Y_t^A &= A\left(\frac{K_t^A}{L_t^A}\right)^{\theta} L_t^A = A\left(K_t\right)^{\theta} L_t^A \\
Y_t^M &= M\left(\frac{K_t^M}{L_t^M}\right)^{\theta} L_t^M = M\left(K_t\right)^{\theta}\left(L_t - L_t^A\right)
\end{aligned}
\tag{23}
$$

Furthermore, the relative price reduces to

$$
p_t = \frac{A}{M}, \tag{24}
$$

using (20) yields the following aggregate budget constraint,

$$
\left(\dot{K}_t + C_t^M\right) p_t + C_t^A = A\left(K_t\right)^{\theta}\left(L_t\right)^{1-\theta} \tag{25}
$$

Maximizing welfare, given by the present value of (5) discounted using a rate of time preference ρ, subject to (25), yields (apart from (10) and the transversality condition) an additional intertemporal allocation condition that governs the evolution of consumption through time,

$$
\frac{\dot{\lambda}_t}{\lambda_t} = \rho + n - r_t - \frac{\dot{p}_t}{p_t} \tag{26}
$$

where $r_t = MF_k\left(k_t, 1\right)$ is the marginal 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 non-agricultural sector as

$$k^*(M), \text{ with } \frac{dk^*}{dM} = -\frac{F_k}{MF_{kk}} > 0. \tag{27}$$

Combining (10), (23), (24) and (27), we reach the counterpart of (11) that determines the steady state allocation of labor across sectors:

$$\frac{\gamma}{A} = (k^*(M))^\theta l^A - \alpha\left[(k^*(M))^\theta\left(1-l^A\right) + \frac{\mu}{M}\right] = \phi(l^A, M), \tag{28}$$

where $l^A \equiv \dfrac{L^A}{L}$ is the share of labor employed in agriculture[23]

$$\begin{aligned}\phi_{l^A} &= (1+\alpha)(k^*(M))^\theta > 0 \\ \phi_M &= a(k^*(M))^{\theta-1}\left[l^A - \alpha\left(1-l^A\right)\right]\frac{dk^*}{dM} + \alpha\frac{\mu}{M^2} > 0\end{aligned} \tag{29}$$

As a consequence, $\partial l^A/\partial M < 0$ and $\partial l^A/\partial A < 0$.

Finally, differentiating (24) gives the responses of the steady state relative price to changes in the level of technology in each sector as

$$\frac{\partial p^*}{\partial A} = \frac{1}{M} > 0 \text{ and } \frac{\partial p^*}{\partial M} = -\frac{A}{M^2} < 0. \tag{30}$$

Now let us turn to the other limiting case, where $\theta_M = \theta > \theta_A = 0$. Using (20), we obtain the following aggregate budget constraint,

$$\left(\dot{K}_t + C_t^M\right)p_t + C_t^A = p_t M(K_t)^\theta (L_t^M)^{1-\theta} + AL_t^A. \tag{31}$$

The counterpart of (26) implies that the steady state level of capital is implicitly defined by $MF_k\left(k^*, 1-l^A\right) = \rho + n$ with the following comparative statics.

$$k^*\left(M, l^A\right), \text{ with } \frac{\partial k^*}{\partial M} = -\frac{F_k}{MF_{kk}} > 0 \text{ and } \frac{\partial k^*}{\partial l^A} = \frac{F_{kl}}{F_{kk}} < 0. \tag{32}$$

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

$$\frac{\gamma}{A} = l^A - \alpha\frac{\left(1-l^A\right)^\theta}{(1-\theta)\left(k^*\left(M,l^A\right)\right)^\theta}\left[\left(k^*\left(M,l^A\right)\right)^\theta\left(1-l^A\right)^{1-\theta} + \frac{\mu}{M}\right] = \phi(l^A, M), \tag{33}$$

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

where[24]

$$\phi_{l^A} = 1+\frac{\alpha}{(1-\theta)} > 0 \tag{34}$$

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

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

Combining (22) with (32), we reach the following expression for the steady state relative price,

$$p^* = \frac{A}{(1-\theta)M\left(k^*\left(M,l^A\right)\right)^\theta\left(1-l^A\right)^{-\theta}} = \frac{A}{MF_L\left[k^*\left(M,l^A\right),\left(1-l^A\right)\right]}, \tag{35}$$

with the following comparative statics[25],

$$\frac{\partial p^*}{\partial A} = \frac{1}{(1-\theta)M\left(k^*\right)^\theta\left(1-l^A\right)^{-\theta}} > 0 \tag{36}$$

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

Given (29), (34), (30) and (36), 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.

[24]Notice that we can write the last term of (33) as $\Psi\left(M,l^A\right) \equiv \frac{\alpha\mu}{MF_l\left(k^*\left(M,l^A\right),1-l_A\right)}$, with $\frac{\partial\Psi}{\partial l^A} = -\alpha\mu M\left(F_l\right)^{-2}\left(F_{lk}\frac{\partial k^*}{\partial l^A}-F_{ll}\right) = 0$. This last equality uses (32) and the fact that any function of two variables that is homogeneous of degree one satisfies $F_{kk}F_{ll}-\left(F_{lk}\right)^2 = 0$.

[25]Since $p^* = \frac{A}{MF_l\left[k^*\left(M,l^A\right),\left(1-l^A\right)\right]}$, the first expression is

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

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

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

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

B Basic results under CES preferences

Assume preferences of our representative household are given by,

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

where c_t^A and c_t^M denote individual consumption of food and non-agricultural goods respectively, η is the relative weight of non-agricultural 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

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

On the one hand, the labor pull hypothesis requires $\phi_M^{CES} > 0$ which implies that the elasticity of substitution has to exceed unity, $\nu > 1$.[26] On the other hand, since $sign\left(\phi_M^{CES}\right) = -sign\left(\phi_A^{CES}\right)$, the labor push hypothesis requires that $\nu > 1$ is not too large.[27] If these two restrictions on the degree of substitutability between agricultural and non-agricultural goods hold, then all the results presented in Section 2 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.[28] 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 non-agricultural 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 non-agricultural sector. An increase in agricultural productivity reduces the price

[26] 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.

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

[28] 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.

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 v 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.

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 $\bar{u}$ and $\bar{P}$ the minimum expenditure needed to reach utility $\bar{u}$. $\bar{P}$ solves the problem

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

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

$$\begin{aligned}p_m &= \frac{P}{c_m+\mu} \qquad (37)\\ p_a &= \frac{\beta P}{c_a-\gamma}.\end{aligned}$$

Plugging this into the constraint and solving for P yields

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

Using this,

$$\frac{P}{p_a}=\beta^{-\frac{\beta}{1+\beta}}[\exp(\bar{u})]^{\frac{1}{1+\beta}}\left(\frac{p_m}{p_a}\right)^{\frac{1}{1+\beta}}. \qquad (38)$$

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

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

$$\begin{aligned}\bar{P} = p_m c_m + p_a c_a &= (1+\beta)P - p_m\mu + p_a\gamma \\ &= (1+\beta)\beta^{-\frac{\beta}{1+\beta}}[\exp(\bar{u})]^{\frac{1}{1+\beta}} p_m^{\frac{1}{1+\beta}} p_a^{\frac{\beta}{1+\beta}} - p_m\mu + p_a\gamma \\ \frac{\bar{P}}{p_a} &= (1+\beta)\beta^{-\frac{\beta}{1+\beta}}[\exp(\bar{u})]^{\frac{1}{1+\beta}} \left(\frac{p_m}{p_a}\right)^{\frac{1}{1+\beta}} - \frac{p_m}{p_a}\mu + \gamma\end{aligned} \tag{39}$$

Then

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

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.

D Data sources

The main sources we rely on are Mitchell (1988, 2003, 1998) and the Groningen Growth and Development Centre (GGDC) 10-sector and Historical National Accounts databases. They are described in this section. We complement these with additional sources described below if these are reliable and provide longer series.

D.1 Main sources

Mitchell (1988, 2003, 1998) contain data on the history of sectoral labor allocations in many countries, sometimes going back until 1800. After 1960, Mitchell mainly draws on national statistical yearbooks. For the period up to 1960, the main source is Bairoch and colleagues (1968), who in turn draws on national censuses. While they have made "every possible effort to achieve international and intertemporal comparability" (Mitchell 2003, p. 144), "frequent changes in criteria and methods used in census taking [make it] practically impossible to come up with statistics that are perfectly comparable in time and space" (Bairoch 1968). Comparing trends and orders of magnitude, however, is feasible. As a consequence, while the precision of numbers for employment shares in agriculture before 1960 should not be overstated, the main patterns of the data that we present in Section 5 should be correct. Focusing mainly on stages of the transformation rather than on precise figures for the employment share is also in line with data quality.

For historical relative prices, the Groningen Growth and Development Centre Historical National Accounts database is very useful. Data is available at `http://www.ggdc.net/databases/hna.htm` and described in Smits et al. (2009). The dataset was created "to bring together the available, but fragmented, data on GDP at the industry level for all major economies and to standardise these series to make a consistent long run international comparison of output and productivity feasible". The database contains series on GDP at current and at constant prices in local currency for the total economy and broad sectors in parts of the 19th and 20th century (about 1870 to 1950 for most countries) using a common industrial classification (2-digit NACE rev. 1.1). All sources are country-specific; detailed references are given below. The GGDC considers the dataset a complement to Maddison's World GDP series and to its 10-sector database and the EUKLEMS data which are both discussed below. The GDP series at current and at constant prices allow imputing sectoral and aggregate price indices. Whereas some of the earlier-generation estimates (essentially the ones on which the series for Germany and for the UK are based) may suffer from some methodological problems mainly due to changes in relative price levels between countries, this is less of a problem for the more recent estimates for other countries. Moreover, given that we use ratios of price levels (p_m/p_a), these problems should be attenuated in our use of the data. Other issues to be borne in mind when using historical data are discusses in Section 3.

Another important source we draw on for post-war labor allocations and relative prices is the GGDC 10-sector database. For Europe, this is an update of van Ark (1996), for Asia it is described in Timmer and de Vries (2007). The data and documentation are available on `http://www.ggdc.net/dseries/10-sector.html`. The database covers 1950 to 2005. It contains information on employment and value added at current and constant prices in ten main sectors of the ISIC rev. 2 classification, one of which is "agriculture, hunting, forestry and fishing". Together, the ten sectors cover the whole economy. We use the series on employment in agriculture and on total employment, and use the two value added series to impute sectoral and aggregate price indices. Employment is defined as "all persons employed". This includes all paid employees, the self-employed and family workers, which is particularly important for agriculture. For Europe and Japan, the database draws on OECD National Accounts and OECD Labour Force Statistics and on National Accounts of the individual countries. For South Korea, it mainly draws on the Bank of Korea's National Accounts and before that on data from the Economic Planning Bureau.

Data thus largely come from sources designed for comparability, use common definitions (employment concept), and a harmonized sectoral classification.[29] Series are thus consistent over time and comparable across countries. Timmer and de Vries (2007) provide a detailed comparison of their data with data from the World Bank World Development Indicators and show that the GGDC data has fewer gaps and a more consistent methodology that suffers less from changes in methodology or survey coverage, which occasionally lead to implausible numbers or jumps in WDI data. This database is preferable to the EUKLEMS databased described below (see the entry on Belgium) because it provides a longer time series.

D.2 Sources by country

D.2.1 Employment shares in agriculture

Belgium: 1846-1960: Economically active population by major industrial groups, Agriculture, forestry and fishing and Total, Mitchell (2003, Table B1).

1970-2005: Employment in Agriculture, forestry and fishing and Total Employment, EUKLEMS database, November 2009 release, described in O'Mahony and Timmer (2009) and available at `http://euklems.net`. This database is based on national accounts and labor force survey data. It is similar to the GGDC 10-sector database in focussing on maintaining intertemporal and international comparability. Containing more disaggregate information, the EUKLEMS time series is shorter, starting in 1970 rather than 1960.

Canada: 1881-1971: Population of working age and either gainfully occupied (1881-1941) or labour force (1951-1971), in non-agricultural and agricultural pursuits, census years, Historical Statistics of Canada, Table D1-7. Publicly available at `http://www.statcan.gc.ca/cgi-bin/IPS/display?cat_num=11-516-X`.

1976-2006: Total employed, all industries and agriculture respectively, Statistics Canada CANSIM series v2057603, v2057605. Labour force survey estimates.

Finland: 1880-2000: Economically active population by major industrial groups, Agriculture, Forestry and Fishing and Total, Mitchell (2003, Table B1).

[29] While there are minor differences in how countries construct industry-level numbers, these do not tend to change over time and are more of a problem in services.

France: 1856-1936: Economically active population by major industrial groups, Agriculture, Forestry and Fishing and Total, Mitchell (2003, Table B1).

1950-2005: Employment in Agriculture, Forestry and Fishing and Total Employment, GGDC-10 sector database.

Germany: 1849-1939: Employment by sector from Hoffmann (1965, p. 204), which draws on German Statistical Yearbooks. In the period where they overlap (1882-1939), this series is fairly close to that in Mitchell (2003, Table B1). Fremdling (2008) shows that Hoffmann's 1939 number for the level of employment in agriculture includes (annexed) Austria and Sudetenland, unlike the numbers for previous years. Using data from the *Statistisches Jahrbuch für das Deutsche Reich* (1942, p. 411) to correct this leads to an employment share in agriculture just slightly below that reported by Hoffmann and in line with that reported by Mitchell.

1950-1990: Employment in Agriculture, Forestry and Fishing and Total Employment, GGDC-10 sector database.

Japan: 1872-2000: Economically active population by major industrial groups, Agriculture, Forestry and Fishing and Total, Mitchell (1998, p. 97).

Netherlands 1800-1913: Labour Force, agriculture and total, Smits, Horlings and van Zanden (2000, Table C.1). This monograph summarizes results from the project 'Reconstruction of the National Accounts of the Netherlands', which involved more than 20 members for around a decade. The project used a variety of sources in order to compile a set of consistent historical national accounts. The numbers on the employment share in agriculture are fairly close to the series in Mitchell (2003, Table B1) in the years 1849-1909 where they overlap.

1920-1947: Labor force in agriculture and fisheries and total labor force, van Zanden (1998, Table 6.5): In his monograph on Dutch economic history in the 20th century, van Zanden extends the previous series, drawing on work by authors also involved in the National Accounts project. Where they overlap (1909-1947), this series features a slightly lower level and a smoother decline of the employment share in agriculture than Mitchell (2003, Table B1).

1950-2005: Employment in Agriculture, Forestry and Fishing and Total Employment, GGDC 10-sector database. This series lies between the levels of data cited in van Zanden (1998, Table 9.4) and that in Mitchell (2003, Table B1). Mitchell's series features a rather abrupt decline in L^A between 1947 and 1971.

The series we use thus put part of the decline in L^A at an earlier date than the alternative series by Mitchell, with an L^A that is about 3 percentage points lower around 1910-20 and then declines more slowly. However, the difference occurs within a "stage" of our empirical specification and therefore does not affect our results.

South Korea: 1918-1943: Share of households in agriculture, personal communication from Nak Nyeon Kim of Dongguk University, South Korea. The series improves on the series used in Cha and Kim (2006). For this period and place, the share of households (rather than employment) is considered a more reliable measure.

1955-2005: Economically active population by major industrial groups, Agriculture, Forestry and Fishing and Total, Mitchell (1998, p. 97).

Spain: 1860-2001: Economically active population by major industrial groups, Agriculture, Forestry and Fishing and Total, Mitchell (2003, Table B1).

Sweden: Number of employed, including self-employed, in agriculture and ancillaries and in the total economy, Edvinsson (2005), who draws on Statistics Sweden. Data available at `www.historicalstatistics.org`. Compared to the series for Sweden by Mitchell, this series features a higher employment share in agriculture until 1890, and therefore faster structural change in the 19th century. The stage dummies used in Section 5 are robust to these differences.

UK: 1801-1910: Share of the labor force in agriculture, Clark (2002, Table 3). The series in fact extends back to 1500. From 1801 on, it draws on population censuses, so we use this more reliable part of the series.

1920-30: Economically active population by major industrial groups, Agriculture, Forestry and Fishing and Total, Mitchell (1988).

1948-2005: Employment in Agriculture, Forestry and Fishing and Total Employment, GGDC 10-sector database.

USA: 1800-1900: Labor force in agriculture and total labor force, Weiss (1992, 1993): The series relies on censuses and improves on earlier series in the classification of some groups of laborers.

1909-1947: Farm employment and total employment (14 years old and over), U.S. Department of Commerce (1975, series D5 and D6). The series actually starts in 1900 and reports an agricultural employment share of 41% for that year, compared to only 36% according to Weiss (1993). This difference is due to a different age cutoff (10 vs 14 years). Following Dennis and Iscan (2009), we use Weiss's numbers until 1900 and the Department of Commerce numbers starting in 1909. (From 1910 on, the employment share in agriculture for 10- vs 14-year olds is virtually identical (Tostlebe 1957).)

1948-2000: Agricultural employment and total employment (16 years old and over), Bureau of Labor Statistics.

The series for the 20th century is close to that in Carter, Gartner, Haines, Olmstead, Sutch and Wright (2006, Table Ba652-669), which however has a lower frequency.

D.2.2 Prices

Belgium: 1836-1953: Price indices for agricultural output and for total output, imputed from the GGDC Historical National Accounts Database, which for Belgium mainly draws on Horlings (1996).

1970-2005: price indices for gross value added in agriculture and the total economy, EUKLEMS database, November 2009 release (O'Mahony and Timmer 2009, also see above).

Canada: 1936-1960: Price indices for agricultural output and for total output, imputed from Statistics Canada CANSIM series v501034, v501035, v11752 and v11753 (GDP at factor cost by industry, current and constant prices, Agriculture and Total industries).

Finland: 1860-2000: Price indices for agricultural output and for total output, imputed from the GGDC Historical National Accounts Database, which for Finland draws on Hjerppe (1989, 1996).

France: Price indices for agricultural output and for total output. 1815-1938: imputed from the GGDC Historical National Accounts Database, which for France draws on Toutain (1987).

1946-1995: Price indices for value added (total and agriculture, fisheries and forestry) from Villa (1993), with data available on the CEPII website at `http://www.cepii.fr/francgraph/bdd/villa/mode.htm`.

Germany: 1852-1913: Price indices for agricultural output, imputed from value added in agriculture, forestry and fishing in current and constant prices (Hoffmann 1965, p. 331, 333) and for net national product (p. 598).

1968-1990: Price indices for value added in agriculture and the total economy, imputed from the GGDC-10 sector database.

Japan: Price indices for agricultural output and for total output, for 1885-1940 imputed from the GGDC Historical National Accounts Database, which for Japan draws on Ohkawa, Takamatsu and Yamamoto (1974), and for 1950-2000 from the GGDC 10-sector database.

Netherlands: Price indices for agricultural output and for total output, for 1808-1939 imputed from the GGDC Historical National Accounts Database, which for the Netherlands draws on various sources, in particular Smits et al. (2000), and from 1970-2005 from the GGDC 10-sector database.

South Korea: 1913-1940: Price indices for agricultural output and for total output, imputed from total GDP and GDP in agriculture in current and constant prices, Cha and Kim (2006, Tables 1 and 2).

1970-2005: Price indices for agricultural output and for total output, imputed from series on GDP in current prices and its growth rate in chained prices, agricultural share of GDP in current prices and growth of agricultural value added in chained (agricultural) prices, available from the Korean Statistical Information service (`www.kosis.kr`).

Spain: Price indices for agricultural output and for total output, for 1850-1950 imputed from the GGDC Historical National Accounts Database, which for Spain draws on Prados de la Escosura (2003), and for 1970-2001 from the GGDC 10-sector database.

Sweden: 1800-2000: Price indices for agricultural output and for total output, imputed from Swedish Historical National Accounts, described in Krantz and Schön (2007) and available at `http://www.ehl.lu.se/database/LU-MADD/National%20Accounts/default.htm`.

UK: Price indices for agricultural output and for total output, for 1861-1938 imputed from Mitchell (1988, Tables 16.2 and 16.8), which draw on Deane and Cole (1962) and Feinstein (1972), and for 1960-2005 imputed from the GGDC 10-sector database.

USA: There are no sectoral value added price series for the U.S., so we rely on wholesale prices. (In 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.")

1800-1890: Wholesale price indices for all commodities and for farm products (Hanes 2006*b*). These series result from a project by George F. Warren and Frank A. Pearson (1933) to create wholesale price indices for the 19th century that would "correspond with" the Bureau of Labor Statistics wholesale price indices, which go back to 1890. (The series up to 1797 is due to Herman M. Stoker and uses the same methodology.) Sources are mainly newspapers and government reports, and prices refer to New York City. (Series for other cities are also available but are less reliable.) Both this series and the early-19th century BLS series cover few finished goods and no services. However, according to Dennis and Iscan (2009), other price indices with more comprehensive coverage (but more sparse observations) exhibit similar trends.

1890-2000: Wholesale and producer price indexes for all commodities and for farm products (Hanes 2006*a*). This series links two series from the BLS Handbook of Labor Statistics. From 1947 on, the series consists in the BLS producer price indices by commodity group. This is linked to the wholesale price indices collected by the BLS before that.

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