

Chapter 20

Mechanization and the Intersectoral Migration of Agricultural Labor



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Abstract For most countries, the historical path to development includes a sectoral shift of labor from agriculture to other sectors, an inflow of capital to agriculture, and a boost in land productivity. Early in the process of structural transformation, when populations are primarily rural and agrarian, the pace of sectoral migration can appear slow, as births that occur in much larger rural populations nearly match out-migration. As populations become increasingly urban, the dynamics shift, as rural populations experience continued out-migration matched with a declining share of births. This sets the stage for rising wages and labor-saving mechanization in agriculture. In many places, mechanization is associated with economies of scale that encourage a transformation in farm structures toward larger farms. Still, farm structures have been slow to change in Asia and Africa, where most farms are small, limiting potential productivity gains. This chapter uses a cross-country panel of data spanning five decades to examine the relationships among sectoral migration, gaps in sectoral incomes, and mechanization.

20.1 Introduction

In a process repeated in the history of most countries, agrarian economies transform. Central to that process is the reallocation of labor from agriculture to other sectors. In 1975, the geographer David Grigg (1975) noted that agriculture remained the world's most important source of employment, as it had since Neolithic times. This enduring dominant role of agriculture for livelihoods drew people to rural areas where land, water, and climate resources were well suited to agriculture.

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J. P. Estudillo et al. (eds.), *Agricultural Development in Asia and Africa*,
Emerging-Economy State and International Policy Studies,
https://doi.org/10.1007/978-981-19-5542-6_20

In a lifetime, the way most people work and the places they live have changed dramatically. Grigg estimated that the share of the world's workers employed in agriculture fell from 72 to 62% between 1900 and 1950. Little changed in the developing world; agriculture's share of employment fell from 78 to 73% during the same period. Nearly 70 years later, the International Labor Organization (ILO) estimates that agriculture employed 27% of the world's workers in 2019. The trend has been pervasive and not limited to wealthy countries; among middle- and low-income countries, agriculture's share of employment averaged 32% in 2019 (World Bank 2022).

Closely associated with the movement of labor from agriculture to other sectors has been the movement of people from rural areas to cities and suburbs as the need for workers to live near the fields and pastures they tended gave way to jobs in sectors that benefit from economies of scale and agglomeration (Williamson 1988; Quigley 2008). Between 1950 and 2020, the share of the global population living in rural areas declined from 70 to 40% (UN 2022). The changes were apparent in most countries. In 1950, the United Nations reported that rural populations exceeded the urban population in 75% (151 of 201) of the countries it had data on (UN 2022). By 2020, the number had fallen to 32% (159 of 234). Increasingly, the countries, and places within countries, that remain predominantly rural with high rates of employment in agriculture are poorer. For example, two-thirds of people living in low-income developing countries live in rural areas.

In this chapter, we return to the topic of what determines rates of sectoral migration. We extend a cross-country panel of sectoral income and labor data reported in Larson and Mundlak (1997) to take advantage of national experiences that have occurred in the 25 years since the paper was published. A focus of that paper was to test whether sectoral adjustments in the allocation of labor responded to differences in average-value labor products, as economic theory would suggest. The results supported the notion that they did, as do the findings of this chapter. As explained later, several reasons, including uncertainty and a reluctance to forgo place-specific social capital, could create a wedge between equilibrium labor-product values so that sectoral migration would halt before average incomes in and out of the sector were equal. The Larson-Mundlak estimates revealed evidence of a quantitatively small average-product wedge that was not statistically distinguishable from zero. Our results indicate the same.

Unlike the earlier paper by Larson and Mundlak (1997), we also look at the role played by mechanization. Potentially, imperfections in capital markets could result in less-than-optimal capital-to-labor ratios in rural areas, particularly in agriculture. This could lead to a situation where agricultural labor is substituted for capital made unavailable due to poorly functioning markets. Said differently, capital constraints could preclude otherwise justifiable adoptions of labor-saving mechanization technologies. We find evidence that migration rates speed up as tractor inventories build up, but only when potential regional differences are ignored. Ignoring regional differences has otherwise little impact. This suggests that differences in capital markets or other regional differences may affect mechanization outcomes.

20.2 Background

This chapter is concerned with what determines the restructuring of labor from agriculture to other sectors and its pace. From a macroeconomic perspective, the flow of labor to other sectors, where incomes are higher, is part of an economic growth process that boosts incomes and reduces poverty. So, it is important to understand why the process moves faster in some places than others and why gaps in average sector incomes linger. This chapter is part of a broad literature concerning the links between migration and livelihoods.¹

Applied studies in this area attempt to explain actions measured at an aggregated level, and related empirical models rely on sector data in countries over time or cross-country panel data. For example, early studies examined the transformation of the British economy during the Industrial Revolution (Williamson 1990); the growth in the US and Japanese economies during the twentieth century (Bellante 1979; Barkley 1990; Minami 1967, 1968; Mundlak and Strauss 1978); and cross-country experiences (Mundlak 1978, 1979; Squire 1981). For early reviews, see Greenwood (1975), Yap (1977), and Molho (1986).

The empirical model is influenced by Sjaastad's (1962) view of migration as an investment in future welfare and Todaro's (1969) observation that migration depends on expected rather than actual wages. Subsequently, a series of empirical models emerged that explained observed migration using wage and, later, income differentials. Still, as Ramsey et al. (2021) point out, early empirical studies were largely empirical constructs that lacked a basis in microeconomic foundations.

Later, the empirical models of aggregate migration indicators would be linked to models of individual choice, building links between theory, household-based empirical studies, and sector studies (Mundlak 1979; Barkley 1990; Larson and Mundlak 1997). Our empirical model is derived from an individual choice model, where migration is motivated by differences in lifetime expected utility, which at the sectoral level is related to sectoral differences in average incomes. We explain the empirical model further in the next section. The conceptual model behind it is derived from a technical annex in Larson and Mundlak (1997). Related studies include Butzer et al. (2002, 2003).

20.3 Applied Model

The empirical model we use is derived from a conceptual model of individual choice in an appendix of Larson and Mundlak (1997). Broadly, the intuition behind the model is that potential sectoral migrants of age g with attributes z compare expected welfare differences between a lifetime employed in agriculture and a lifetime employed in alternative sectors. Age matters, partly because the evaluation occurs over a lifetime,

¹ For insights into the breadth of the literature, see Lucas' (2014) edited handbook.

and also because stocks of skills best suited to one sector or another can accumulate with time. Attitudes toward risk aversion may also shift with time.

Historically, income gaps have been significant, sustained, and easily observed, especially in developing countries, so expected incomes are central to the applied model. We use average incomes rather than wages as our indicator of expected incomes. Measured as sector value-added divided by the size of the labor force, income indirectly accounts for unemployment and provides an averaging across wage differentials within sectors. In our conceptual model, the pool of individuals who conclude that they would be better off seeking employment outside of agriculture grows as income gaps widen.

We use educational attainment, that is, years of schooling, as a measure of portable human capital since greater educational attainment should lower the costs of the new skills needed to do well in a new sector. Alternatively, workers also acquire skills with experience and, as children, may learn from their parents, especially in rural areas. However, these experiential skills are not necessarily transferable to other sectors. This is another reason to expect that younger workers are more likely to migrate since migrating later in life means abandoning greater accumulations of human capital.

Studies based on household and migrant surveys reveal additional factors tied to social capital, which are harder to measure in sectoral labor studies. Some likely work in ways similar to human capital. For example, in choosing to migrate, workers who have become part of a community and whose families may have been part of the community for generations must abandon ties that provide support, solidarity, and informal forms of insurance—costs to migration that increase with age.

Illiquid forms of productive capital, especially smallholder land, which likely accumulates with age, also work to constrain migrants.

Other forms of social capital can work to lower migration costs. A supportive extended family and being rooted in a community can provide a backstop for expected gains from leaving the sector, mitigating potential risks. Moreover, young migrants may be motivated by the potential to improve the lives of their extended family through remittances, and networks are an important form of social capital that can lower migration risks and transaction costs.

Last, empirical migration models must account for existing stocks of sector labor and natural rates of change due to population increase. This is especially important for agriculture because the places most conducive to agriculture are often spatially separate from where non-agricultural jobs are concentrated. Consequently, children born to parents employed in agriculture will more likely develop human and social capital stocks that support livelihoods related to agriculture and face greater obstacles when seeking jobs in non-agricultural sectors than children born to workers in other sectors. Said differently, migration costs are avoided for workers who remain in the places they were born and work using skills they learned growing up; consequently, the initial states of labor allocations matter in models of sectoral migration.

With this as background, our empirical model is written as:

$$m_t = b_0 [\delta_{t-1} - (1 + k)]^{b_1} r_{t-1}^{b_2} (1 + n_t)^{b_3} z_{t-1}^{b_z} + u_t \quad (20.1)$$

where

$m = M/L_a$ is the ratio of migrants (M) to agricultural labor (L_a);

$\delta = w_n/w_a$ is the ratio of income in non-agriculture (w_n) to that in agriculture (w_a);

r is the ratio of labor in non-agriculture to that in agriculture (L_n/L_a);

n is the rate of labor-force growth; and

z is a vector of additional determinants.

For estimation purposes, the equilibrium point $(1 + k)$ is estimated directly, where $c_0 = (1 + k)$.

The model is structured such that the migration rate increases with the intersectoral income differential, dependent on the labor-force composition and other attributes (z). A key reference point for δ is the equilibrium point at which migration would cease. Under ideal circumstances, it might be reasonable to think that migration from agriculture would stop (an equilibrium point reached) when average incomes in agriculture equaled average incomes out of agriculture; that is when $\delta = 1$. However, as discussed, there are compelling reasons to believe that the equilibrium point is elsewhere. To account for this, an additional parameter, k , is introduced so that the equilibrium point could be reached despite an inequality of average incomes, that is, for values of δ other than 1.

Transaction costs associated with moving from agriculture are numerous and include information barriers, misaligned skills, poorly functioning land markets that make land assets illiquid, location-specific social capital, and uncertainty. For these reasons, an equilibrium point may be reached even when incomes in agriculture remain slightly below non-agriculture, that is, when $\delta > 1$.

Richards and Patterson (1998), Dennis and İşcan (2007), and Önel and Goodwin (2014) suggest that real-options values, which place a premium on waiting due to uncertainty, are important migration costs and therefore help explain lingering sectoral wage or income gaps. On the other hand, Ramsey et al. (2021), using data from Japan and the United States, dispute this assertion and find no empirical support for the complex non-linearities that arise from including option costs in empirical models of sectoral migration.

Recently, Foster and Rosenzweig (2022) have argued that high transaction costs associated with hired labor, together with hurdles to land accumulation in India, create a locally- but not globally-optimal farm size that is small; a condition that precludes potential productivity gains via mechanization. Because mechanization substitutes for labor, the disequilibrium described by Foster and Rosenzweig as “too many small farms” is also a disequilibrium of too many farmers. Potentially, constraints to out-migration may also explain the set of forces that keep farms small in Asia and Africa. Conversely, the successful adoption of mechanization may free labor resources locked in labor-intensive small farms and speed up migration rates.

Evidence elsewhere suggests a range of relationships between mechanization and labor intensity (Otsuka et al. 2016). For example, the adoption of mechanization can be associated with partial substitution of machines for labor where on-farm labor inputs decline, and household labor is split between on- and off-farm employment, muting the transformation of labor markets. See, for example, the transition

toward mechanization in the Philippines described by Estudillo and Otsuka (1999). Elsewhere, mechanization is associated with an increase in the size of cultivated farms and labor specialization. For example, Wang et al. (2016) describe how mechanization has been associated with increased average areas cultivated by farmers, increased migration, and a selection process whereby less educated farmers tend to specialize in farming. Still, it is worth pointing out that the disparities in the adoption of mechanization technologies share some similarities with the uneven adoption of Green Revolution technologies in Sub-Saharan Africa, where adoption rates are place-specific (Otsuka and Larson 2012, 2016).

Under ideal conditions, the productivity impacts of mechanization are fully reflected in agricultural wages and the average-value product of agricultural labor. Still, there are good reasons to believe this is not the case, including the effects of constraints on labor markets, land markets, and the well-known constraints on agricultural lending (Yadav and Sharma 2015). For this reason, we also include a measure of mechanization in our analysis.

20.4 Data

For most countries, migration is not directly measured, so it must be inferred from observations on labor. For our purposes, the underlying assumption is that without migration, labor in agriculture and non-agriculture would grow at the same rate as the labor force. Deviations from this are attributed to sectoral migration. In most cases, labor force and population data depend on censuses taken every ten years in most countries. Consequently, we base our calculations of migration on data that are ten years apart. Letting L_T represent total labor, migration from the agricultural sector is given as:

$$M_t = \left[\frac{L_{Tt}}{L_{Tt-10}} \right] L_{at-10} - L_{at} \quad (20.2)$$

Annualized migration rates are calculated as:

$$m_t = \left[\frac{M_{Tt}}{L_{a-10}} \right] \div 10 \quad (20.3)$$

The data in our analysis covers five decades, beginning in 1960 up to 2010. Using various sources, we extended the data reported in Larson and Mundlak (1997). The additional labor data is from the International Labor Organization, as reported in the World Bank Development Indicators (2022). The data on GDP and agricultural share of GDP is also from the World Bank, supplemented with data from the Food and Agriculture Organization of the United Nations (FAO 2022). Data on educational attainment is from Barro and Lee (2013), while additional population data comes

Table 20.1 Sample averages, by decade

Decades	1960s	1970s	1980s	1990s	'00 s
Observations	77	105	108	111	130
Migration	2.01	2.24	2.65	1.47	2.60
Labor growth	2.05	2.48	2.36	2.47	2.39
Ratio of incomes	1.86	2.85	4.20	6.65	15.80
Education, years of schooling	3.50	4.07	5.14	6.19	7.67
Share of population, 15–39	0.37	0.36	0.38	0.39	0.40
Tractors in use, thousands	121.68	129.80	170.01	196.68	197.24

Note Migration rates and labor growth rates are reported as percentage change per year from the beginning to the end of the decade. The remaining statistics are reported at the start of the decade

from the United Nations (2022). To proxy the extent of mechanization, we use data on the stock of tractors in use from FAO (2022).

The original data from Larson and Mundlak (1997) begins in 1950; however, the data on tractors are only available from 1961 to 2008. Using the 1961 data to proxy the beginning inventory value of tractors in 1960, the available data limits our analysis to five decades, starting in 1960 and ending in 2010.

As shown in Table 20.1, the panel is unbalanced, with the number of countries and the composition of countries changing each decade. We have data for 77 countries in our sample for the decade starting in 1960 and 130 countries from 2000 to 2010.

Annualized migration increased through the first three decades, slowed during the tumultuous 1990s, then quickened again in the '00 s. The size of the labor force grew consistently across decades. Consistent with trends in urbanization, the size of the non-agriculture sector relative to agriculture has increased rapidly during the past two decades. Educational attainment steadily increased, and the share of the working-age population under 40 increased slightly. Mechanization rates were already high in most countries in our sample by the 1960s, but gains were made in some places that the cross-country averages obscure.

20.5 Estimation Results

The model given in (Eq. 20.1) is nonlinear because of the inclusion of the wedge parameter k , so we estimated the model using nonlinear least squares, weighted by population. The full model estimates, complete with decade and regional dummies, are given in Table 20.2. Except for the parameter association with stocks of tractors, the estimated parameters are all statistically significant and take on the expected sign.

Of special interest is the equilibrium point parameter, c_0 , reported at the top of Table 20.2. The estimate implies that migration halts when the ratio of non-agricultural income to agricultural income reaches 0.97, implying a wedge equal to -0.03 . While the estimated parameter, c_0 , is statistically different from 0, it is not

statistically different from 1, as shown by the test statistic reported near the bottom of the table. Consequently, we cannot reject the notion that migration from agriculture continues until average incomes in and out of agriculture are equal. It is worth noting that when $k = 0$, the nonlinear migration model in (Eq. 20.1) collapses to a nested linear model. This is consistent with the preference of Ramsey et al. (2021) for linear over nonlinear models in their study of Japan and the United States.

The parameter on relative incomes (b_1) shows that migration out of agriculture speeds up as income differences increase. The parameter is slightly lower than the estimated value of 0.36 in Larson and Mundlak (1997). The model shows that migration increases as the labor force grows, but not proportionately. In line with expectations, the estimates show that youth matters; as the share of the working-age population under 40 increases, migration rates increase dramatically. That said, the spread in this demographic category is quite small in our sample, with a standard deviation of 0.03. Consequently, a two standard deviation increase in ‘youthfulness’ would only increase migration rates by 0.15% per annum.

The results also show that increases in educational attainment also speed up out-migration. At 0.50, the estimate is higher but consistent with Larson and Mundlak’s (1997) estimate of 0.29. It is also consistent with the finding that farmers leaving agriculture in China tend to be better educated than those that remain (Wang et al. 2016).

As noted, the estimated parameter on the tractor stocks is statistically indistinguishable from zero and takes the wrong sign. However, this is not true in comparable regressions where regional dummies have been omitted (Table 20.3). Moreover, excluding regional dummy variables does not affect the sign or significance of other parameters. Neither does excluding decade dummies.

Looking closely at the tractor-related results, it is important, at the start, to note that each of the individual time and region dummies are statistically significant and that tests that all regional dummies are equal can be rejected, as can the assertion that all time dummies are equal. Further, it could be that our proxy for mechanization (i.e., FAO’s count of tractor stocks) is a poor indicator of the extent of mechanization. Still, our sample rates of mechanization differ significantly relative to other determinants by region and region over time (Table 20.4).²

As such, it is plausible that the combination of time and regional dummies adequately sweeps up the effects of mechanization in the context of our cross-country panel. After all, under ideal land, labor, and capital markets, the impacts of investments in mechanization are captured by the value products of labor. Still, while these diminish the likelihood that our estimates are biased and imprecise, it leaves unsettled the degree to which constraints on the adoption of labor-saving technologies, especially mechanization technologies, impact the structural transformation of labor markets and economies.

² See Binswanger (1986) for a historical perspective on tractor use in Africa.

Table 20.2 Nonlinear regression results, full model

Parameter	Estimates	<i>t</i> -score	<i>P</i> > <i>t</i>
Equilibrium point ($c_0 = 1 + k$)	0.97	4.44	0.00
<i>Parameters on</i>			
Income ratio (b_1)	0.20	3.10	0.00
Labor ratio (b_2)	0.17	4.83	0.00
Labor growth (b_3)	0.50	2.14	0.03
Age (b_4)	2.46	6.29	0.00
Education (b_5)	0.50	5.23	0.00
Tractors (b_6)	-0.02	-1.26	0.21
<i>Dummies</i>			
1960s	0.59	6.04	0.00
1970s	0.28	3.13	0.00
1980s	0.41	6.32	0.00
'00 s	-0.25	-3.05	0.00
Africa	-2.88	-5.99	0.00
Asia & Oceania	-2.86	-6.11	0.00
Latin America	-2.64	-5.55	0.00
North America & Europe	-2.63	-5.10	0.00
Related tests	Test statistic	$p > F$	
Wedge (k) equals zero	$F(1, 516) = -0.03$	0.891	
Time dummies are equal	$F(3, 516) = 26.78$	0.000	
Regional dummies are equal	$F(3, 516) = 3.51$	0.015	

Note The model was estimated using Stata 17's nonlinear least squares estimator

20.5.1 The End of Surplus Labor and the Dual Economy

The gap between incomes in agriculture and other sectors was central to early theories of economic development. The disparity in economic welfare was apparent between the places where households depended on agriculture for their livelihoods and places where they did not, both within and among countries.

Early development theory focused on so-called 'surplus labor' locked in agriculture. This gave rise to a class of dual-economy models, where the dynamics of developing economies centered on labor, capital, and technology flows between agriculture and industry. The models were central to early debates about development theory (Lewis 1954; Ranis and Fei 1961; Jorgenson 1961, 1967). Broadly, the models were based on observations that, on average, wages and per capita incomes were lower in agriculture and higher in industry, and the dynamics centered on moving labor

Table 20.3 Nonlinear regression results, with and without regional dummies

Parameter	Estimates	<i>t</i> -score	<i>p</i> > <i>t</i>	Estimates	<i>t</i> -score	<i>p</i> > <i>t</i>
Intercept (b_0)	-4.31	-9.30	0.00			
Equilibrium point ($1 + k$)	0.99	4.65	0.00	1.02	14.84	0.00
<i>Parameters on</i>						
Income ratio (b_1)	0.21	3.16	0.00	0.71	6.07	0.00
Labor ratio (b_2)	0.99	4.65	0.00	0.68	14.76	0.00
Labor growth (b_3)	0.18	5.08	0.00	3.50	11.10	0.00
Age (b_4)	0.95	4.01	0.00	3.76	8.68	0.00
Education (b_5)	0.88	2.56	0.01	1.44	8.83	0.00
Tractors (b_6)	0.46	4.26	0.00	2.41	31.76	0.00
<i>Dummies</i>						
1960s				-37.81	-32.25	0.00
1970s				-38.94	-33.78	0.00
1980s				-37.38	-33.52	0.00
'00 s				-38.00	-33.35	0.00

Notes Tests where the income wedge k equals zero could not be rejected in either alternative version of the model. In the model with neither regional nor decade dummies, the test returned a test score $F(1, 523) = 0.00$, with $p > F = 0.95$. Including regional dummies resulted in $F(1, 519) = 0.09$, with a $p > F = 0.766$. Each decade dummy is significant individually, and a test that the decade dummies were equal to one another yielded an $F(4,519)$ score of 1,586, with $p > F = 0.00$

Table 20.4 Tractors in use divided by the number of workers employed by agriculture (FAO 2022)

Year	Africa	Asia and Oceania	Latin America and Caribbean	North America and Europe	Total
1960	0.004	0.007	0.016	0.214	0.059
1970	0.006	0.041	0.027	0.371	0.096
1980	0.012	0.060	0.035	0.542	0.137
1990	0.015	0.087	0.032	0.720	0.173
2000	0.012	0.088	0.032	0.724	0.220
Total	0.010	0.065	0.029	0.540	0.145

from traditional agriculture. Core debates centered on the extent to which agricultural labor could supply economic growth in other parts of the economy. Dual models of development gave rise to the type of analysis presented here and early explanations of inequality (Todaro 1969; Knight 1976; Robinson 1976; Bourguignon and Morrisson 1998).

The idea that agriculture was a nearly endless source of labor was understandable when the dual model emerged. After all, in the developing world, agriculture employed nearly three-quarters of the labor force in 1950, down only slightly from

77.9% in 1900. Moreover, the number of developing-country workers in agriculture had increased by 44% in that period.

To see this, consider the following decomposition, derived from our earlier definition of migration:

$$\Delta L_a = 1 + n - m \quad (20.4)$$

When migration rates (m) approximate labor-force growth rates (n), changes in the number of agricultural workers are easily obscured, especially when measures of the sector's workforce are inexact (Larson and Mundlak 1997). Our sample showed that differences between the two rates were generally small. Nonetheless, the effects accumulate with sufficient time as the share of labor outside of agriculture grows. At a point, the flows from agriculture become less important than the natural growth within non-agriculture. Specifically, in (Eq. 20.5), the number of migrating workers (M) becomes small relative to the number of workers born into the sector ($L_{nt-1}e^n$).

$$\Delta L_n = L_{nt-1}e^n + M_t \quad (20.5)$$

In 1970, Dixit wrote, "In the long run, one hopes, the dual economy will cease to be dual" (p. 229). As shown in Table 20.5, that time is upon us.

Table 20.5 reports the share of the population living in rural areas, which historically closely follows the share of labor engaged in agriculture. The underlying data is taken from FAO's (2022) historical and projected population numbers. The series runs from 1950 to 2050. The table reports the share of populations living in rural areas by region in 1950 and projected shares for 2050. The table also reports 'inflection years,' which are years in which rural population shares dipped below 50%.

The table shows that most of the world's population (70%) lived in rural areas in 1950 and that most people lived in rural areas until well into the twenty-first century. However, by 2050, nearly 70% of the world's population will not live in rural areas. Harkening back to David Grigg's quote, agriculture's dominant role as an employer, which began in Neolithic times, ended in this century.

Still, the disparities in income that motivated early dualistic models of development remain. In the wealthy countries of North America, Northern Europe, and Oceania, rural population shares had already fallen below 50% by 1950. During the late 1950s and early 1960s, urban majorities had emerged in Central and South America and Eastern and Southern Europe. In contrast, Asia's population remained primarily rural until 2018, and Africa's population is projected to remain primarily rural through 2035. Projections suggest that rural populations will remain in the majority beyond 2050 in Eastern Africa, Melanesia, and Polynesia.

As Menashe-Oren and Bocquier (2021) point out, global urbanization is no longer driven by sectoral migration, and as Taylor et al. (2012) note, the era of farm labor abundance is ending in many places.

Table 20.5 The transformation of rural populations. (FAO 2022 and authors' calculations)

Area	Share 1950	Inflection year	Share 2050
World	0.70	2007	0.32
Africa	0.86	2035	0.42
Eastern Africa	0.95	post-2050	0.55
Middle Africa	0.86	2019	0.33
Northern Africa	0.75	2012	0.35
Southern Africa	0.62	1994	0.22
Western Africa	0.91	2024	0.37
Americas	0.47	pre-1950	0.12
Northern America	0.36	pre-1950	0.11
Central America	0.61	1966	0.17
Caribbean	0.64	1976	0.18
South America	0.57	1959	0.10
Asia	0.83	2018	0.34
Central Asia	n.a	2026	0.37
Eastern Asia	0.82	2007	0.18
Southern Asia	0.84	2044	0.46
Southeastern Asia	0.84	2021	0.34
Western Asia	0.73	1978	0.19
Europe	0.49	pre-1950	0.16
Eastern Europe	0.61	1963	0.20
Northern Europe	0.28	pre-1950	0.11
Southern Europe	0.54	1958	0.18
Western Europe	0.35	pre-1950	0.13
Oceania	0.37	pre-1950	0.28
Australia and New Zealand	0.24	pre-1950	0.09
Melanesia	0.82	post-2050	0.68
Micronesia	0.69	1972	0.24
Polynesia	0.77	Post-2050	0.51

20.6 Conclusions

We extended the dataset used by Larson and Mundlak (1997) and replicated their analysis. We also expanded the analysis to consider the impact of labor-saving mechanization on migration rates. Our analysis covers migration across five decades, beginning in 1960 and ending in 2010.

During that time, the process described conceptually and empirically in Larson and Mundlak (1997) continued. Rates of migration out of agriculture to other sectors

proved responsive to income differences. The model suggests that younger and better-educated workers were most likely to leave agriculture. Moreover, the flow of migration was path-dependent and depended on the initial allocation of labor between sectors and labor growth rates.

Despite reasons to believe that transaction costs and imperfect labor markets might cause migration to cease before income gaps between the sectors disappeared, no evidence was found to support the existence of an equilibrium income wedge, a finding also consistent with Larson and Mundlak (1997).

Evidence favoring the notion that the use of labor-saving mechanization technologies was elusive, perhaps due to the limitation in our proxy measure (i.e., national tractor inventories). An alternative explanation is that the heterogeneity in the adoption of mechanization technologies is largely explained by regional differences and that measured impacts of adoption on migration rates are subsumed into measured regional effects. Regardless, further research along the lines of Estudillo and Otsuka (1999), Otsuka et al. (2016), and Wang et al. (2016) is needed to fully understand the constraints on the adoption of mechanization technologies.

More broadly, the inherent dynamics of sectoral migration have played out in a dramatic but predictable way over the last 70 years. Proportionally, small flows of labor out of agriculture into other sectors were at first hard to distinguish from natural rates of population growth, leaving economists to speculate about nearly perfectly elastic supplies of labor originating in agriculture. Over time, the small flows of labor accumulated, and the shift in labor allocations shares accelerated, shifting populations from rural spaces to urban centers.

The structural transformation of labor, away from its long-standing center in agriculture, is nearly complete in many places but continues to play out in others. Still, the broad dynamics driving change are already in place. In all likelihood, the seeds of the next transformation are also in place.

Recollections of Professor Keijiro Otsuka

Gershon Feder introduced me to Kei when I was a researcher at the World Bank. The meeting launched a collaboration resulting in journal articles, book chapters, and two edited volumes on Green Revolution technology adoption in Africa. In addition to having the opportunity to work with Kei, I had the chance to enjoy his company and meet his students over dinners in Washington, Tokyo, and Nairobi. Kei is a prolific and influential researcher, well known to the international community and policymakers. He is energetic and engaging. Importantly, he is a supportive teacher and mentor. He launched and guided a new generation of skilled economists, especially during his stewardship of GRIPS (National Graduate Institute for Policy Studies). I would like to thank the editors for inviting me to contribute to this volume. It is a special honor and pleasure to be part of the *Festschrift* celebrating Keijiro Otsuka.

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