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A World Without Farmers?
The Lewis Path Revisited

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Abstract

This paper questions the Lewis Path perspective of a “world without agriculture” which underpins the “structural transformation” paradigm of “modern growth.” It shows that the Lewis Path is only one of four potential structural paths, and that half of the world’s population is spiralling into a “Lewis Trap” with more farmers and an increasing income gap between them and other workers. After showing how land constraints and the productivity dynamics outside agriculture might prevent this population from switching to a Lewis Path, it delineates the condition of an alternative path that would not transfer the disparity problem to cities.

Keywords: Agriculture, Productivity, Development, Structural transformation, Poverty, Agro-Ecology.

***U**n monde sans paysans ?*
Le chemin de Lewis revisité

Résumé

Cet article interroge le paradigme de « transformation structurelle » et de « croissance moderne » qui conduit *in fine* à un « monde sans agriculture ». Il montre d’abord que ce « chemin de Lewis » (*Lewis Path*) n’est qu’une voie parmi quatre possibles, et que seuls les pays industrialisés ou en transition l’ont suivi durant les dernières décennies. La moitié de la population mondiale est plutôt embarquée dans une direction diamétralement opposée (*Lewis Trap*) où la population active agricole croît ainsi que son écart de revenu avec les autres travailleurs. En recomposant les productivités partielles de la terre et du travail en calories de 1961 à 2007, l’article montre ensuite comment la contrainte en terre interdit à la plupart des actifs agricoles d’augmenter la productivité de leur travail par la moto-mécanisation à grande échelle. Enfin, des simulations numériques projetant l’Inde en 2050 montrent quels facteurs extérieurs à l’agriculture barrent la route de Lewis à ce pays et d’autres. L’article introduit et discute alors un autre paradigme de développement, celui d’une intensification écologique hautement productive à petite échelle, intensive en travail comme en savoirs génériques et locaux, insérée dans le secteur manufacturier comme dans celui des services.

Mots-clés : Agriculture, Productivité, Développement, Transformation structurelle, Pauvreté, Agro-Ecologie.

A World Without Farmers?
The Lewis Path Revisited

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Contents

1. Introduction

In the aftermath of the sharp 2007-08 increases in food prices, many agricultural economists denounced the lack of interest in agriculture which began the mid-1980s in both the academic and donor communities (Janvry, 2010). The soaring prices exacerbated the pre-existing concentration of poverty and under-nutrition in rural areas of developing countries (Chen & Ravallion, 2007). The recommendation emerged to increase R&D (research and development) spending "to restore productivity growth" (Alston, Beddow, & Pardey, 2009) "so that agriculture can play its role as an engine of growth and poverty reduction and act as the longer-term pillar of the twin-track approach to fighting hunger" (FAO, 2009).

The role of agriculture as an engine of growth was emphasized early on by the Physiocrats (Quesnay) and the Classical school (Ricardo). After World War II, agriculture became a key component of the "Structural Transformation" paradigm (Chenery & Srinivasan, 2007: 197-465). This paradigm is anchored in economic theories about interrelated structural changes between the "traditional" (agriculture) and "modern" (non-agriculture) sectors (Lewis, 1954) and in the historical experience of "modern economic growth" (Kuznets, 1966): agriculture provides labour and savings in addition to low-cost food to the process of industrialization and urbanization and, in turn, industry provides increasingly cheaper agricultural inputs that improve yields. Labour productivity of the rural economy then rises, wages are drawn up and poverty is gradually eliminated. This is the "Lewis Path" and this path ultimately leads to a "world without agriculture" (Timmer, 1988, 2009) where the share of agriculture in both total labour and value added is 2-3% once productivity and income across the agricultural and non-agricultural sectors have converged (Larson & Mundlak, 1997).

Whether this virtuous circle is initiated by a technical revolution in agriculture, in industry or in both, this paradigm supports the longstanding view that "low agricultural productivity is a major reason that some countries are poor" and that barriers to "modern agricultural technology subject to exogenous technical change" jam the whole developmental process (Gollin, Parente, & Rogerson, 2002).

In this paper, our aim is to show that, although important, high levels of agricultural productivity per hectare do not suffice to embark upon the Lewis Path with a view to eradicating poverty as this path implies meeting other conditions which remain beyond the possibilities of most developing countries.

We first show that the Lewis Path is only one of four possible paths of structural transformation and that routes actually followed by world regions over the past half century cover this range of options (section 2). Second, we carry out a calorie-based assessment of productivity growth in agriculture since the 1960's that helps characterize the growth engine at play while introducing the role of the relative growth rate of labour productivity in the agricultural and non-agricultural sectors (section 3). Third, we conduct a heuristic exercise on India to show the difficulties of switching to a Lewis Path over the next half-century and beyond (section 4). We conclude by focusing on the necessity to revisit the content of technical progress in agriculture and the relationships between both rural and urban areas and agricultural and non-agricultural sectors.

2. The Lewis path confronted with historical evidence

2.1. Technology and labour productivity in agriculture: a "TALA" fundament

Comparative research on productivity growth in agriculture was stimulated by Schultz (1953) and Farell (1957) in parallel with the growing influence of the Solow (1957) growth model to measure aggregate productivity. Ruttan (2002) detects three stages in its development:

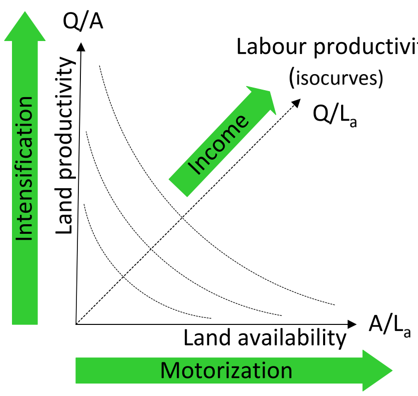
(1) Partial productivity ratios (output per worker and per hectare) reveal wide differences from country to country.

(2) Multifactor productivity estimates through cross-country production functions led Hayami and Ruttan (2002) to conclude that resource endowments (land and livestock), modern technical inputs (machinery and fertilizer) and human capital (including technical education) each accounted for around one-fourth of the differences in labour productivity between developed and less-developed countries, and that scale economies, "present in developed countries but not in less developed countries," accounted for only 15%. They suggested that population pressure on land resources could be circumvented and labour productivity increased by several multiples (up to the levels of Western Europe in the early 1960s) by investing in research, human capital and modern agricultural inputs.

(3) The Malmquist (frontier productivity) approach more recently indicated a widening productivity gap between developed and developing countries from the early 1960s to the early 1990s, and declining total factor productivity in developing countries (relative to the frontier countries) with less technical change against efficiency change.

These three approaches are faced with data limitations that will be discussed in the next section. Let us first introduce a slight change in the usual representation of technology and labour productivity trends in world agricultures. Hayami and Ruttan (1985) or Craig et al. (1997) show them along five graphical dimensions: yield or partial land productivity (y-axis), partial labour productivity (x-axis), acreage of land per agricultural worker (iso-curve), time (years) and space (countries or regions). We instead plot land productivity and land availability per farmer on the y-axis and x-axis respectively (Figure 1) to clearly display the two orthogonal directions along which labour productivity (iso-curves) can be increased in agriculture: "intensification" (higher production per unit of land with irrigation, fertilizers, etc.) and "motorization" (higher cultivated land per worker with tractors, combine harvesters, etc.). "Motorization" means actually "moto-mechanization" (Mazoyer & Roudart, 1997), using motors instead of human or animal energy to drive ploughs, sowers, cultivators, sprayers, harvesters and other agricultural machinery. The higher the acreage of land per agricultural worker, the more profitable under the conditions that cheap machinery and fossil fuels are accessible.

Figure 1. An alternative representation of land and labour productivity pathways



This graphical representation pictures a TALA identity, "Technology, Affluence and Labour productivity in Agriculture," given in Equation 1 where Q denotes the agricultural production (in tonnes or other units), A the acreage of cultivated land (ha) and L_a the workforce in agriculture (heads). In TALA, a variation in labour productivity (Q/L_a, in tonne/worker) is the product of variations in "intensification" (Q/A, in tonne/ha) and "motorization" (A/L_a, in ha/worker):

$$Q/A \bullet A/L_a = Q/L_a \qquad \text{TALA} \quad (1)$$

2.2. Structural transformation: a taxonomy of potential paths

It is easy to pass from this TALA identity to the OTAWA identity, "Outcome, Technology, Affluence and Workforce in Agriculture," used by Malassis and Padilla (1986) to characterize socioeconomic patterns of agricultural production[1]. OTAWA shows how "intensification" and "motorization" co-evolve with the share of agricultural labour into total population (L_a/N) to contribute to total per capita production (Q/N) (Equation 2):

$$Q/N = Q/A \bullet A/L_a \bullet L_a/N \qquad \text{OTAWA} \quad (2)$$

The share of agricultural labour is an important parameter of the "growth engine" at play. It introduces our central question: how far past increases in agricultural per capita production (Q/N) were driven by "intensification" (higher Q/A) and by the "discharging" (Sauvy, 1980) of labour from agriculture to other sectors (lower L_a/N) that enables land per worker to increase and motorization to develop (higher A/L_a)? Is this discharging fast enough to make possible a pace of agricultural motorisation that boosts both agricultural labour productivity and the convergence of labour incomes across sectors?

To explore this cross-sectorial dynamic, two indicators can be extracted from the statistics of value-added (Y) in the agricultural and non-agricultural sectors ($Y=Y_a+Y_{na}$):
• the "Labour Income Gap" (LIG), i.e. the difference (used in Timmer, 2009) between the share of agriculture in total value-added and that of farmers in total labour (Equation 3)
• the "Labour Income Ratio" (LIR), i.e. the ratio (used in Yujiro Hayami & Godo, 2004) between the above two shares (Equation 4):

$$(Y_a/Y) - (L_a/L) \qquad \text{Labour Income Gap } (LIG) \quad (3)$$
$$(Y_a/Y) \; / \; (L_a/L) \qquad \text{Labour Income Ratio } (LIR) \quad (4)$$

In the Lewis Path, *LIG* is initially negative (income per agricultural worker lower than national average) and tends towards zero, while *LIR,* initially less than one, increases towards unity.

The *LIR* indicator can be used heuristically to characterize the conditions under which the structural transformation towards a "world without agriculture" can take place, and to identify alternative pathways when these conditions are not met. To do so, let us crossbreed two derivatives with respect to time.

Equation 6 shows that *LIR* increases only when agricultural labour productivity $\Theta_a = Y_a/L_a$ grows faster than average labour productivity $\Theta = Y/L$:

$$ln(LIR) = ln(Y_a) - ln(Y) - ln(L_a) + ln(L) = ln(\Theta_a) - ln(\Theta) \quad (5)$$
$$\Rightarrow \dot{LIR}/LIR = \dot{\Theta}_a/\Theta_a - \dot{\Theta}/\Theta \quad (6)$$

Equation 8 shows that the number of agricultural workers decreases only when agricultural labour productivity Θ_a grows faster than agricultural output Y_a:

$$ln(\Theta_a) = ln(Y_a/L_a) \quad (7)$$
$$\Rightarrow \dot{L}_a/L_a = \dot{Y}_a/Y_a - \dot{\Theta}_a/\Theta_a \quad (8)$$

[1] OTAWA (our own denomination as for "TALA") is similar to the "IPAT identity" used in the environmental literature (Ehrlich & Holdren, 1972; Waggoner & Ausubel, 2002), where I (environmental impacts) = N (population size) • A (level of affluence) • T (level of technology), and the "Kaya identity" in the energy literature (from the name of the Japanese engineer Yoichi Kaya).

Depending on the sign of the variation of LIR and of L_a, three other pathways than the "Lewis Path" can be identified and characterized according to the relative growths of Y_a, Θ_a and Θ (Table 1).

(a) In path A, farm and nonfarm labour incomes converge ($LIR \rightarrow 1$) while the number of farmers increases ($\dot{L}_a/L_a > 0$). High growth in demand for agricultural products (Y_a) pulls farmers wealth up (Θ_a) faster than average (Θ). This is a "Farmer-Developing" path. The interpretation of this path is not univocally optimistic since if agricultural demand comes from the foreign rather than the domestic market, it may be consistent with growing urban poverty.

(b) In path B, labour incomes also converge but the agricultural workforce decreases. Outgoing farmers are replaced by motorized equipment that boosts agricultural labour productivity (Θ_a): it grows faster than demand for agricultural products (Y_a) and than average labour productivity (Θ). This is the Lewis Path.

(c) In path C, the income differential widens ($\dot{LIR}/LIR < 0$) and the agricultural workforce increases. Farmers' labour productivity (Θ_a) increases less rapidly than agricultural output (Y_a) and average labour productivity (Θ). This is a "Lewis Trap," the polar opposite of the Lewis Path. Unless new arable lands become available, average acreage per farmer decreases, thereby diminishing the possibility of increasing labour productivity with motorization.

(d) In path D, the number of farmers decreases and the income gap with non-agricultural workers widens. This is a "Farmer-Excluding" path where farmers become fewer and poorer relative to other workers.

Table 1. Typology of structural transformation paths

			Active population in agriculture: Increasing	Active population in agriculture: Decreasing
			$\dot{L}_a/L_a > 0$ ($\dot{\Theta}_a/\Theta_a < \dot{Y}_a/Y_a$)	$\dot{L}_a/L_a < 0$ ($\dot{\Theta}_a/\Theta_a > \dot{Y}_a/Y_a$)
Income differential between agricultural & non-agricultural workers	Narrowing	$\dot{LIR}/LIR > 0$ ($\dot{\Theta}_a/\Theta_a > \dot{\Theta}/\Theta$)	(A) FARMER-DEVELOPING $\dot{Y}_a/Y_a > \dot{\Theta}_a/\Theta_a > \dot{\Theta}/\Theta$	(B) LEWIS PATH $\dot{\Theta}_a/\Theta_a > \dot{Y}_a/Y_a, \dot{\Theta}/\Theta$
	Growing	$\dot{LIR}/LIR < 0$ ($\dot{\Theta}_a/\Theta_a < \dot{\Theta}/\Theta$)	(C) LEWIS TRAP $\dot{\Theta}_a/\Theta_a < \dot{Y}_a/Y_a, \dot{\Theta}/\Theta$	(D) FARMER-EXCLUDING $\dot{\Theta}/\Theta > \dot{\Theta}_a/\Theta_a > \dot{Y}_a/Y_a$

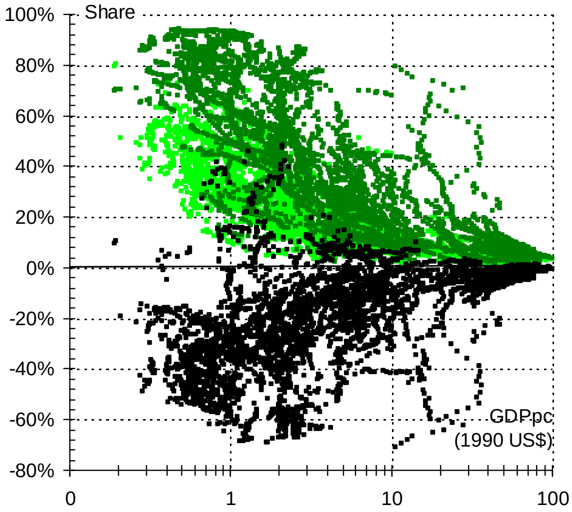
2.3. Historical evidence: contrastive paths without convergence

On the basis of available worldwide statistics on value-added (see next section for data details), let us now see which of the above pathways have been followed over the last decades (1970-2007) and what part of humanity has embarked upon a "Lewis Path."

It is often suggested that all countries have embarked upon a Lewis path by plotting country GDP per capita against the share of agriculture in total value-added and in total employment, and the difference between these two shares (LIG), as in Figure 2. This vision is questioned by Figure 3 where countries are grouped into regions (see details in next section and Figure 6 in appendices). The latter clearly shows that the Lewis Path is followed only by industrialized countries and countries in transition. Latin America, the Middle East and Africa follow a "Farmer-Developing" path with an increasing number of farmers and a narrowing gap between farm and non-farm incomes[2], while Asia has entered a "Lewis Trap." At the aggregate level, the whole world looks as if it is oriented towards a "Lewis Trap" given the demographic importance of Asia.

[2] aggregated regional tendencies: within these regions, most countries followed this path but some followed a Lewis Path (Brazil, Cuba, Dominican Republic, El Salvador, Guyana, Jamaica, Uruguay, Venezuela; Israel, Lebanon, Libya, Saudi Arabia; Gabon, Nigeria, South Africa) and others entered a Lewis Trap (Haiti; Turkey; Angola, Botswana, Burundi, Chad, Gambia, Kenya, Lesotho, Mali, Mauritania, Mozambique, Senegal, Swaziland, Tanzania, Uganda, Burkina Faso)

Figure 2. The structural transformation (1970-2007)

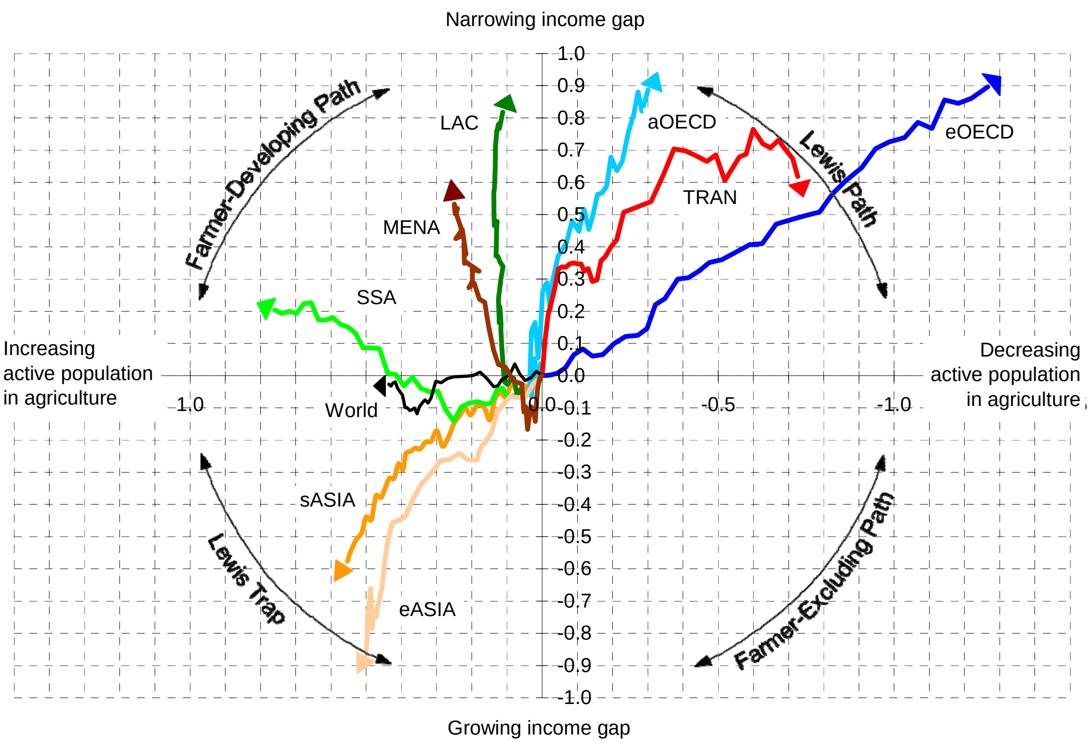


Based on Timmer and Akkus's representation of structural transformation (Timmer, 2009: 7), the figure shows all countries from 1970 to 2007 (5,020 points without Kuwait and Iceland) and their respective:

- share of agriculture in total value-added (light green points),
- share of agriculture in total employment (dark green points),
- agricultural value-added share minus agricultural employment share (black points),

according to average value-added per capita (GDPpc in 1990 US$ per day, values between [0.1-100.0]).

Figure 3. The structural transformations (1970-2007)



The figure represents the cumulative annual growth rates from 1970 (=0) to 2007 of:
- the active population in agriculture (x-axis) (FAO, 2010),
- the income differential between agricultural and non-agricultural workers (y-axis) measured with the Labour Income Ratio (LIR, equation 4) in 1990-US$ (UNSTAT, 2010),

in order to show what type of structural transformation path is followed (Table 1). The longer the curve, the faster the process.

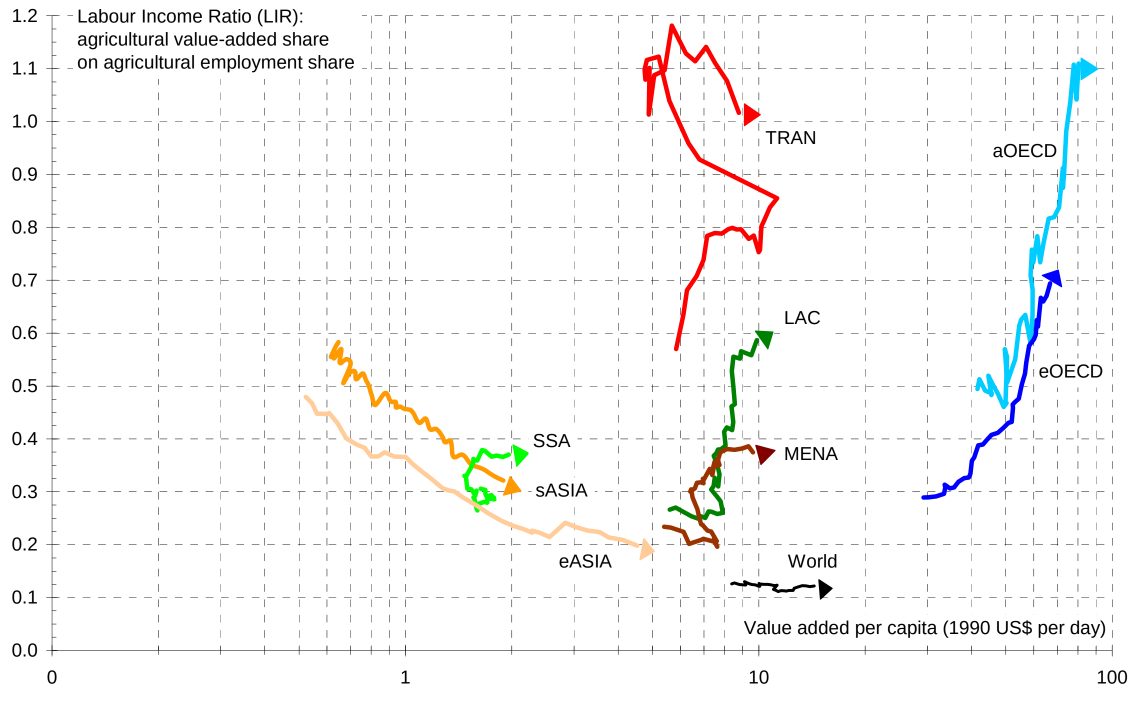
Table 2 provides additional information. Total GDP and labour productivity growths were the highest in Asia. In 2007, this region caught up with sub-Saharan per-capita income. This level was, however, lower than that all other regions held in 1970 (Figure 4). In these other regions as well, per-capita income increased, more slowly but with a growing convergence of labour income between farm and non-farm sectors. This convergence was the fastest in industrialized countries where per-capita income doubled to reach 72 US$ per day in 2007 although it did not exceed 10 US$ anywhere else.

Table 2. The structural transformation paths (1970-2007)

	Population (heads)	Workforce (workers)		Economic growth (1990-US$)		Labour productivity (1990-US$ / worker)		Labour Income Gap/Ratio		Pathway
	Total	Total	Agriculture	Total	Agriculture	Total	Agriculture	LIG (Eq.3)	LIR (Eq.4)	(Table 1)
aOECD	1.08%	1.62%	-0.89%	2.91%	2.76%	1.27%	3.69%	-7.85%	2.40%	Lewis Path
eOECD	0.47%	0.82%	-3.42%	2.74%	0.79%	1.90%	4.36%	-6.32%	2.42%	Lewis Path
TRAN	0.38%	0.38%	-1.96%	1.91%	1.07%	1.50%	3.07%	4.44%	1.67%	Lewis Path
LAC	1.89%	2.92%	0.30%	3.50%	3.03%	0.56%	2.73%	-4.01%	2.21%	FD growth
MENA	2.44%	3.00%	0.67%	4.10%	3.07%	1.08%	2.40%	-2.79%	1.36%	FD growth
SSA	2.75%	2.80%	2.05%	3.28%	3.09%	0.46%	1.01%	-0.98%	0.55%	FD growth
sASIA	2.13%	2.28%	1.49%	5.17%	2.76%	2.82%	1.25%	0.58%	-1.56%	Lewis Trap
eASIA	1.49%	2.07%	1.35%	7.61%	4.38%	5.44%	3.00%	0.47%	-2.31%	Lewis Trap
World	1.61%	1.95%	1.18%	3.10%	2.25%	1.13%	1.06%	-0.74%	-0.07%	Lewis Trap

Note: percentages are average regional annual growth rates between 1970 and 2007

Figure 4. Income convergence/divergence (1970-2007)



3. Structural paths and agricultural technology: the land driver

3.1. Agricultural productivity through the lens of an alternative metric

Are these diverging trends from the Lewis Path driven by insufficient agricultural productivity that modern agricultural technology could boost if barriers were lifted? Comparative research on productivity growth in agriculture tends to support this diagnosis through evidence of a technology gap between developed and less-developed countries (e.g. Mueller, et al., 2012). But such studies faced one of the following limits:

(1) They compare agricultural output per hectare crop-by-crop whereas a crop can be the main annual output of a unit of land or just a part of it. The first model dominates in developed countries under a continental climate whereas in tropical and subtropical countries, several crops can be harvested yearly with good irrigation and fertilization. The two models obey two different logics. In the multi-crop model, farmers have no interest in maximising the yield of one crop if it jeopardizes the returns of the others. They may be below the technical frontiers observed elsewhere for each crop but at the technical frontier for their complex combination of crops.

(2) They compare indexes of total annual agricultural outputs, with production data in monetary terms deflated by a general price inflation to capture production changes over time and aggregated over baskets of agricultural products (Craig, et al., 1997). This method faces well-known difficulties: the PPP versus real exchange rates dilemma in comparing monetary indexes across countries, the structural change in the composition of the representative output basket, and the absence of detailed data on local prices.

To overcome these limitations, we estimated levels and trends in land and labour productivities after having converted and aggregated all tonnages of plant food harvested during a year into kilocalories (kcal), for (almost) all countries and over a 47-year period (1961-2007)[3]:

(a) We first checked and merged five international statistical series: "Commodity Balances,"[4] "Land,"[5] "Population"[6] and "Machinery"[7] from the FAO (2010) over 47 years (1961-2007) and, to analyse cross-sector incomes (see previous section), "Value Added by economic activity"[8] from UNSTAT (2010) over 38 years (1970-2007). Many islands or micro-states plus Afghanistan, Iraq, Oman, Papua New Guinea and Somalia had to be removed because of missing or inconsistent data, but our database covers 98% of the world population (2000) and of the world land area (Antarctica excluded).

(b) We then converted and aggregated all harvested edible plant biomass into calories to produce the index of plant food productions $Q_r = \sum_i (q_{ir} c_i)$, where r is a region, i a plant biomass edible in its primary form (cereal, oilseed, root, fruit, etc.) regardless of its final use as food, feed, seed or other[9], q the volume of production in metric tonnes, and c the conversion factor into food calories (kcal per tonne) according to the FAO (2001) or the USDA (2006)[10]. The regions are Sub-Saharan Africa (SSA), the Middle East and North Africa (MENA), Latin America and the Caribbean (LAC), developing Asia (ASIA) divided into South Asia (sASIA)

[3] See Bairoch (1999) for a preliminary tentative in this direction. Actually, this use of a calorie metric in agriculture is similar to using the ton-oil-equivalent or exajoules to build energy balances.
[4] of which agricultural production in tonnes
[5] of which "Arable land" (annual crops) and "Permanent crops" (perennial crops); we named "cultivated area" the sum of the two land surfaces
[6] of which "total population," "urban population," "agricultural population," "total economically active population" and "total economically active population in agriculture"
[7] of which "agricultural tractors in use"
[8] of which "Total value added" and "Value added from agriculture, hunting, forestry, fishing" at constant 1990 prices in US dollars (US$)
[9] 55 product lines of the FAO's Commodity Balances: Wheat, rice & other grains of cereals; Beans, peas & other pulses; Cassava, potatoes & other roots or tubers; Tomatoes, onions & other vegetables; Apple, oranges & other fruit; Soya bean, cottonseeds, olives & other oilseeds or tree nuts; Sugars & molasses; Cocoa, coffee & tea; Pepper, cloves & other spices
[10] for details on calculations and general checking of the estimates, see Dorin (2011)

and East Asia (eASIA), Transition Countries (TRAN), and industrialized countries of 1990-OECD[11] (OECD) divided into Eurasia (eOECD) and North America + Oceania (aOECD) (Figure 6).

(c) We concluded by estimating partial land and labour productivities by dividing regional productions Q_r by, respectively, the FAO net area under annual and permanent crops (A) and the FAO "economically active populations in agriculture" (L_a). For the latter, since the FAO uses new ILO[12] estimates starting only from 1980 (5th edition, revision 2008), we reconstructed 1961-1979 active populations using the updated 1980 values and the 1961-1980 annual growth rates computed from earlier estimates[13]. The labour data include male and female workers involved in agriculture, forestry and fisheries, and not only people producing plant food. Similarly, cultivated lands include land dedicated to other production than edible biomass, such as fibres, rubber, tobacco or fodders. The land and labour productivities thus tend to be underestimated, especially in countries with important non-edible biomass production or animal production[14].

3.2. Contrastive agricultural productivity paths

With TALA and OTAWA identities, let us now study how agricultural outputs and partial productivities in calories have evolved from 1961 to 2007. During that period, the world population increased by 116% and the production of food calories of plant origin by 186%, from less than 12 tera kcal (Tkcal) a day in 1961 to over 33 in 2007 (Figure 7a in appendices). This unprecedented production growth enhanced the world daily availability of plant food per capita by one third to reach 5,070 in 2007 (Figure 7b). This growth resulted from a large 156% increase in land productivity (8,620 kcal.ha^{-1}.day^{-1} in 1961 to 22,110 in 2007: Figure 8b) and a small 11% increase in cultivated land (Figure 8a)[15]. Only 153 million additional hectares were indeed cultivated for 514 million additional farmers (+68%) (Figure 9a): the average cultivated area per worker declined from 1.8 ha in 1961 to 1.2 in 2007. On average, per-farmer productivity increased only by 70%, from 15,320 to 26,095 kcal per day (Figure 9b)[16].

Figure 5 displays the regional 1961-2007 evolutions of the three TALA parameters and shows that world averages of land availability and productivity per farmer mask huge discrepancies between regions around a critical interval between 2 and 3 ha.

(a) Labour productivity: a boom in industrialized countries

Annual growth rates of TALA/OTAWA parameters (Table 3) confirm that the regions which embarked upon a Lewis Path increased their agricultural labour productivity the fastest, measured here in calories[17]. In 2007 (Table 4), OECD's plant food production per farmer reached 670,000 kcal per day on average (up to 1,992,000 in Canada, 1,908,000 in USA, 1,118,000 in France, 1,107,000 in Denmark) while it remained below 120,000 kcal in other regions, and even below 14,000 in Asia and Sub-Saharan Africa (Figure 9b). This contrasting

[11] Organisation for Economic Co-operation and Development as in 1990

[12] International Labour Organisation, Geneva

[13] "Population-Estimates 2004 rev." as released by the FAO in 2008. With these previous estimates, our world active population in agriculture reached 1,058,355 thousand people in 1980 (841,922 in 1961 and 1,308,611 in 2000) while it reached only 948,580 with the latest estimates (760,656 in 1961 and 1,217,540 in 2000).

[14] It is tricky to include animal products in the calculations (about 10% of the total world production of food calories) since their production relies on *(i)* domestic plant foods (already taken into account in our calculations) and imported ones (such as oilcakes), *(ii)* large but very poorly known surfaces of permanent grazing areas (pastures, savannah, shrubs, etc.).

[15] This leads us to estimate that 90% of the world plant food production growth was based on an increase in land productivity and not land extension, with of course regional specificities (about 65% in Sub-Saharan Africa and Latin America for example): see Table 3 ([5]/[3]).

[16] As a combined effect of these evolutions, the world average number of persons nourished by a farmer has increased from 4.0 to 5.2 (+29%).

[17] Similar growth rates of labour productivity in agriculture are obtained despite the change of metric, from per-worker value-added in 1990-US$ (Table 2, column [7]) to per-worker production of plant calories (Table 3, column [8]). One exception is East Asia where high value-added productions such as meat grew faster than the plant food productions. Results of Table 3 over 1970-2007: 3.90% (aOECD, *vs.* 3.69% in 1990-US$), 4.77% (eOECD, *vs.* 4.36%), 2.61% (TRAN, *vs.* 3.07%), 2.98% (LAC, *vs.* 2.73%), 2.11% (MENA, *vs.* 2.40%), 0.51% (SSA, *vs.* 1.01%), 1.13% (sASIA, *vs.* 1.25%), 1.55% (eASIA, *vs.* 3.00%).

result is explained by differences in per-farmer land availability (Figure 5) and in motorization (Figure 9c) that substitutes fossil energy for human and animal labour (Giampietro, Arizpe, & Ramos-Martin, 2011; Krausmann, et al., 2012). It results in huge incomes gaps[18]: 115 US$ a day in 2007 for a farmer in industrialized countries compared to less than 2 $ in Sub-Saharan Africa and Asia (3.7 US$ on the world average).

(b) Land productivity: the Asian leadership

There is a growing discrepancy between regional plant food productions per cultivated hectare, from one to two in the early 1960s (5,100 to 10,400 kcal a day) to one to three in 2007 (10,300 to 31,400 kcal a day) (Figure 8b). Asia has the highest land productivity in food calories after having overtaken OECD countries in the mid-1980s[19]. Its investments in infrastructure, education, credit, irrigation, fertilizers and high-yielding varieties certainly boosted both the number of crops per year on the same plot (crop intensity) and individual crop yields (mainly for wheat, rice, sugarcane and oil palm). By contrast, yield increase in industrialized countries has decelerated since the mid-1980s for many reasons: lower exports, increasing farm-gate prices of fossil energy and other inputs (fertilizers, water), lower incentives for sugar crops and other crops high in calories, soil or biodiversity erosion, environmental regulations, etc. Along with Asia, growth of land productivity was also high in MENA (the highest rate after Asia) as well as in Latin America where production of sugarcane and oilseeds has increased dramatically (for food, feed and biofuels) closing the yield gap with industrialized countries during the 2000s. Conversely, in Sub-Saharan Africa, where yield was at the same level as in MENA in 1961, it was multiplied only by two, the lowest regional growth over 1961-2007. This explains why Sub-Saharan Africa has almost the same labour productivity as Asia in 2007 despite a 2.6 times higher land availability per farmer.

(c) Land per farmer: a symptomatic separation line

Average net cultivated areas per agricultural worker (Figure 5a) constantly decreased in MENA, Sub-Saharan Africa and Asia (down to respectively 2.5 ha, 1.15 ha and 0.45 ha in 2007) while it constantly increased in Latin America, the transition countries and industrialized countries (up to respectively 4.0 ha, 9.9 ha and 26.6 ha)[20]. These divergent evolutions combine trends in:

- cultivated land (Figure 8a), that has decreased in transition and industrialized countries (–64 Mha in total) but expanded in other regions (+217 Mha), especially in Latin America and Sub-Saharan Africa (Table 3) at the expense of forests or permanent pastures[21];
- active populations in agriculture (Figure 9a), that has decreased in transition and industrialized countries (–64 M) and expanded elsewhere (+594 M) except in Latin America since 2000. It has almost doubled in Asia and was multiplied by 2.5 in Sub-Saharan Africa. As a result, 91% of the world's farmers are now concentrated in these two regions (77% in 1961) where farmers still represent 60% of the total workforce (80% in 1961), while the share is far lower everywhere else (Figure 9d)[22].

[18] Average agricultural value-added per farmer in constant 1990-US$. This income has to pay for human work but also fixed assets if any (land, draft animals, buildings, equipment, etc.).

[19] Countries above 40,000 kcal/ha in 2007: Malaysia (62,200), China (46,100), Bangladesh (42,500) and Vietnam (41,500) in Asia, Belgium (56,800), Germany (44,600), the Netherlands (41,400) and the United Kingdom (40,100) in Europe.

[20] This average cultivated area per worker does not account for disparities within a region or a country, which can be large. E.g.: according to the USDA, there were 2.2 million farms in the USA in 2010; their average size was 169 ha, but 56% of them had an average size of 34 ha and cultivated only 11% of the land whereas 10% of them had an average size close to 800 ha and cropped nearly half of the cultivated land. Similarly, in many Latin-American countries a formal sector with a few large-scale capital-intensive enterprises adopting labour-saving technologies coexists with an informal sector composed of numerous small-scale, labour-intensive enterprises based on low wages.

[21] Between 1961 and 2007, the world area under pasture increased by 278 Mha (+9%), with +135 Mha in ASIA (+32%), +77 Mha in MENA (+32%) and +85 Mha in LAC (+19%).

[22] In 2007 15 countries out of 154 in our sample had less than 3% of their workforce employed in agriculture: Belgium, Canada, Denmark, France, Germany, Israel, Japan, Kuwait, Lebanon, Luxembourg, Slovenia, Sweden, the Netherlands, the United Kingdom, the USA. Except for Kuwait, the UK and the USA, all of them had a percentage above 6% in 1980. In 2007, a "world without agriculture" (3% share of total employment) would mean 93 million farmers producing each 358,000 kcal/day on 16 ha (39,3 million farmers and 35 ha, respectively, in 1961).

3.3. The role of land constraints in structural bifurcations

Table 3 sums up the above results over 1961-2007 and shows that available land per farmer is a driver of bifurcations in structural transformation paths: its evolution (column [6]) either accelerates or decelerates the growth of agricultural labour productivity ([8]) enabled by higher yield ([5]+[6]=[8]).

The first key point is that high yield growth does not suffice to overcome the "deceleration effect." As observed before by Hayami and Ruttan (2002: 10-11), in a "land-constrained" context, output per hectare rises faster than output per worker while it is the opposite in a "land-abundant" context. With our caloric accounting, Asia and Sub-Saharan Africa definitely fall in the first group, industrialized and transition countries in the second (Table 3). The latter have embarked upon a Lewis Path; the former are clearly outside it.

The second key point is that for the Lewis followers, high and growing availability of land per farmer A/L_a ([6]) is not driven by an extension of cultivated land A ([1]) but by a massive decrease in the number of farmers L_a ([7]+[2]) resulting from outmigration from agriculture and the development, since World War II, of heavy motorized agricultural equipment to replace farmers. Such "labour-saving" and "energy-intensive" growth did not occur elsewhere, or with delay and at a much slower pace.

Developing motorization and boosting agricultural labour productivity is conditional upon a large land endowment that often implies a high level of agricultural exodus. When this condition cannot be fulfilled, regions below a critical interval of 2-3 ha per worker seem to take a direction opposite to that of the Lewis Path. Before 1970, land availability was below 5 ha per farmer in industrialized Eurasia (eOECD), transition countries and Latin America – much lower than in North America and Oceania (aOECD) but above 2-3 ha – and their Labour Income Ratio (*LIR*) rose to 0.6 or more in 2007 (Figure 4). All other regions kept a *LIR* value below 0.4. This value even declined in Asia which had the lowest availability of land per farmer in 1961 (1 ha or less): it has embarked upon the polar opposite of the Lewis Path, unlike industrial and transition countries that could increase their land availability per farmer as fast as their agricultural population declined.

Table 3. OTAWA/TALA average regional annual growth rates (1961-2007)

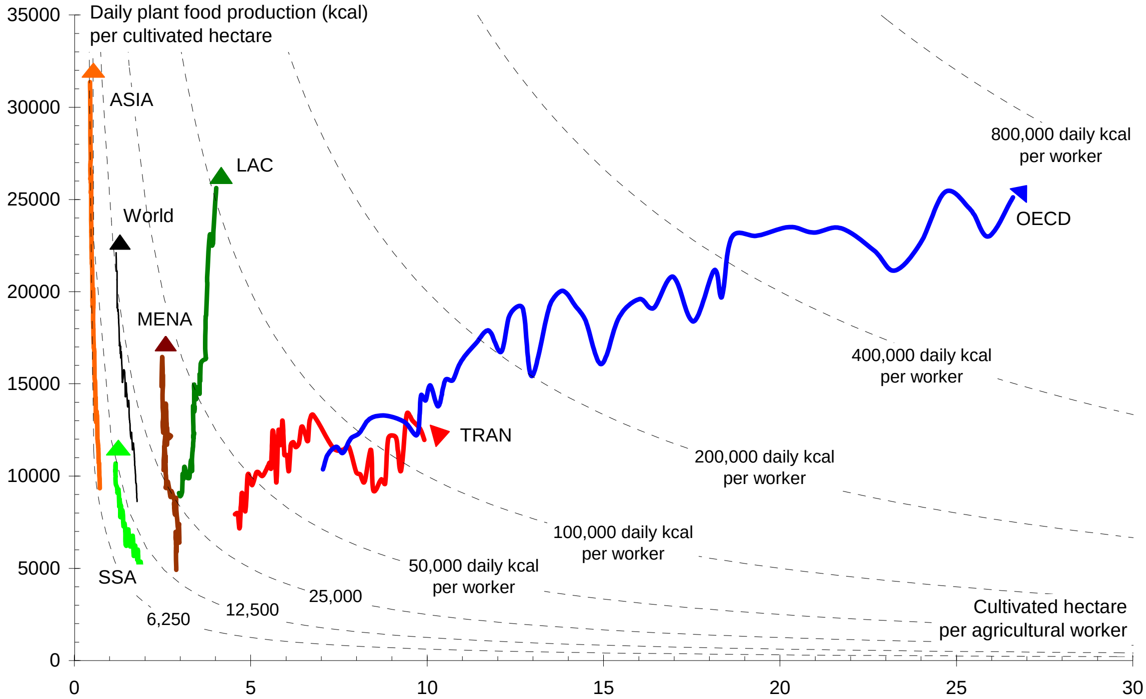
	Land Mha [1]	Population Mcap. [2]	Production Gkcal.day^{-1} [3] = [1]+[5], [2]+[7]+[8]	Outcome kcal.cap^{-1}.day^{-1} [4] = [3]-[2], [5]+[6]+[7]	Technology kcal.ha^{-1}.day^{-1} [5]	Affluence ha.worker^{-1} [6]	Workforce worker.cap^{-1} [7]	Labour kcal.worker^{-1}.day^{-1} [8] = [5]+[6]
aOECD	0.02%	1.11%	2.98%	1.85%	2.96%	1.18%	-2.22%	4.16%
eOECD	-0.42%	0.56%	1.38%	0.81%	1.79%	3.06%	-3.92%	4.92%
TRAN	-0.37%	0.51%	1.21%	0.69%	1.59%	1.72%	-2.54%	3.31%
LAC	1.11%	2.05%	3.49%	1.42%	2.36%	0.67%	-1.58%	3.04%
MENA	0.29%	2.50%	3.04%	0.52%	2.74%	-0.33%	-1.82%	2.40%
SSA	0.93%	2.72%	2.63%	-0.08%	1.69%	-1.06%	-0.68%	0.61%
sASIA	0.15%	2.14%	2.72%	0.56%	2.56%	-1.33%	-0.63%	1.20%
eASIA	0.56%	1.68%	3.34%	1.64%	2.79%	-0.82%	-0.29%	1.93%
World	0.23%	1.69%	2.36%	0.66%	2.12%	-0.88%	-0.55%	1.22%

Table 4. OTAWA/TALA regional values (2007)

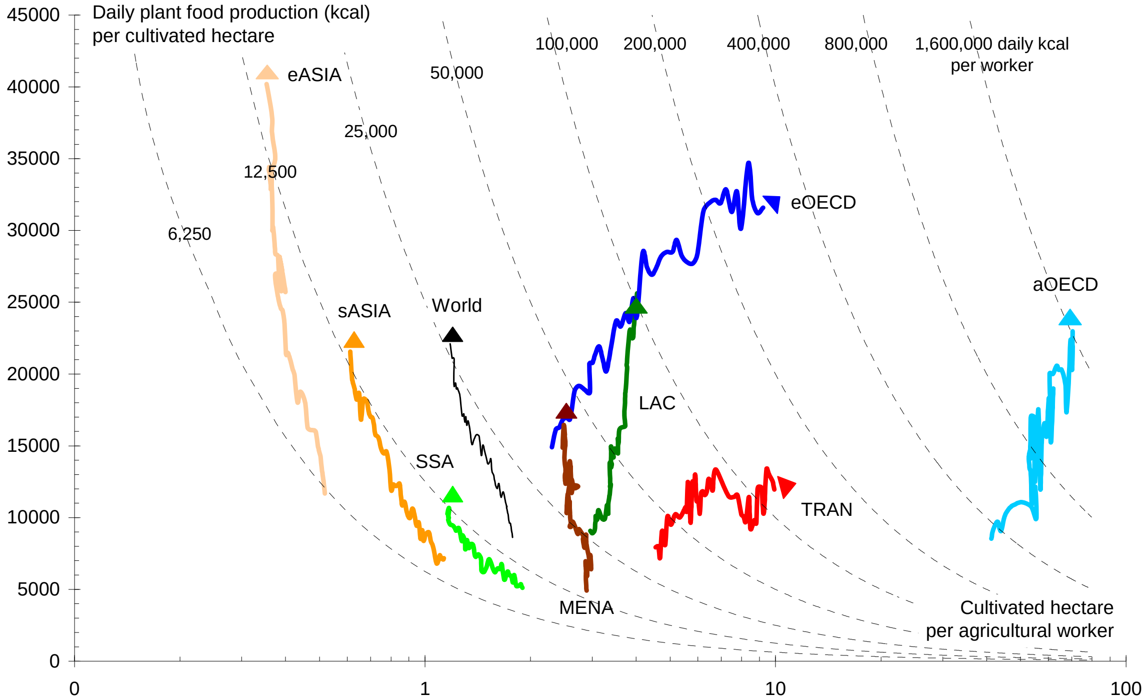
	Land Mha [1]	Population Mcap. [2]	Production Gkcal.day^{-1} [3] = [1]*[5], [2]*[7]*[8]	Outcome kcal.cap^{-1}.day^{-1} [4] = [3]/[2], [5]x[6]x[7]	Technology kcal.ha^{-1}.day^{-1} [5]	Affluence ha.worker^{-1} [6]	Workforce worker.cap^{-1} [7]	Labour kcal.worker^{-1}.day^{-1} [8] = [5]x[6]
aOECD	270	367	6,213	16,920	22,972	73.0	0.01	1,677,808
eOECD	89	578	2,818	4,874	31,586	9.2	0.02	291,241
TRAN	245	403	2,928	7,271	11,966	9.9	0.06	118,696
LAC	170	561	4,355	7,758	25,611	4.0	0.08	103,051
MENA	83	399	1,240	3,111	14,859	2.5	0.08	36,702
SSA	217	789	2,226	2,822	10,257	1.2	0.24	11,882
sASIA	204	1,544	4,399	2,849	21,562	0.6	0.22	13,198
eASIA	226	1,927	9,094	4,721	40,197	0.4	0.33	14,204
World	1,505	6,567	33,273	5,066	22,107	1.2	0.19	26,094

Figure 5. Agricultural productivity paths (1961-2007)

(a) All countries into six regions



(b) All countries into eight regions



4. Unlikely Lewis Path and alternative utopias

4.1. Three scenarios for India by 2050

The key question is to understand under what conditions developing countries can alter their current trends to embark upon a Lewis Path. To provide some elements of response, we focus on the case of India as a typical example of a large country actually taking a polar direction to build a heuristic numerical experiment.

To do so, we use the "simple mathematics" of Timmer (2009: 10) which derives the growth of workforce and labour productivity in agriculture from (*i*) the growth of the total number of workers, (*ii*) the GDP growth in agriculture and other sectors and (*iii*) the labour productivity growth in non-agricultural sectors. We also build upon the Shukla and Dhar (2011) baseline scenario for India (2005-2050) founded on a computable general equilibrium model used for long run projections describing the links between the energy sector, macroeconomic parameters (demography and saving behaviours) and productivity trends at the sector level.

This baseline is characterized by a 7.3% p.a. GDP growth rate[23] and an overall labour productivity growth of 6.2% p.a. until reaching 67 US$ per day per worker or 30 US$ per capita in 2050 (Table 5)[24]. Agricultural growth is 2.6% p.a. against 7.7% in other sectors and agricultural labour productivity growth is 3.0% against 5.4% in other sectors[25]. India, in this scenario, no longer follows a "Lewis Trap;" it switches towards a "Farmer-Excluding" path. Farmers are fewer and they earn on average 17 times less than non-agricultural workers in 2050 compared to 6 times less in 2007. Their share in the total workforce falls to 30% (against 56% in 2007) and urban population passes from 340 million in 2007 to 947 in 2050. Land availability per farmer increases but very slowly: 0.78 ha in 2050 against 0.66 in 2007. From this scenario, we test the sensibility of this transformation path to alternative assumptions about labour productivity growth rates in non-agricultural activities, *ceteris paribus*.

In variant 1, this rate passes from 5.4% to 5.8% p.a. With this optimistic assumption about non-agricultural labour productivity, India remains on the trail of the Lewis Trap. In 2050, farmers are not only the poorest (*LIR* = 0.1 against 0.3 in 2007) but also more numerous than in 2007, still representing 40% of the workforce in 2050. This is due to a less efficient "discharging" mechanism: higher labour productivity in the non-agricultural sector lowers the labour demand of this sector at constant output and its capacity to absorb as high an agricultural population. By 2050, the urban population will be less than in the baseline scenario (795 compared to 947 million) but 575 million poor people (farmers with their family) will be living in rural areas where average available land will have fallen to 0.58 ha per agricultural worker (against 0.66 in 2007 and 0.78 in the baseline).

In variant 2, we calculate the growth of labour productivity in non-agricultural activities which leads to a Lewis Path. This rate is 4.6% p.a. compared to 5.4% in the baseline and 5.8% in variant 1. With this lower labour productivity rate in non-agriculture and a concomitant rate of 9.3% in agriculture to get the same GDP, the discharging mechanism operates very efficiently. After four decades of unprecedented rural drift, the share of agriculture in total labour and in GDP is 2% and incomes between agricultural and non-agricultural workers will converge to 67 US$ in 2050 (*LIR* = 1).

[23] Assumption lying between the 2000-2007 growth rate (5.6%) and very optimistic projections (e.g. 8.5% over 2007-2050 from Hawksworth & Cookson, 2008). Let us note that an average annual growth rate of 7.3% over nearly a half-century would already be very exceptional for a large country and would likely confront constraints in the pace of construction of the underlying infrastructures. Over 1970-2007 (37 years), we found only China above such a rate, with 8.5% (rate measured with total value-added in 1990-US$ from Unstat, 2010). It was followed by countries only in Asia: Malaysia (7.1%), South Korea (6.5%), Thailand (6.2%), Vietnam (6.1%) and Indonesia (6.0%).

[24] See notes of Table 5 for details regarding projections of total and active populations. These projections capture the expected "demographic dividend," i.e. a rise in the rate of per capita economic growth due to a rising share of working age people in a population.

[25] The average growth (6.2%) is higher than 5.4% and 3.0% because each worker passing from agriculture to non-agriculture yields an incremental 2.4% productivity growth rate.

Table 5. Scenarios of Lewis Trap and Path for India (2007-2050)

			1980-2007 Observed [1]	2007-2050 Baseline [2]	2007-2050 Lewis Trap [3]	2007-2050 Lewis Path [4]
Population	Total	Mcap	1,165	*1,615*	*1,615*	*1,615*
		annual growth	1.9%	*0.8%*	*0.8%*	*0.8%*
	Workforce	% population	40%	*45%*	*45%*	*45%*
Area	Cropped	Kha	170,000	*170,000*	*170,000*	*170,000*
	Cities	Kha	2,428	*2,428*	*2,428*	*2,428*
Growth (VA)	Total	annual growth	6.1%	7.3%	7.3%	7.3%
	- Agriculture	annual growth	3.0%	*2.6%*	*2.6%*	*2.6%*
	- Other	annual growth	7.2%	*7.7%*	*7.7%*	*7.7%*
	Total	$US\$_{1990}$/cap.day	2.04	30.51	30.51	30.51
Labour productivity (VA/worker)	Total	annual growth	3.9%	6.2%	6.2%	6.2%
	- Agriculture	annual growth	1.6%	3.0%	2.3%	9.3%
	- Other	annual growth	3.7%	*5.4%*	*5.8%*	*4.6%*
Workforce	Total	annual growth	2.2%	1.1%	1.1%	1.1%
	- Agriculture	annual growth	1.4%	-0.4%	0.3%	-6.2%
	- Other	annual growth	3.4%	2.2%	1.8%	3.0%
	Total	Mcap	463	735	735	735
	- Agriculture	Mcap	259	217	295	17
	- Other	Mcap	204	517	440	718
Overview	Agriculture	% workforce	56%	30%	40%	2%
		% GDP (VA)	16%	2%	2%	2%
		LIR	0.3	0.1	0.1	1.0
		ha/farmer	0.66	0.78	0.58	10.11
	Cities	Mcap	340	947	795	1,337
		% population	29%	59%	49%	83%
		Kcap/km²	14	39	33	55

Notes: Values other than annual growth rates are those of the final year. Figures in italics are assumptions:
(a) population: polynomial function of the year derived from the 2000-2050 annual projections of FAO (2010) (r^2=0.999);
(b) workforce: polynomial function of the population derived from the 1961-2020 annual data of FAO (2010) (r^2=0.999);
(c) cropped area: fixed value of 170 Mha after 2000 (169.3 observed in 2007);
(d) urban area (cities): fixed value of 2,428 Kha after 2000, obtained by dividing the Indian urban population in 2007 (FAO, 2010) by an average density of 14,000 inhabitants per km^2 (13,767 circa 2006 for all Indian urban areas according to Demographia (2011), and 14,083 for urban areas over 500,000 inhabitants);
(e) urban population: urban population of 2007 + new population after 2007 – new agricultural population after 2007;
(f) agricultural population: agricultural workforce * β where β = ((population / workforce) – 0.25) as observed circa 2000;
(g) sectorial annual growth rates (agricultural and non-agricultural value-added – VA): scenario assumptions from which the total annual growth rate is derived;
(h) labour productivity growth rate (agriculture or non-agriculture): scenario assumption from which the other sector growth rate (non-agriculture or agriculture) is derived in order to achieve the sectorial annual growth rates.

4.2. Uncertain bifurcations, unlikely Lewis Path

The limitation of the above numerical experiments is to assume a constant GDP in the absence of a model endogenizing sector labour productivities, final demand (domestic and external) and GDP growth. This limitation does not however prevent showing how embarking upon a Lewis Path, in India as elsewhere, depends on a "fine tuning" of agricultural and non-agricultural parameters. No extreme assumptions about the growth rate of outputs and labour productivity in the non-farm sector is indeed needed to pass from the "Farmer-Excluding" path of the baseline scenario to the "Lewis Trap" of variant 2 or to the "Lewis Path" of variant 1.

The "fine tuning" of the growth rates in the agricultural and non-agricultural sectors would be less problematic with simulations allowing a more distant turning point beyond which the divergent agricultural and non-agricultural per capita incomes turn to convergence. But this turning point has been reached at later and later stages in the past by successful growth performers (Timmer, 2009), suggesting that "perhaps industry is becoming less and less able to absorb labour" (Binswanger-Mkhize, McCalla, & Patel, 2010). This trend might continue and even worsen in the future for two reasons. First, although gains in industrial labour productivity through economies of scale and motorization/automation are reaching saturation in OECD countries, they are continuing elsewhere. Second, industrial production might increase more slowly in the future due to the increasing cost of oil and other non-renewable resources, strengthened environmental regulations, market saturation in industrialized countries, and slower wage increases in developed economies not fully compensated for by an increase of incomes in developing countries, etc.

In addition to this "fine tuning" problem, the end point of our numerical exercise brings to light another obstacle to a Lewis Path. By 2050, more than 80% of the Indian population will be living in cities, the density of which will reach 55,000 inhabitants per km^2 if urban areas do not expand onto cultivated lands and remain at the 2007 level (about 2.4 Mha) (Table 5). As a point of comparison, the two densest cities in the world today, Dhaka in Bangladesh and Mumbai in India, have "only" 35,000 and 27,100 (Demographia, 2011). Such a mega-urbanization would be a challenge never before faced in history. In Europe for example, cities have retained low density populations (e.g. 3,400 inhabitants per km^2 in Paris) and the Lewis Path was facilitated by the emigration of 60 million people to the "New Worlds" (35 million to the USA alone) between 1850 and 1930 (Losch, Fréguin-Gresh, & White, 2012). Large open spaces within cities or outside countries do not exist anymore and this situation could block the mechanism of boosting farm labour productivity through large-scale motorization.

Even with this assumption of mega-urbanization, available land per farmer only reaches 10 ha. Faced with this constraint, Indian farmers may try to increase the land productivity with more external inputs (fertilizers, pesticides, selected seeds, fuels, irrigation) but the marginal productivity of these inputs decreases and the negative externalities of their intensive use are already high (natural resource depletion, biodiversity loss, global greenhouse gases, animal and human health problems) (Dorin & Landy, 2009). They may use industrial inputs more efficiently but the ever-increasing price of the latter may wipe out all their efforts. They may get better prices for their products on international markets but they can hardly compete individually with today's large-scale and well-organized agro-industries. They look trapped, as do most Asian farmers today.

To sum up, our baseline scenario and variant 1 raise a "disparity problem" between agricultural and non-agricultural sectors – by and large between rural and urban areas – which is presented by Yujiro Hayami and Godo (2004) as putting the development of high-performing Asian economies at risk of being undermined by severe social crises. Since farmers cannot migrate rapidly enough to crowded urban shantytowns, they thus might be condemned to stay with a business whose natural capital declines (soil, biodiversity, safe water) while their own capabilities are diminished due to poverty (nutrition, health, education). Variant 2, however, which requires lower average labour productivity in the non-agricultural sectors, might lead to a transfer of the disparity problem to cities with the co-existence, in urban areas, of highly skilled and highly paid labour with highly labour intensive and low wage services[26].

4.3. A tentative economic framework for an alternative utopia

We have seen why removing "barriers to modern agricultural technology" does not suffice to ensure taking a Lewis Path or escaping the risks of a Lewis Trap or Farmer-Excluding growth. GMOs, for example, may help to save some inputs such as energy (for weeding), pesticide, chemical nitrogen or water but they increase the cost of seeds and will not solve the labour absorption problem. It might be wise though to envisage an alternative utopia to the Lewis Path, a form of "Farmer-Developing" path (Table 1) in which the disparity problem would not be transferred to cities.

The economic fundamentals of such an alternative have to support an increase in total agricultural production (Q) and farmers' incomes (Θ_a) without to strongly downsizing their numbers (L_a) or jeopardizing natural resources. They are encapsulated in Equation 9 which

[26] The "Farmer-Developing" growth of Latin America and Africa?

shows how these parameters interplay with the cost of agricultural inputs produced by the non-agricultural sector (Y^a_{na}: chemical fertilizers, pesticides, etc.) and the farm-gate price (p). Equation 9 equals Equation 10 which inserts the TALA parameters Q/A (yield) and A/L_a (land per farmer):

$$\Theta_a = (pQ - Y^a_{na}) / L_a \quad (9)$$

$$\Theta_a = (pQ/A - Y^a_{na}/A) \bullet A/L_a \quad (10)$$

Over the past decades, R&D and institutions have tended to focus on a few monocultures (wheat, rice, maize, soybean, etc.), the production of which has tremendously increased (Q), albeit with increasing input costs (Y^a_{na}) and growing environmental externalities (Foley, et al., 2005). Since unit prices (p) have simultaneously declined, these productions have been logically profitable (Θ_a) only with fewer farmers (L_a) on larger acreages (A/L_a).

Equations 9 or 10 indicate the parameters of an alternative to this labour-saving, input-dependent and ecologically simplified food production system:

(1) less industrial inputs Y^a_{na} to lower environmental and production costs;

(2) better context-specific biological synergies between numerous plant and animal species, above and below ground, to boost production (Q) and increase resilience to natural and economic shocks;

(4) improved dedicated human abilities (L_a) to develop these small-scale and complex biological synergies on heterogeneous land quality and under variable weather conditions;

(5) higher price p to farmers to *(i)* stimulate the provision of diversified tasty nutritious food and other goods such as fuels, fibres, drugs and building materials, *(ii)* sustain ecosystem services of local and global importance (safe water, carbon and biodiversity pool, soil fertility, nutrient recycling, pollination, disease and flood control, climate mitigation/adaptation), (*iii*) limit costly social safety nets in urban or rural areas.

This agenda actually resembles those of the "agro-ecological perspective" (Altieri, 1999), "agro-ecological matrix" (Perfecto & Vandermeer, 2010), "Doubly Green Revolution" (Griffon, 2006) or "ecological intensification" (www.cirad.fr). It is trivial to say that it cannot be deployed without institutional improvements, in particular, land access and competition of small farmers[27]. Less trivial is to highlight its potential of high economic efficiency. Indeed, contrary to widespread opinion, agriculture, unlike other sectors, seems largely subject to diseconomies of scale, i.e. more efficient at small rather than large scale. From Sen (1964) to Wiggins et al. (2010), an abundant literature discusses this "inverse size-productivity relation" in agriculture, and much data from all over the world shows that large farms, dependent on hired managers and workers, are less productive and profitable per hectare than small farms operated primarily with family labour. Economies of dimension in large-scale operations (information, credit, inputs, marketing, etc.) are indeed often offset by no monetary incentives for family members to work, by special institutional arrangements (cooperative or contract farming) and by the premium obtained from closer management and supervision of farm operations (Binswanger-Mkhize, et al., 2010).

The conventional agro-industrial farming model will certainly continue to expand, especially in places where marginal productivity of external "modern inputs" (lab-seeds, petrochemical fertilizers, pesticides, etc.) is still high, such as in sub-Saharan Africa, or where land constraint is still low, such as in parts of Latin America. But working on alternative models remains relevant for these ever-growing populations since they have to avoid urban chaos or a Lewis Trap.

[27] A small number of farmers and related upstream and downstream agro-industries with good education and communication usually constitute powerful lobbies that national and international policymakers can hardly resist. These lobbies tend to increase the costly "protection problem" of agriculture in high-income economies (Yujiro Hayami & Godo, 2004; Schultz, 1953) and a worldwide concentration of firms into a few agro-food complexes with oligopolistic positions that limit competition and control both prices and technical innovations.

5. Conclusion

This paper questions the Lewis perspective of a “world without agriculture” which is embedded in the Structural Transformation paradigm of “modern growth.” It does so by providing a heuristic model showing that the “Lewis Path” is being followed only by industrialized countries and those in transition: Latin America and Africa are following a “Farmer-Developing” path with an increasing number of farmers but a narrowing gap between their average incomes and those of other workers, while Asia is engaged towards a “Lewis Trap” where farmers are increasingly numerous and poorer compared to other workers and most other farmers in the world[28].

We have demonstrated how land constraints underlay these results by recomposing worldwide productivity trends in caloric terms from 1961 to 2007 and we have shown, through an illustrative numerical example on India, that switching towards a Lewis Path demands a “fine-tuning” of productivity growth in agricultural and non-agricultural sectors to solve the “discharging” problem from the latter to the first. These land and fine-tuning obstacles cannot be addressed through the route followed by industrialized countries in the past. In Western Europe for example, Lewis Structural Transformation began long ago, was eased by labour-intensive industry, by labour emigration to low-density cities as well as to outside Europe until World War II, then by policies encouraging a “modern agriculture” (Servolin, 1989) with no more “peasants” (Gervais, Servolin, & Weil, 1965; Mendras, 1967) but few heavy-motorized “agriculturalists” until reaching a “world without agriculture” in the early 21st century (3% of workforce and GDP).

Asia cannot replicate this experience nor share the utopia of a few large-scale farmers and agro-industries feeding the bulk of humankind in huge megacities. We then delineated the economic conditions of an alternative “farmer-inclusive” path that does not transfer the disparity problem to cities. This path demands deep redirections of technical and institutional innovations for supporting “minifundists” *(i)* developing integrated agro-food systems manufacturing food, energy and other products *(ii)* paid for the many ecological and social services they can deliver and that humankind is now looking for at local and global scales.

A paradigm shift may be necessary not only in Asia but also in *(i)* Africa and Latin America to avoid unexpected bifurcations towards a Lewis Trap, or growing poverty and violence in cities, *(ii)* industrialized countries faced with the ecological, economical and social limits of large-scale specialized agro-industrial farming in almost empty rural areas.

Minifundist knowledge-intensive and context-specific agriculture embedded in manufacture and service sectors has to be largely invented. It has to be incorporated in reflections on the redeployment of R&D whose “payoffs will only happen if the effort is sufficiently massive, concerted, and sustained” (Janvry, 2010). Although indeed the consensus about this effort is enlarging it remains urgent to specify its contents and expected benefits (UNEP, 2011). It opens a research agenda for economists, integrated modelling and institutional research in view of answering two intertwined questions and avoiding a “perfect storm” in the future (Hertel, 2011): *(1)* what institutions to promote and remunerate properly collective and public goods provided by agriculture and related rural activities? *(2)* how this new agriculture and rural organization can emerge and coexist with large-sized agro-industries that now feed a growing portion of humankind?

[28] We conducted the analysis at a scale disregarding sub-regional and sub-national discrepancies not to blur the presentation with an overflow of data and figures. We deliberately presented the results by large regions without separating large countries like China, India, Brazil or South-Africa. Actually, further analysis would show the necessity of an even finer degree of granularity, but this would not change the overall message of this paper.

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Appendices

Figure 6. Map of countries and regions
Cartographic source : Articque

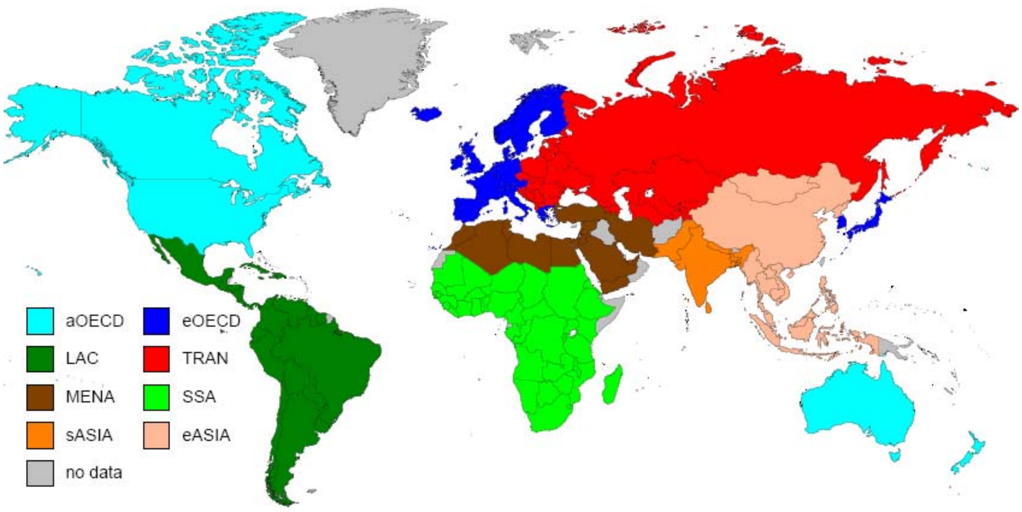

Figure 7. Plant food Production (1961-2007)

(a) Plant food production (b) Plant food production per inhabitant

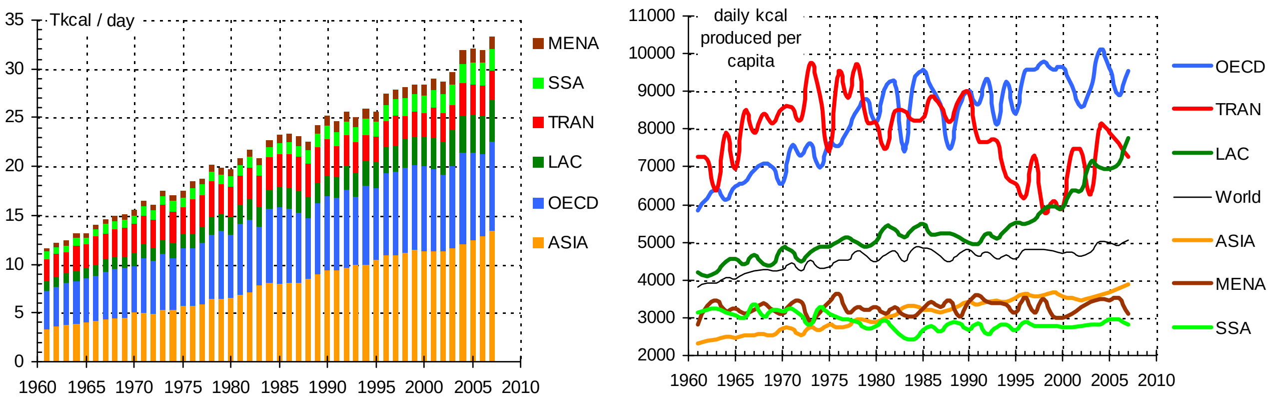

Figure 8. Land productivity (1961-2007)

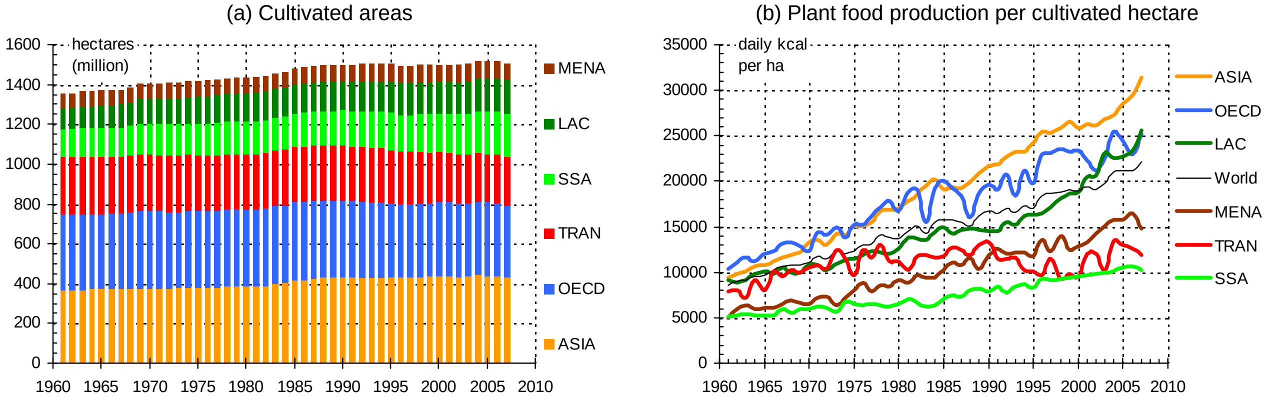

Figure 9. Labour productivity (1961-2007)