Agricultural Transformation for Small (Island and Developing) States

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ABSTRACT

Agriculture in the development literature has been postulated as providing impetus for urban industrialization through its role in capital accumulation. While large states with concomitant large export potential of agricultural surpluses may subscribe to this paradigm and may also allow growth of a rural agricultural sector in parallel with an urban industrial sector, small states find it difficult to use the agriculture sector as a springboard toward national economic growth by virtue of size limitations. Small states require alternate capitalization modalities to grow their economies, and some have sidelined agriculture in favor of urban activities, such as manufacturing, finance, banking, and tourism. It is plausible, based on demonstrated successes like Singapore, that structural transformation may take a path in which the agriculture sector is initially sacrificed in favor of more high value urban activities. Since its independence in 1965, Singapore made policy decisions to focus on developing its non-agriculture sectors such as finance, banking, and entrepôt trade. In 1983, the country even reduced its agricultural activities to less than one percent of land area located in six agrotechnology parks. Capital accumulation through the non-agriculture sectors proceeded to consequently make its GDP per capita one of the highest in the world. However, the country did a "U-turn" in the 2010s to re-invest in agriculture, but through high-tech farming, such as indoor plant factories, indoor aquaculture, and alternative (novel) proteins. The increased level of food self-production is strongly augmented by importing food from over 170 countries in diverse geographic regions, so as to confer supply resilience. This alternate development pathway, which emphasizes urban industrialization, may serve as a "leapfrogging" model for small cities and small developing states in a contemporary, technology-enabled landscape.

Keywords: food security, agricultural transformation, small island developing states

JEL codes: Q180, O110

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INTRODUCTION

Agriculture has been postulated in development literature as an enabler and precipitator of economic restructuring by serving as a source of capital for establishing the industrial sector. Many countries are known to have followed the development path of evolving from predominant agrarian economies to urban industrialized economies. A notable example of this is the USA, in which the population living on farms declined from about 40 percent in the early 20th century to about one percent in the 21st century (Lusk 2016). Concurrently, the contribution of the agriculture sector to national gross domestic product (GDP) has declined to 0.7 percent in 2023 (USDA-ERS 2023) and the US economy is now dominated by the non-agriculture sector. Yet the US remains one of the world's major food baskets, exporting much of its surpluses, such as corn and soybeans, and is the world's largest exporter of food (World Bank 2020) despite the relatively small farm population and the small size of the agriculture economy relative to the whole US economy.

Most examples of this development pathway, in which agriculture has contributed to capital formation in the urban sector, have been with countries having large land spaces. Although agriculture's contribution to the national economy has declined in many developed economies, it is no less important from the perspective of national security, especially with respect to food security. Examples exist of countries like China, in which concurrent development of the industrial urban sector has advanced without underplaying the role of the rural, farming sector (Zhang, Donnellon-May, and Tortajada 2023). Can this pathway of development, in which agriculture catalyzes and provides the foundation for an urban industrial sector, be replicated for small states, such as small island developing states (SIDS) with limited natural, human, and financial resources? Or is there an alternative?

In contrast to majority of countries that are large states, there are today over 57 SIDS, which the United Nations Commission on Sustainable Development (UNCSD 1992, 193) has seen as "a special case both for environment and development." This is given their ecological fragility and vulnerabilities and "their small size, limited resources, geographic dispersion and isolation from markets."

We argue in this paper that an alternative pathway may have to be followed in the case of small states, where agriculture is not as scalable, and therefore where agriculture cannot realistically be expected to provide capital formation for developing industrial sectors. We draw on the generally acknowledged success story of Singapore, a small island state that transcended in status from a low-income developing state to a high-income developed state in less than three decades (Lee 2000; Goh 2016). This paper is not an exhaustive review of development pathways in small states but, rather, a presentation of a possible alternative pathway that small states (island and/or developing) *could* consider in their strategic planning for development.

THE AGRICULTURE TRANSFORMATION PROBLEMATIQUE IN SIDS

The dominant economic paradigm is that economic development necessitates a process of industrialization, or a movement away from high dependence on lower-value-adding agriculture, and toward a high dependence on higher-value-adding non-agriculture sectors (manufacturing and services) (Lavopa and Szirmai 2018; Kuznets 1955). This assumes a linear pathway from predominantly agrarian economies, which include low income, developing countries, to become highly industrialized and urbanized economies, as can be seen in high income developed countries today. It is worth pondering however, whether such a pattern is applicable to SIDS. Small states, unlike large ones, face greater pressure in achieving the innovation-based transformation of their agriculture sectors, which allows for overcoming the limitations of space in improving agricultural value-addition. Their financial constraints likewise mean that they have less leeway to make mistakes, such that small states are compelled to have a more definitive specification of the transformation process.

Agricultural Transformation, Economic Development, and Role of Capital

An earlier model that captured the interaction between agricultural transformation and economic development was Peter Timmer's (Timmer 1988) agricultural transformation model. This seminal work synthesized the prevalent thinking on the roles of agriculture in economic development, with each stage building on previous works:

1. ***Mosher Stage.*** The first stage of this transition, Timmer argued, began with "getting agriculture moving" as earlier noted by Mosher (1965). This involved transforming and "capitalizing" the agricultural sector, in which productivity improvement was enabled by use of higher-productivity agricultural inputs such as machinery, synthetic fertilizers, and improved seeds. These lead to greater profits that are retained as capital within agriculture.

2. ***Johnston and Mellor Stage.*** After agriculture grows in the first stage of transformation, it would then have surplus funding to flow into an industrial sector, in the second stage (Timmer 1988; Briones and Felipe 2013). At this point, agriculture has already reached a certain level of capital, which can be used for investment in higher-value, urban industrial sectors (Johnston and Mellor 1961). This marks a beginning too for growing linkages between rural agriculture sectors and urban industrial sectors.

3. ***Schultz-Ruttan Stage.*** In the third stage, agriculture then becomes interlinked with the larger macroeconomy, leading to increased vulnerability due to the variability in prices. When the larger macroeconomy includes the new urban industrial sector, the effects of increased activity and trade in the latter sector may have backward impacts on agricultural prices (Timmer 2017). Because urban industrial sectors offer higher wages and rates of return on investment than the agriculture sector (Lewis 1954), not only investments but also labor flow from the agriculture to the industrial sector. Labor and credit in rural agriculture start to be used or transferred for higher income purposes to the industrial sector.

4. ***D.G. Johnston Stage.*** Finally, in the fourth stage, agriculture's contributions to value-addition have already shrunk, contributing only 30 percent or lower of per-capita income (Timmer 1988), and employing 20 percent or lower of total labor, as exemplified by the US (USDA-ERS 2023). Furthermore, Engel's law says that as household income increases, the percentage of that income spent on food relatively declines. In other words, a smaller share of the income of a richer consuming class goes into food. Consequently, the decline in growth in agricultural consumption reduces agriculture's profitability. These changes in consumption patterns are more visible at higher income per capita (Timmer 2009; 2017). To sustain investments and output growth in agriculture as a newly inferior sector, governments have skewed price policies on food to enable further agricultural investments (Johnson 1987). These were popular in countries, such as Japan, the US, and Western Europe (Timmer 1988; Anderson and Hayami 1986).

As such, capital is seen as playing an important part in the sequence from an agricultural to an industrialized economy. For many SIDS today, however, the problem lies in the inability to move from the first and second stages of agricultural transformation that fails to get the agriculture sector moving, and in turn, the failure to develop modern industrial sectors too. From the viewpoint of Timmer's model, this can be attributed to the inability to develop the agricultural sector so that it can serve as a source of funds for establishing the urban industrial sectors (Johnston and Mellor 1961; Timmer1988; Briones and Felipe 2013).

Natural Limits to Agricultural Expansion in SIDS

Small states are considered in United Nations (UN) terminology as those with limited land and water resources and relatively small human populations (LKYSPP-NUS 2018).[1] As such, they have limited natural food production resources, which require land, water, and labor. Lower income small states are also lacking in capital to be able to invest significantly in inputs, such as seeds and agrochemicals (synthetic fertilizers and pesticides) to boost agricultural productivity.

Thus, in their natural state, the geographical endowments of small states impose a maximum production capacity or amount of production possible with their limited land area. This places a limit or "carrying capacity" of human populations within small states, assuming too that lower-income small states are less capable of procuring food at higher prices in international markets.

Even in recent discourses at the UN Committee on World Food Security's (CFS) High Level Panel on Food Security and Nutrition (HLPE), imports are seen as a part of the food baskets of small states. Food systems in small states, encompassing agriculture, have evolved or been adapted to suit the resource limitations and demands of the prevailing human population, leading to the need to have some balance of self-production of food vis-à-vis food imports (HLPE 2017). This implies that small states must accept that as their populations grow and economies expand, their agricultural sector is unlikely to meet the food, feed, and fiber needs of the country.

An immediate implication, if small states are unable to expand their agricultural production capacity, is that they will be unable to develop their capital base for developing their industrial sectors, if Timmer's (1988) agricultural transformation model was to be followed.

Innovation Complexity and "Productivity-Capital Traps" in Agriculture

It must be further considered that technology adoption drives the maximum production capacities and carrying capacities within SIDS. Historically, with growing populations, food systems have had to intensify in crop and animal culture, commonly with the use of modern inputs, such as improved seed varieties, fertilizers, pesticides and with farming systems using mechanization and irrigation. In the 20th century, all these technologies were responsible for the gains in crop yield (Teng 2021) experienced by both large and small states. Technically speaking, if enhancing productivity was not an issue, then the natural limits of space would not serve as a barrier to scaling up agriculture.

However, the potential of technologies to enhance productivity is limited, partly because of low adoption of such technologies. The Lewis (1954) model posited that because agriculture is more labor-dependent, its capability to benefit from technologies, which are a form of productivity-enhancing capital, is limited. As such, agriculture's "capital-dependence" too is low. Therefore, as the agriculture sector is not as capitalized as the industrialized sector, the potential for productivity improvement is less; this means that wages and profits in this sector are less likely to grow, leading to lower capital accumulation, or a "productivity-capital trap."[2] Even in the late 20th and early 21st centuries, as agriculture became strongly influenced by new "disruptive technologies" such as improved seed, digitalization, and automation (Teng 2021), countries still struggled to increase the adoption of these technologies (Montesclaros 2023).

[1] Indeed, the UN recognizes a Forum of Small States (FOSS) with over 100 members across the world, and members regularly come together to discuss issues, exchange ideas, and coordinate positions. The FOSS was formed by Singapore in 1992 and is a diverse, non-ideological and informal grouping at the UN whose members are nations with a population of fewer than 10 million (LKYSPP-NUS 2018).

[2] The productivity-capital trap was first introduced in the dissertation of the second author (Montesclaros 2023), where it was applied in the Philippine context.

The "productivity-capital trap" does not occur automatically but may be shaped by institutional weaknesses that prevent smallholder farmers from obtaining capitalization from other sources, given challenges such as the failure to draw financing from commercial banks into agriculture, as well as land ownership debacles, which make smallholder farmers less competitive whether domestically or internationally.[3] Timmer and others had in fact noted that there are several challenges peculiar to the agriculture sector, which makes capitalization or "getting agriculture moving" (Mosher 1965) a herculean task. Such challenges are held in common by both small states and larger states. As such, apart from the small state – large state divide, the (rural) agriculture sector faces challenges that other sectors do not face and which must be considered when planning transformation, as shown in Box 1 (Montesclaros 2023).[4]

An important point to raise at this juncture relates to the distinction between agriculture as a highly "labor-dependent" sector especially in developing countries, and the apparent contradiction in that some agricultural technologies, such as digital and mechanical technologies, can be conceived as "labor-saving" technologies. While such a contradiction may lead one to question the relevance of the reference to Lewis' model, it is equally important to note technologies can be labor-saving and land-saving at the same time. As such, the low use of such technologies further "traps" the farmers into lower levels of productivity, whether in land productivity or labor productivity and in turn, limits their competitive potential over time.

Box 1: Challenges faced by the agriculture sector

- **Organizational setting**: Unlike non-agriculture sectors, decision-making among farmers is decentralized. This lack of corporate coherence makes it challenging to coordinate the achievement of particular target aggregate production levels, to negotiate prices, or to encourage the use of more technologies among themselves, unlike in more corporatized settings like in the cement industry (Timmer 1988).

- **Ownership structure.** When landowners hire farmers during planting/harvesting seasons, the latter's interests may not cohere with those of landowners. Timmer refers to this as the "efficiency cost of separating labor and management," which is higher in agriculture (Timmer 1988, 294). Landowners may even be inclined to keep the productivity of farmers down to reduce the wage bill that they pay them (Lewis 1954). Given their disorganized nature and these conflicts in interests, farmers thus decide on how much to produce, without an idea of how much the other farmers are producing (Timmer 1988). Furthermore, when farmers do not own the land, they are even less likely to possess capital for upgrading their own levels of productivity.

- **Seasonality of agricultural production.** A sufficient number of workers is needed for specific operations (e.g., seeding, fertilizing, soil conditioning) for every planting season within a limited time window (Timmer 1988). Thus, the failure to put labor to task in a timely manner, or to acquire seeds, fertilizers, etc., when they are needed, would translate to lower yields. This brings to fore, too, the importance of mechanization in improving the productivity of hired labor, as well as the presence of water service provision (i.e., irrigation) to enable more stable access to water.

- **Geographical spread (geographically immobile factors).** The distance between farmers and markets matters, or between farmers and their sources of inputs matters, given that agricultural production is immobile (i.e., it is pegged to the land area). This raises the importance of transportation (Timmer 1988).

Continued on next page

[3] These challenges are further discussed in Chapter 5 of the second author's dissertation (Montesclaros 2023), focusing on how agrarian reform challenges in the Philippine context have precipitated capitalization challenges of smallholder farmers.

[4] The compilation of these differences between agriculture and non-agriculture sectors builds on Chapter 5 of the second author's PhD dissertation, where Montesclaros (2023) explains the challenges faced by the agricultural sector to becoming a financially viable, capitalised sector.

Box 1 continued

If inputs are not brought in a timely manner to producers, then planting is delayed. Furthermore, if produce is not brought to markets or storage areas in a timely manner, they can be eaten by rodents, insects, or be affected by other forms of infestation. At the core of this are problems with the lack of efficient marketing systems.

- **Engel's Law on the income insensitivity of consumers with respect to food** (i.e., increase in incomes does not lead to increase in food consumption), such that an increase in food prices over time benefits those who market food, with farmers receiving a smaller share of this income (Timmer 1988). In fact, Timmer hypothesizes that the result of economic development in the larger world economy can lead future food prices to fall so low that a "world without agriculture is an obvious possibility" (Timmer 2017, 1).

Source: Adapted from Montesclaros (2023)

This leads to lower levels of capital accumulation over time. In contrast, greater integration of capital into an intrinsically labor-intensive sector could also help to improve labor productivity, thus benefiting countries that are facing shrinking and aging agricultural workforces. Regrettably, today, much of the agriculture in developing countries is still highly labor dependent and the capacity to use modern labor-saving capital/technology, including digital technologies, is still limited.

Optimizing Agriculture in SIDS

Therefore, when discussing structural transformation of the rural sector and the lack of capitalization of agriculture, following Lewis' (1954) perspective, the suboptimal behavior of farmers would have to be considered in order to find approaches to organize and mobilize farmers to enable capitalization. For small states, these issues are amplified due to the limitations of resources (natural, human, and financial).

For policy planners in SIDS, the "inconvenient question" then is whether agriculture should still play a key role in economic development, and how it can bring value to the overall goal of developing the national economy, i.e., to increase gross national product (GNP) and GNP per capita (Teng 2022). Such questions necessitate a rationalization of agriculture's role in small states by considering the unique optimization problems they face, of the different resource types shown in Figure 1.

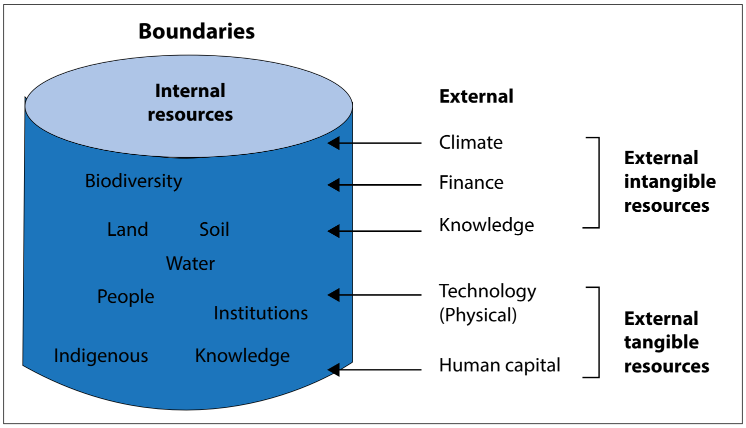
At a macro national level, agriculture serves to meet any of the following goals—to assure (i) food security, (ii) support export trade and earn foreign exchange through earnings from surplus food that is exported, and (iii) to serve as a potential source of technology intellectual property (for export). However, to achieve any of these requires optimal use of the internal and external resources shown schematically in Figure 1:

- Internal resources of the agriculture sectors of countries refer to extant biodiversity, land, soil, water conditions, as well as people, institutions, and indigenous knowledge.
- Resources external to the agriculture sector include both intangible resources such as favorable climate, financing, knowledge, as well as tangible resources in the form of physical technologies and human capital improvements.

The key *problematique* (or set of challenges) lies in finding the "sweet spot" of having the right balance and synergistic uses of both internal and external resources premised on the limitations posed by size. In small island states, the challenge of allowing agriculture to "step up" to meet the three aforementioned goals are intensified due to the intense competition to utilize the limited resources. It is with this consideration that small states need to optimize their use of resources, whether it is for export production or for domestic food security.

The sustainability imperative increasingly underpins any actions that SIDS take, since most states have pledged to do their part in achieving the 2030 Sustainable Development Goals (SDGs).

Figure 1. Schematic of internal and external resources in small states' agricultural sector



In turn, the sustainability of food systems hinges on having a sustainable agricultural system, which can indefinitely meet the requirements for food and fiber at economic and environmental costs of agricultural production and intensification that are socially acceptable (Crosson 1992).

CASE STUDY OF SINGAPORE

Singapore as a small island state provides learnings to support the thesis proposed in this paper, that SIDS need to explore alternative economic development and agriculture transformation approaches, owing to the unique challenges they face. Of interest is how agricultural transformation in Singapore was bypassed in the preliminary stages of economic development (post-independence in 1965 to become a sovereign nation), and how urban industrialization took off without capital from agriculture. Of further interest is how the industrial base, once developed, could subsequently drive the development of technology-enabled agriculture to partially meet food needs (Teng 2020). This creates a "leapfrogging" (Goh 2016) effect to jumpstart economic development. Singapore's experience presents a paradox in development as it would suggest that governments with limited investment resources have the potential to leapfrog rural transformation and invest in urban transformation —this is the premise of this paper.

Transformation of Urban Industrial Landscape in Singapore

Singapore achieved its independence in 1965, and after two decades surviving as an independent nation, the policy imperative became one driven by higher value-creation economic activity to use limited natural resources (Chou 2014). Singapore's leaders made decisions in the early days of independence that to grow the economy, it would be necessary to industrialize and develop the finance, trade, service, and tourism sectors, in which the limited natural resources would better serve the purpose of increasing both GNP and GDP.

In 1961, Singapore established its Economic Development Board (EDB) to spearhead its industrialization process. Further developments are drawn from published information by the EDB (2020). NatSteel, which is short for National Iron and Steel Mills, was opened in 1964 as a key driving force behind industrialization, allowing for cheaper raw materials that would feed into its manufacturing sectors. In 1968, NatSteel set up National Semiconductor as the first manufacturing facility in the country.

International companies from overseas played a significant role in bridging capital as well as expertise gaps, allowing Singapore to develop its economic sectors. By 1972, the

British company Beecham Pharmaceuticals began its manufacturing of pharmaceutical products in Singapore. In 1974, American company Hamilton Sundstrand established a close to 7,000 m^2 facility manufacturing aircraft equipment to develop Singapore's aerospace industry. Watch manufacturing company Seiko Instruments opened operations in Singapore in 1976. By 1981, the city-state was able to attract Apple Company to begin its operations. By 1998, Exxon Mobil, an American company, had opened an integrated refinery and petrochemical facility in Singapore, which served as its largest facility in Asia. Such initiatives significantly transformed Singapore's urban landscape, including through the development of Jurong Island as a complex for oil refining and chemical manufacturing opened in 2000.

Digital transformation in Singapore further progressed, prompted in part by the long-term Industry 21 (I21) economic blueprint that EDB developed in 1997. This furthered a unified and focused state policy on industry development, with further investments by Dyson, a company founded in Great Britain, to develop digital motors and upgrade the manufacturing industry. Singapore likewise opened the Biopolis in 2004 as a research hub for medical science and began constructing major solar plants through the Renewable Energy Corporation (REC) in 2008. Infineon Technologies, a German semiconductor company, likewise invested significantly in expanding manufacturing capacity in Singapore. By 2019, Digital Industry Singapore (DISG) was established by the government as a means of developing Singapore's technology sector. Today, there are over 21 interconnected infrastructure and ecosystems for businesses, innovation, and talent.

As a result, there emerged a paradigm of investing to move from a nation of "traders to (a nation of) innovators" in which all these sectors fueled value-adding activities (Goh 2016; Chang 2003). Singapore eventually achieved first-world status as a high-income country in the 1990s. The official basis for a high-income country was officially Gross National Income per capita of USD 6,000 in 1987 prices (Fantom and Serajuddin 2016). Lee Kuan Yew, Singapore's first prime minister, noted in his memoir that by 1990, the country already had a GDP per capita of USD 12,200, indicating that Singapore reached first-world status earlier on in the late 1980s and subsequently USD 22,000 by 1999 when he stepped down (Lee 2000).

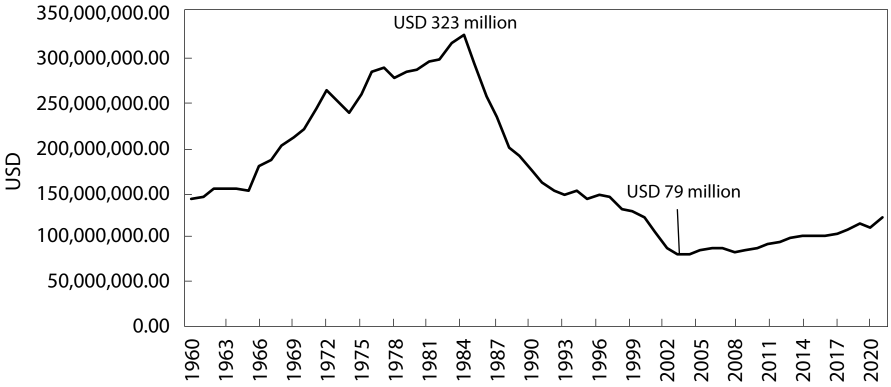
Bypassing Agricultural Development in Early Stages of Transformation

As a consequence of deliberate industry development policies, Singapore had turned away from agricultural development. In the 1970s, approximately nine percent of the population was engaged in agriculture-related activities while the current estimate is less than one percent. More than 70 percent of leafy greens and 100 percent of pork were locally produced then; intensive farming and policies pushing for productivity and quality control increased Singapore's self-sufficiency of food (CLC 2018).

By 1984, the government announced that agriculture would be phased out and re-organized into six agro-technology parks, each of which would focus on modern farming (Ngiam 2016; Tortajada and Zhang 2016). For instance, Singapore shut down pig and duck farms in the city-state from the 1990s onward, owing partly to the "smell pollution" that affected those living near farms (Ngiam and Cheong 2006). In the process, agriculture's value-addition fell from USD 323 million in 1984 to below USD 90 million in 2003–2008 (Figure 2).

By 2000, Singapore as a small island state of about 800 km^2 or 80,000 ha, had about 780 hectares or less than one percent of its land for agriculture. This included approximately 248 farms (excluding sea-based activities). The Agri-food and Veterinary Authority (AVA) was established in 2000, a reorganization of the former Primary Production Department (PPD), with the mission of "ensur(ing) a resilient supply of safe food, safeguard(ing) the health of animals and plants and facilitat(ing) agri-trade for Singapore" (AVA 2001, 3).

Figure 2. Singapore: Agriculture, forestry, and fishing, value added (constant 2015 USD)

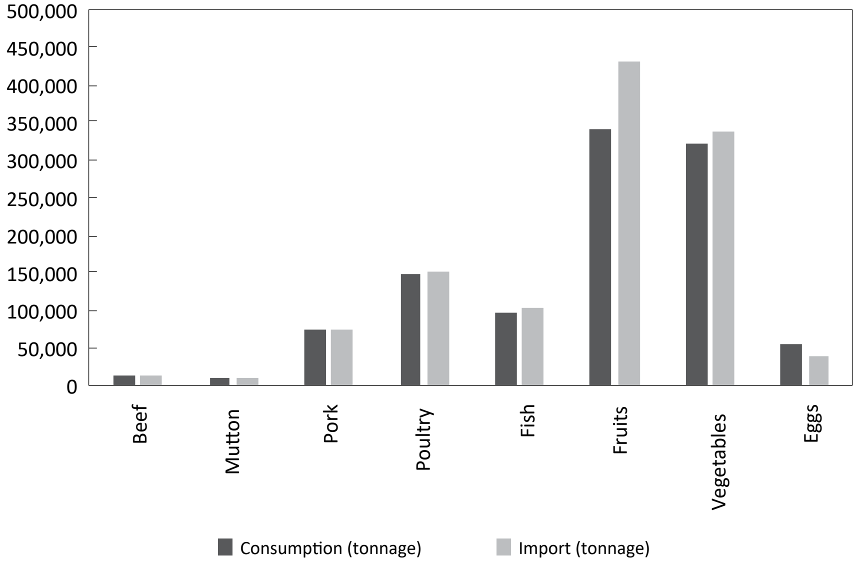


Source: World Bank (2023)

At that time, Singapore's domestic production figures were not even included in AVA's annual report, which only included the quantities of imports. The data in Figure 3 presents the quantities of imports and consumption of key commodities based on AVA's categories in 2000. It is unknown why importation figures are larger for most commodities relative to consumption except eggs. In the case of eggs, which have shorter shelf life, there are understandably no excess imports above domestic consumption. It is potentially because the rest of the commodities had longer shelf life, and thus, the excess import quantities were kept for storage.

The fact that AVA was not reporting domestic production figures implicitly reveals that Singapore did not intend to rely on domestic production and achieve food self-sufficiency; it was not a key tenet

Figure 3. Consumption and imports of key food items in Singapore, January–December 2000, in tonnage (MT)



Note: Table created using data from AVA (2001) for ensuring its food security. In fact, land allocated for agriculture has since decreased from 15,000 ha in the 1960s to approximately 780 ha. Less than one percent of Singapore's land is dedicated to agriculture (CLC 2018). This trend is also reflected in the employment rate of the agriculture sector.

Tortajada and Zhang (2016) likewise noted the implicit recognition that Singapore would strive for a policy of "self-reliance" rather than "self-sufficiency" in its approach to food security. The logic behind Singapore's approach of "self-reliance" is that Singapore's households would become economically empowered to purchase food because of their increased GDP per capita through high-value economic activities. Data from the Global Food Security Index (EIU 2019), for instance, showed a strong positive correlation between GDP per capita and food security.

The U-Turn in Singapore's Approach to Food Security

After achieving first-world status in 2000, Singapore found food security in its approach of "self-reliance", which was in fact heavily import-reliant. Nonetheless, this aligned with the UN Food and Agriculture Organization's definition of Food Security as a situation that "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 1996).

In particular, within Singapore's "model", it envisioned that households would have sufficient income to purchase sufficient food from international markets. These would in turn be guaranteed that as Singapore's population grew, it would be able to obtain the food it needed through imports.

However, the sense of security Singapore had in its model of "self-reliance" was soon shattered amidst the 2007–08 crisis. It learned that having a high GDP per capita would not be sufficient in maintaining food security. During the 2007–08 global food price crisis, which coincided with the 2007–08 global financial crisis, unexpected agricultural production shocks led to panic reactions by governments to restrict food exports and accumulate domestic stocks.

These precipitated a chain of events leading to temporary food shortages, price spikes, price gouging, and food hoarding by consumers. As a spillover effect of the 2008 global financial crisis, exponential increases in oil prices led to spikes in food commodity prices (Lin and Martin 2010). The international price of rice rose as major supplier countries stopped exporting and import-dependent countries responded by panic buying (ADB 2012).

From here on, Singapore took a U-turn in its approach to agricultural transformation (Teng 2019). While its import-driven model worked well during "peace times" or times of stability, it learned that food would not always be physically available, especially when food-producing countries themselves banned the export of food. Apart from market disruptions, climate-related challenges created further potential for disruption. Increasing frequencies of natural disasters and worsening environmental conditions have led to declining growth in productivity and increasing undernourishment within the broader Southeast Asian region since 2014 (Montesclaros 2021).

Singapore launched its Food Fund of SGD[5] 30 million to strengthen both food source diversification as well as local production levels, the latter supporting farm productivity upgrades in 141 projects and 71 farms (SFA 2013). A second tranche was launched in August 2011, which amounted to SGD 19.37 million, covering 141 productivity-improvement projects (SFA 2014).

The country moved toward having a "food supply resilience" strategy, which unlike the "self-reliance" approach placed emphasis on robustness of supply. This was highlighted in AVA's 2013 Food Security Roadmap. Its strategies included further diversifying import sources; investing in overseas food production; building buffers against short term supply disruptions

[5] Singaporean dollar; USD 1.00 = SGD 1.25 (2013 average exchange rate) (https://data.worldbank.org/indicator/PA.NUS.FCRF?locations=SG)

through stockpiles (e.g., rice); and boosting its self-production of specific food items (e.g., fish, vegetables, eggs). It also launched the third tranche of the Food Fund, of another SGD 10 million in 2013, with 131 projects including farm capability upgrading, "technical boosters", research and development (R&D) challenge calls, and food diversification initiatives (SFA 2014).

Drive toward High-Tech Commercial Agriculture and Re-ignition of Food Sector

The turn toward a strategy of "food supply resilience", which revisited the role of domestic agricultural production to provide a buffer against such disruptions, set domestic production self-sufficiency targets of 30 percent for eggs (in particular, hen shell eggs), 10 percent in leafy vegetables, and 15 percent in fish (CLC 2018). By 2018, it had exceeded the 10 percent target for leafy vegetables, achieving 13 percent self-sufficiency instead, which was close to double the 2010 level of seven percent (SFA 2019). While it saw a more than doubling in fish self-sufficiency, from four percent in 2010 to nine percent in 2018, this was one percent below target. It also fell short in self-sufficiency targets for eggs, achieving only 24 percent, or a slight increase from the 2010 level of 22 percent. Thus, it saw significant improvement in two of the three commodities, but it seemed like there was a "glass ceiling" on how much productivity-improvement could be achieved.

To further strengthen its efforts, the country launched in March 2019 its ambitious "30by30" target of 30 percent nutritional self-sufficiency by 2030, in which the agriculture sector is expressly tasked to provide minimally 30 percent of the country's nutrition needs, up from close to 10 percent in 2019. It also launched the Singapore Food Agency (SFA) as a reorganization of AVA (Teng et al. 2019).

Singapore has opted for high-tech farming, which uses indoor vertical space and other underutilized space. Urban indoor agriculture and aquaculture have enabled optimization of land, water, and labor to significantly increase the production of vegetables and fish per unit area of land. However, high-tech indoor farming requires high investments in capital expenditure (CAPEX), which make up on average two-thirds of total investment costs (Montesclaros and Teng 2019; Kozai, Niu, and Takagaki 2015). It likewise consumed much energy with the resultant produce, costing more than similar produce from open fields (Montesclaros and Teng 2019).

The trade-offs between using limited production resources, in the form of high CAPEX and higher costs of produce, have to be optimized for the type of crop and the price affordability of consumers, as shown mathematically in the UrbanAgInvest (UAI) tool.[6] While high-tech vertical farms may not be a viable alternative for lower-income countries, the UAI tool showed that it saw promise in Singapore, owing to the higher per-capita income levels that allowed higher-priced imports, both the consequence of economic development that emerged from its industrialization experience.

The opportunity for such high-cost urban agriculture lies in "shortening supply chains" by allowing Singapore to replace imports of leafy vegetables with domestic production, based on findings from the UAI tool. The model showed, however, that only a few of the higher-priced vegetables could be grown in a financially viable manner, limited to the highest-priced vegetables such as lettuce and kale imported from Japan or the US. Nonetheless, earlier model findings showed that if the goal were to increase leafy vegetable production from 13–14 percent in 2018 to 30 percent,[7] then such indoor farms would be financially viable, while also reducing "food miles" or carbon emissions from food transport.

6 The tool has been copyrighted as an invention by Jose Ma. Luis Montesclaros (first inventor) and Paul S. Teng (second inventor/co-inventor), Ref. No. 2018-259, © NTU, Singapore, and can be used/further adapted via standard licensing agreements with the university, in collaboration with the inventors.

7 Financial viability of investing in such farms, or importing technologies from overseas, were computed assuming property tax exemption was given, and optimizing with the goal of internal rate of return of eight percent over a 20-year period, among others.

In 2020, the Singapore Ministry of Sustainability and Environment (MSE) also launched the "Singapore Food Story" program, which provided funding support to three themes: (1) urban agriculture and aquaculture (high-tech indoor and outdoor farms); (2) future food (targeting alternative proteins like plant-based protein and cellular meat, etc.); and (3) food science and technology, which would be the basis for innovations in farming and food processing. This was backed by an initial tranche of SGD 144 million (about USD 101 million) and tapped into all the existing expertise in higher education institutes, government agencies, and the private sector.

Even as the country continued with its industry development initiatives, with the EDB maintaining its focus on industrial development, the SFA under the MSE concurrently invested to make agriculture more efficient to meet the "30by30" goal.

Dealing with Future Uncertainties

Despite Singapore being ranked the most food secure country in 2019, its weakness in food resilience was further revealed in the recent outbreak of COVID-19 in early 2020 (Montesclaros and Teng 2023).[8] The pandemic disrupted global food supply chains as countries implemented lockdown policies to contain the virus (Teng, Caballero-Anthony and Montesclaros 2021). This impacted all stages of producing, processing, transporting, and consuming food, reducing the physical availability and accessibility of food (Teng 2020; Montesclaros 2020). Fear of food shortage in Singapore was visible in the form of panic-buying, leading to public announcements assuring citizens of food security (SAFEF 2020).

To sustain the imports that are responsible for the bulk of its food needs, the country in March 2020 developed binding "supply chain connectivity agreements" with five other trading partners. Concurrent with this are existing overseas food production collaboration projects, which allow a portion of the production to be exported back to Singapore; an example is a 2,500 km^2 agri-food zone in Jilin province, China, which has been exporting rice back to Singapore (Tortajada and Zhang 2016).

To address concerns about the disruption of food supply chains from measures to reduce the pandemic's progress, the government has since further established various "whole-of-government" committees and task forces to tackle Singapore's food security. COVID-19 further led to another SGD 30 million (about USD 21 million) being made available from April 2020 to ramp up production of vegetables, eggs, and fish by local farms in the shortest time possible (SFA 2022). This was backed by "30x30 Express" Inter-Agency Task Force, formed in April 2020 to drive and coordinate inter-agency efforts to support the ramping up of local food production. It was tasked to "oversee efforts to: (i) accelerate the ramping up of local food production; (ii) address hurdles related to the setting up or expansion of farms; and (iii) ensure farms are highly productive, sustainable and resilient" (MSE 2020). Increasingly too, research has been funded in Singapore universities and their overseas collaborators to improve agriculture in neighboring countries.

IMPLICATIONS FOR SIDS FROM SINGAPORE'S EXPERIENCE

Stabilizing food security is a goal that most countries have but with small island states, it requires a fine balance between supply (imports, self-production, and stockpiles) and demand (consumer diets, expectations, and wastage). Unlike large countries with arable land, fresh water, labor, and availability of inputs, SIDS are always vulnerable to external phenomena beyond their control and have low resiliency. As Singapore has shown, what SIDS can do is to develop solutions that assure a capacity to buffer against

[8] Further challenges faced by Singapore in future, building on the experience of the rice sector amid COVID-19, are discussed in Montesclaros and Teng (2023). They argued that even if the "30-by-30" target is achieved, Singapore will still need to account for disruptions to the "70%" that is imported (161–189).

supply disruptions for a brief period and assume that not all its import channels are cut.

Bypassing Agricultural Transformation: The Role of External Capital

Reflecting on how Singapore's model reflects on the previous approaches within the agricultural transformation *problematique* for SIDS, allows for drawing insights for SIDS.

Viewed from the standpoint of Timmer's agricultural transformation model (Timmer 1988; Briones and Felipe 2013; Adriano and Teng 2021), Singapore's experience would appear counterintuitive. This is because it would appear to defy the logic that capital in agriculture is required for industrialization to occur, as covered in Timmer's first and second stages.

Rather, Singapore's experience showed that capital does exist beyond the agriculture sector. In other words, it is possible to bypass the Mosher stage of "getting agriculture moving"; and the Johnston and Mellor stage of agricultural financing serving as financial base for industrial sectors need not be a requisite. Timmer (1988) initially referred to this as a "jump strategy" although he earlier emphasized the undesirability of such a strategy, owing to the arguments shared previously.

Singapore was able to boost the productivity of its non-agricultural sectors, even before its agriculture sectors could develop (Goh 2016). Given this perspective, it may appear more compelling to return to the earlier dual sector model of Arthur Lewis (1954), which assumed that both agriculture and non-agricultural sectors co-existed, initially, but that agricultural productivity was not a pre-requisite for industrialization. A key difference between the dual sector model and the dominant model is that the former assumes that capital is available and can be drawn from other sources apart from agriculture.[9]

In the presence of external sources of capital/financing, as well as deliberate government intervention to transform the economy, it therefore becomes possible to bypass Timmer's first two stages of agricultural transformation. With the presence of external capital, including development financing, SIDS too can build their own development stories as Singapore has.

Singapore's strong governance has played a prominent role in shaping the combination of industrial transformation and agricultural transformation in the past five decades, as a pre-requisite for making capital work the way it did for the city-state. SIDS will therefore need to ensure transparent and efficient governance processes to draw in foreign investments, as well as foreign expertise, as Singapore has done.

The Need for Flexibility and Coordination: Multi-Level Perspectives

Singapore's experience can be further understood from the viewpoint of Geels and S'hot's multi-level perspective (MLP) model, which provides further nuances to the complexity of improving innovation, including socio-technical transitions toward sustainability (Geels and Schot 2007). This framework model defines three levels of transition that need to be addressed if technology potential is to be maximized:

1. ***Niche innovations level (micro-level).*** The first is the micro "niche innovations" level, which concerns the adoption processes of technologies, as well as the learning processes among individuals and companies/businesses. In the agriculture sector, such individuals may include farmers adopting agricultural innovations.
2. ***Socio-technical landscape (macro-environment).*** The second level is the socio-technical landscape, which includes the exogenous changes in the environment at the macro-economic, cultural, and

[9] This theoretical discussion builds on the theoretical argument of the second author's PhD dissertation, where Montesclaros (forthcoming, 2023) juxtaposes Timmer's (1988) agricultural and structural transformation model and "jump strategy" against Lewis' (1954) dual sector economy model and Lavopa and Szirmai's (2018) depiction of structural transformation.

political levels. Such factors are usually beyond the agriculture sector but can nonetheless influence innovation adoption.

3. ***Sociotechnical regime (policy actors and interests).*** The third level involves the socio-technical regime, which includes the web of actors in the broader community, alongside their interests and the policies they espouse. These may include deliberate state policies for industrialization, for instance, which can in turn transform both the micro- and macro-levels.

Therefore, the natural limits to agricultural expansion in SIDS are framed within a broader set of challenges in achieving agricultural innovation across multiple levels.

Applying the MLP approach to Singapore, it can be seen that in the 1960s through to late 1990s, the deliberate state policy of industrialization (socio-technical regime) has led to changes in the socio-technical landscape, which have reduced incentives for innovation among farmers (niche innovation). This made land scarcer, raising the opportunity costs of land and leading to less agricultural production. Singapore saw that it was undesirable to have a stagnant economy with low value-addition by its workers, which were also its citizens. Given land limitations and the government's statist approach to the provision of public housing services, it also saw as undesirable the negative impacts on the quality of life brought about by sparsely located pig and duck farms. This led to a shift from "self-sufficiency" to "self-reliance" (Tortajada and Zhang 2016).

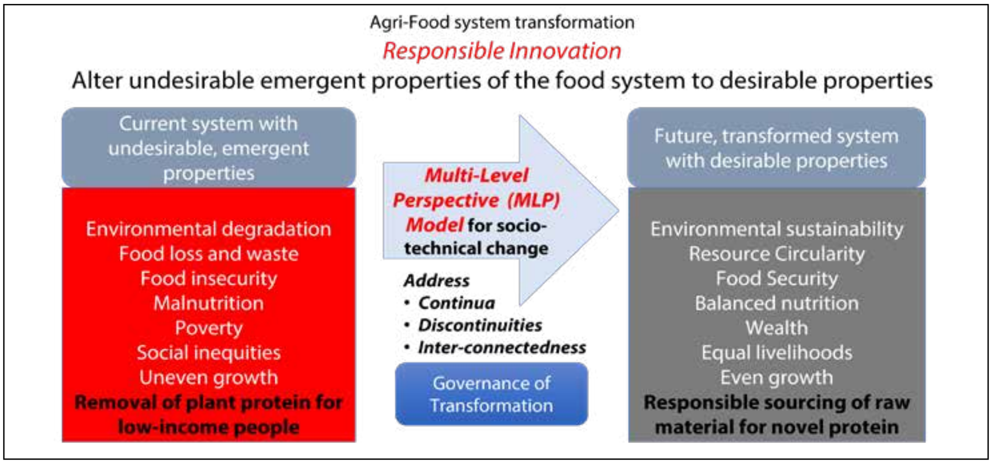
The further rise in international grain prices in 2008 (alluded to earlier), amid the simultaneous food price crisis and financial crisis in 2007–08, acted as an exogenous shock to the food security level of the country because of food export disruptions from source countries (i.e., a shock to the socio-technical landscape). This discontinuity triggered the fear of further risk of food insecurity on the part of the policy actors (socio-technical regime), forcing them to revisit their current approaches. This led to the deliberate "U-turn" in state policies toward "food supply resilience" strategy, which included promoting food self-sufficiency at the country level through agricultural innovation among its farmers. This involved the formation of the Food Fund for productivity-improvement as well as AVA's 2013 Food Security Roadmap (SFA 2014), as discussed earlier.

Addressing Sustainability: Application of MLP to SIDS

The need to address multiple facets in achieving agricultural transformation requires a notion of "responsible innovation" to further underpin the transformation. It involves ensuring that during the transformation process, the negative impact on the farming sector is minimized especially with regards to lost livelihoods due to innovation. A schematic of the use of MLP in designing transformation policies is shown in Figure 4, which involves asking (1) what aspects of current systems need to be changed at multiple levels; (2) for what purpose; and, subsequently, (3) how to minimize emergent (harmful) properties and maximize benefits in the process of transformation.

In the case of SIDS, an immediate implication of the MLP approach is the need to minimize or eliminate negative factors that are undesirable in the process of transition into a new system, where agriculture co-exists with the industrial sector. A case in point are the negative externalities, such as environmental degradation caused by using "green revolution" technology and transforming these to positive externalities, such as environmental sustainability. This is illustrated by the current increasing interest in converting conventional agriculture with high levels of synthetic inputs to regenerative agriculture, which makes much use of biological waste and soil microbes. Likewise, technologies that perpetuate social inequities within the agriculture sector are conceived as being turned into wealth generation and livelihood improvement (Figure 4). The MLP approach provides a heuristic framework for applying experiential knowledge to transform

Figure 4. Application of multi-level perspective model to agricultural transformation



Source: Authors' interpretation of Geels and Schot (2007)

agri-food systems, as shown by the strong interest in resource circularity; undesirable food loss and waste are used to produce either beneficial compost or insect protein to feed chicken and fish (Teng 2021). As noted in Figure 4, another challenge is the growing plant-based protein industry, which is sourcing protein-rich seeds like pulses and mung beans to manufacture processed plant-based protein. This is often at the detriment of the rural poor who depend on these seeds as a vital source of protein. Using the MLP model as a guide, current food systems need to find alternate sources of plant proteins to make novel, processed plant-based protein to feed the appetites of the middle-class and rich, in order not to prolong the negative impacts on the nutrition of the rural poor (Teng 2021).

A helpful rubric to measure the sustainability of agricultural systems is the "EES" rubric of being "**e**nvironmentally friendly" and conserving the natural resource base, "**e**conomically viable" and enabling farmer livelihoods, and "**s**ocially just" to equally benefit small and large farms and producers and consumers. For a small state, the second "E" (economic viability) remains the most challenging. This is partly due to the small scale of production, limited market, likely prohibitive cost of technology relative to product pricing, and higher labor cost given agriculture's competition with non-agricultural sectors (Teng 2022).

CONCLUDING REMARKS

Our work in Singapore and other small states led us to postulate that for small (island and developing) states, a clearer path to economic transformation may be to develop a functional urban industrial and service sector first, and leverage that to support development of a limited agriculture sector to meet defined food and livelihood needs. And that implicit in this approach is the capacity to import food from diverse sources at prices within the price affordability of households.

Small island and small continental states have responded in recent years to the disruptions in supply chains of food and agricultural inputs by developing strategies to cope through increasing their level of food self-production or securing stable supply chains. Countries like the United Arab Emirates, Oman, and Singapore, which have built up financial resources from non-agricultural sectors (tourism, industrial, manufacturing, and financial) or other resources, have leveraged these to jumpstart their agriculture sectors, both urban/peri-urban and rural. In this century, "disruptive technologies" such as digital technologies, biotechnology, and new breeding innovations are also proving themselves as essential productivity-enhancing technologies for small states.

Singapore has demonstrated our thesis through its economic growth from a less developed economy to a developed one in less than three decades by adopting a strategy based on optimal use of its limited natural resources of land, water, and biodiversity. This would not have been possible without investments in enabling urban infrastructure, foreign direct investment, and human capital development. The latter is considered today to be the result of one of the best educational systems globally.

As a final note, the goal of our thesis is not to overturn the earlier theories of transformation, but rather to build on them and to identify an alternate development pathway that does not depend on agriculture as the foundation for capitalization. However, we note that no two small states are the same. Singapore may admittedly be the extreme positive example of small states, given its highly favorable geographic location for trade and to act as an entrepôt center. There may be other approaches to build the capital base apart from agriculture, that build on each SIDS' competitive advantage, whether as a financial hub, or tourism. This too will require the formulation of enabling policies, such as tax incentives and attracting foreign direct investment to further catalyze transformation in non-agricultural sectors. As such, lessons learned from the Singapore case and the efforts of other small states will need to be adapted to suit the circumstances prevailing in any other small state.

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