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Can Structural Transformation Be Induced?: Upgrading Comparative Advantages and Climbing the Value Chain in Singapore

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Abstract
Since the 1800s, the theory of comparative advantage has been extolled for illustrating the gains from trade when countries specialise based on their relative strengths. Using the standard neoclassical lens, comparative advantage best evolves through a gradual and sequential process. However, the theory says little about how countries induce structural change and why some countries transform their economies more rapidly than others. Drawing on Singapore’s experience, this paper studies how its comparative advantage evolved in parallel with the structural transformation of its economy. By adapting the product space analysis by Hidalgo et al. (2007), this paper proposes a new empirical strategy to identify how much of Singapore’s structural change was the result of introducing new ‘comparative advantage-defying’ products. Singapore’s economic success was found to arise not just from gradual and evolutionary changes to its comparative advantage, but also from the relentless search for new capabilities, particularly in uncharted areas.
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1. Introduction

When challenged by the mathematician Stanislaw Ulam for a proposition in the social sciences that was both true and non-trivial, Paul Samuelson (1969) named the theory of comparative advantage: “That it is logically true need not be argued before a mathematician; that it is not trivial is attested by the thousands of important and intelligent men who have never been able to grasp the doctrine for themselves or to believe it after it was explained to them” (p. 9).

Under the theory, countries specialised in producing goods based on their relative factor productivities or endowments. As such, countries without cost efficiencies in producing any good (i.e. countries with no ‘absolute advantage’) could still focus on producing goods that they were less inefficient in compared to other countries (i.e. they still had a ‘relative’ or ‘comparative’ advantage in producing these goods). Capturing the imagination of generations of economists, the ‘law’ of comparative advantage has been extolled as being a necessary – even if it is not sufficient – condition for welfare gains from trade. Even in the presence of trade impediments such as tariffs and transport costs, countries still stood to gain from trade by specialising according to their comparative advantages (see Deardorff, 1980). Arising
from its pre-eminent position in international trade, the theory of comparative advantage has formed the basis for many neoclassical policies (e.g., the push towards trade liberalisation).

Under the neoclassical interpretation, structural change in the East Asian newly industrialised countries (NICs) such as Singapore occurred as the technological composition of its goods upgraded in a natural and sequential manner in line with the evolution of factor proportions and thus comparative advantages (see Ariff & Hill, 1985; James et al., 1989; Tan, 1992; Chowdhury & Islam, 1993; Kosai & Takeuchi, 1998). By specialising in and channelling FDI into industries based on its comparative advantage (Balassa, 1981; Soon, 1996), Singapore followed a cumulative process of technological learning and did not leapfrog industries along its path of economic development (Hobday, 1994, 1995). Following this account, a common historical narrative of Singapore’s economic development posits that it moved up the value chain as its comparative advantage evolved in stages from entrepôt goods (before 1960) to labour-intensive goods (1960s to early 1970s) to capital-intensive goods (mid-1970s to mid-1980s) and to human capital and technology-intensive goods and services (from the mid-1980s) (e.g., Leu, 1996).

Such an interpretation does not adequately explain why Singapore’s structural transformation was associated with a production and export structure that changed at a pace and to an extent that far surpassed that of other countries. According to UNIDO (1985), Singapore exhibited the most significant structural change among the countries studied between 1965 and 1980, with its index of structural change in manufacturing being 3.5 times the average level for developing countries.¹ This was corroborated by Rana (1990) who found that Singapore’s pattern of comparative advantage had the most significant change between 1965 and 1984 in a group of 13 Asian and Pacific countries.² In a later study by UNIDO (2013), Singapore’s structural change index, continued to record the highest value among the countries studied.³ Separately, Felipe et al. (2013) also identified Singapore as the only country, out of 114 countries between 1995 and 2010, that successfully ‘teleported’ into manufacturing more complex (and distinctive) products.

¹ The index of structural change in manufacturing for Singapore (48.32) exceeded other countries including South Korea (31.37), Brazil (30.03), India (20.89), Argentina (15.90), Malaysia (15.86), Yugoslavia (12.01) and Hong Kong (9.87) (UNIDO, 1985). The average level for developing countries was 13.83.
² The 13 countries included Singapore, Hong Kong, South Korea, Taiwan (NICs); Indonesia, Malaysia, Philippines, Thailand (ASEAN-4); India, Pakistan, Sri Lanka (South Asian countries); Fiji and Western Samoa (South Pacific countries).
³ Singapore was the only country in Asia with scores for trade openness and structural change that were both above average in 2007 (UNIDO, 2013, chapter 5).
How did a country that initially manufactured feathers in pillows, plastic flowers and mosquito coils climb the value chain and branch its manufacturing capabilities into sophisticated industries such as wafer fabrication, petrochemicals and pharmaceuticals within a generation? Thus far, there has been little resolution over whether Singapore’s economic development model conformed to the neoclassical interpretation of a sequential and staged evolution of comparative advantage.

Two challenges account for this. First, there is difficulty in defining what it means to make a ‘sequential’ transition in comparative advantage. As an example, if a country with a comparative advantage in producing men’s shirts gains a comparative advantage in producing women’s dresses, intuition suggests that this represents a ‘sequential’ transition in comparative advantage because the production of different types of garments tends to require similar capabilities. However, when a country transitions from having a comparative advantage in labour-intensive electronics assembly to having a comparative advantage in the capital-intensive petrochemicals industry, more judgement has to be made on whether this represents a ‘natural’ evolution in its comparative advantage.

Second, even if a suitable definition can be established on what constitutes a ‘natural’ transition in comparative advantage, there needs to be a framework that can map the relationships across all sectors or products in the economy at a detailed level.

Arising from these challenges, different authors have analysed the same phenomenon and had different interpretations on whether it represented changes in comparative advantage based on pre-existing or newly-injected capabilities (see the contrasting assessments by Lin and Chang, 2009, on South Korea’s foray into the steel industry, for example).

This paper proposes a new systematic method of addressing the two challenges by leveraging on the product space framework by Hidalgo et al. (2007). The empirical strategy is applied to the case of Singapore to study if structural transformation was due to ‘natural’ transitions between related products with comparative advantage, or jumps between ‘distant’ products. In other words, did structural change occur based on Singapore’s predetermined position in the product space or was it the result of active government interventions that defined new comparative advantages? This paper therefore aims to answer (i) whether, (ii) to what extent, and (iii) in what areas (at the detailed product level) Singapore conformed to or defied its comparative advantages in order to achieve its phenomenal economic development over the past 50 years. To the best of our knowledge, such a study has not been done for Singapore before.
The remainder of the paper is organised as follows. Section 2 reviews the literature on comparative advantage. This is followed by an overview of the key concepts in the product space methodology in Section 3. Section 4 shows the structural transformation in Singapore’s manufacturing sector through the evolution of its product space maps. Section 5 then introduces the new empirical strategy to evaluate the areas where Singapore ‘defied’ its comparative advantage. Section 6 broadly describes industrial policy in Singapore. Finally, concluding remarks are provided in Section 7.

2. Literature Review

The concept of comparative advantage dates back to the works of Robert Torrens, David Ricardo, James Mill and John Stuart Mill. Although Torrens (1815) first conceptualised the idea of comparative advantage, it is more commonly associated with Ricardo (2004/1817) who investigated empirical examples in greater detail. The idea was further clarified by Mill J. (1821), and expanded by Mill J. S. (2004/1848) who described how the gains from trade were distributed.

The terms of comparative advantage shifted from differences in technological capabilities to differences in factor endowments when Heckscher and Ohlin (1991)4 described countries as exporting goods that more intensively used factors that they were relatively better endowed with. Broadly, the Heckscher-Ohlin (H-O) model of comparative advantage highlighted that labour-intensive goods would be produced in low-wage (and labour-abundant) countries while capital-intensive goods would be exported by more technologically-advanced economies. Much subsequent research went into reaffirming the relationship between relative factor endowments and trade patterns (e.g., Debaere, 2003; Romalis, 2004).

In the neoclassical framework, economic development is driven by trade openness, which promotes – or even necessitates – a comparative advantage-driven pattern of specialisation (see Lal, 1983; Kowalski & Stone, 2011). With well-functioning and deregulated markets, relative prices (determined by demand and supply) allocate resources to activities aligned with countries’ comparative advantages. Any deviations from existing comparative advantages therefore distort the allocation of productive factors (Balassa, 1979a).

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4 The early genesis was based on work by Heckscher (1919) and his student Ohlin (1933).
While emphasis is placed on the importance of specialising based on existing comparative advantages, a future ‘ideal’ pattern of comparative advantage that accounts for externalities (e.g., inadequate infrastructure or clustering effects), steady-state dynamics and long-run potential is usually targeted. The latter is known in various forms as ‘incremental’, ‘long-run’ or ‘latent’ comparative advantage, as opposed to ‘established’ and ‘momentary’ comparative advantage (see Brown, 1943; Nurkse, 1961; Findlay, 1973; Lin, 2012).

According to the mainstream view, a country’s transition towards the ideal state is best developed through a ‘stages approach’ to comparative advantage with continuous changes to its export structure as the economy accumulates physical and human capital (Balassa, 1979b). At the initial stage of industrialisation, developing countries, generally endowed with surplus labour from the agricultural sector, have a comparative advantage in labour-intensive industries. As these industries expand, labour demand and costs increase. Investments by these industries will also increase the capital stock (human and physical) in the economy. Eventually, the economy reaches a ‘tipping point’ where it became more efficient in the use of capital relative to other less developed countries. Along this ‘technological ladder’, comparative advantages generally evolves from producing primary goods to labour-intensive, capital-intensive, skill-intensive, technology-intensive and then knowledge-intensive goods. Such ‘gradualism’ was advocated as the key fundamental development strategy for developing countries (Oshima, 1987; Kosai & Takeuchi, 1998).

In the neoclassical world, a country’s comparative advantage evolves naturally and gradually through market and trade interactions. However, such an interpretation of economic development offers few insights on the process of structural change (i.e. changes in the patterns of production and specialisation) – structural change is regarded as a by-product of growth. Technological progress, which alters the production structure and determines factor intensities of products, is seen to be exogenous. Although supply-side factors (e.g., productivity growth, capital accumulation and human capital improvements) have the potential to drive the economy’s growth, changes in the economic structure respond to the demand in internal and external markets. Economies therefore depend on larger markets and changing patterns of demand to foster new production processes and grow.

Trade specialisation based on static comparative advantage sets up a deterministic pattern of trade and production. When an advanced economy specialises in producing high-technology products while a developing country specialises in manufacturing unsophisticated goods, the theory of comparative advantage illustrates how trade gains can be maximised by
having greater relative differences (in technological capabilities or factor endowments) across countries, but says little about how the developing country can more rapidly accelerate its structural transformation to more sophisticated products beyond a gradual process of factor accumulation. With markets reflecting and entrenching existing comparative advantage patterns and factor endowment distributions, adherence to the theory tends to maintain the status quo in terms of productive capabilities across countries.

Importantly, the standard H-O theory of comparative advantage is premised on many assumptions such as identical technologies across countries. By assuming that countries tailor a specialised basket of goods based on equal access to common, tradable technologies, the theory glosses over a key tenet of economic development: Differences in technological and learning capabilities are precisely what differentiates rich and poor economies (see Pack & Westphal, 1986; Stiglitz, 1999; Clark & Feenstra, 2003; Chang, 2007; Cimoli et al., 2009; Greenwald & Stiglitz, 2013; Stiglitz & Greenwald, 2014).

History has shown that differences in technological and productive capabilities across countries can be facilitated by strategic governments. As Ocampo et al. (2009) described, “structural change can be planned or, at least, induced” (p. 144). The theory of comparative advantage therefore places inadequate weight on the long-run potential of dynamic gains through short-run distortions (Tan & Jomo, 1995). Many advanced economies achieved their level of development today through judicious policy interventions that accelerated industrial development and tilted the system towards sectors with longer-term growth potential (see Chang, 2002; Reinert, 2007; Studwell, 2013). In the late 20th century, the NICs experienced strong economic growth and development by flexibly evolving the productive capacity of their exports rather than focusing on static comparative advantages (Palma, 2009). As a result, structural change in Asia was more significant than in other parts of the world (see McMillan & Rodrik, 2011).

Industrial policy plays a key role in defining a country’s comparative advantage. In this context, Weiss (2013) distinguished between ‘market-based’ and ‘promotional’ approaches to industrial policy. While the ‘market-based’ approach targets closer or similar activities to the country’s existing specialisation, the ‘promotional’ approach aims to shift more rapidly into distant activities that have weaker links to existing comparative advantages. Such a

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5 Other assumptions associated with the standard theories of comparative advantage included perfectly competitive factor and product markets, comparable factors of production, undifferentiated products, constant economies of scale, identical consumption patterns, perfect labour mobility, full employment, a fixed pool of national resources, and a universally-stable ranking of sectors based on factor use.
characterisation has parallels with the differentiation between ‘intensive’ and ‘extensive’
technological changes described by Pack and Westphal (1986). While the former builds
incrementally on existing capabilities through technological investments that have small
indivisibilities, the latter targets new capabilities through technological investments with
large indivisibilities.

The divergent views towards the ‘economic distance’ of new products that countries
can reasonably target were captured in the debate between Lin and Chang (2009). Adopting a
more neoclassical position, Lin argued that countries should follow a “comparative
advantage-conforming” (CA-conforming) strategy by facilitating the growth of related
activities that are consistent with their ‘latent comparative advantage’ based on their
endowment structure. On the other hand, Chang argued that more aggressive interventions to
upgrade technologies and capabilities were essential to build new and distinct comparative
advantages. In other words, countries should endeavour to introduce more “comparative
advantage-defying” (CA-defying) products to their production and export baskets.

3. Key Concepts and Definitions

Any analysis of whether countries conformed to or defied their comparative advantages
will need to define (i) how comparative advantage is measured, (ii) how products are related,
and (iii) what it means to defy a country’s comparative advantage. This section lays out the
definitions of (i) and (ii) used in the product space methodology by Hidalgo et al. (2007). Section 5 describes (iii) in its analysis of whether Singapore pursued a CA-conforming or
CA-defying strategy.

3.1 Revealed Comparative Advantage (RCA)

Comparative advantage is the outcome of numerous measurable and unmeasurable
factors (e.g., inter-country differences in production functions and factor proportions), and is
best analysed through cost comparisons across different sectors. However, as data for non-
price factors and the costs in different sectors are seldom available, a country’s comparative

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6 A country’s ‘latent comparative advantage’ refers to industries which have low factor costs of production as
determined by its factor endowments, but high transaction costs in domestic and international markets because
of externalities or constraints in hard and soft infrastructure (see Lin & Monga, 2011). Hard infrastructure refers
to roads, ports, airports, telecommunication systems and public utilities while soft infrastructure includes
institutions, regulations and social capital.
advantage is assumed to be ‘revealed’ by its exports to the world (i.e. its trade specialisation). Balassa’s (1965) Index of Revealed Comparative Advantage (RCA) is denoted as follows:

$$RCA_{i,j,t} = \frac{\sum_{j} X_{i,j,t}}{\sum_{j} \sum_{i} X_{i,j,t}}$$

where $X_{i,j,t}$ refers to the value of exports by country $i$ of good $j$ at time $t$.\(^7\) The RCA Index compares two components. The numerator shows the share of a good’s exports in the country’s merchandise export basket while the denominator highlights the world’s total exports of the same good as a proportion of the world’s total merchandise exports. If $RCA_{i,j}$ is greater than 1 (i.e. the country exports a larger share of the good in its export basket compared to the world’s share of exports of the same good), country $i$ is said to have a revealed comparative advantage in good $j$. If $RCA_{i,j}$ falls below 1, country $i$ lacks a revealed comparative advantage in good $j$. In a mathematically-equivalent interpretation, a country reveals its comparative advantage if its share of exports for a particular product in the world is greater than its share of the world’s total merchandise exports (i.e. $RCA_{i,j,t} = \frac{\sum_{j} X_{i,j,t}}{\sum_{j} X_{world,j,t}}$).

To analyse structural change in Singapore, the RCA Index is suitable for at least two reasons. First, small, open economies are very dependent on foreign demand in order to meet the minimum efficient scale necessary to sustain many manufacturing industries.\(^8\) Unlike large countries that may produce goods competitively for its domestic market and not have these strengths adequately captured in the export-based RCA Index, this is less of an issue for small economies such as Singapore which export a significant share of its manufacturing output.

Second, the RCA Index’s emphasis on post-trade statistics (which are affected by policy) rather than pre-trade relative prices (which form the basis of the theory of

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\(^7\) The use of gross exports to calculate RCA scores has been critiqued for not reflecting production structures and fundamental capabilities, particularly for entrepôt economies which re-export imported goods. In Singapore’s case, there has generally been a close relationship between the distribution of activities in its manufacturing output and merchandise exports baskets as the pattern of re-exports influenced its manufacturing production structure (see Kuan, 2015). For instance, Singapore’s re-exports of natural rubber led to the development of a sizeable rubber processing industry in the 1960s. Additionally, RCA scores calculated using gross exports and available trade in value added (TiVA) data (i.e. value of exports that is produced domestically and excluded intermediate goods and exports) (OECD, 2013) for broad industries remained fairly similar. As TiVA data become more extensive (i.e. at a more disaggregated commodity level and for earlier time periods) in future, the potential to incorporate it to product space analysis will increase.

\(^8\) With an internal market of only 1.9 million people in 1965 (DOS, 2015), manufacturing growth in Singapore was largely driven by external demand.
comparative advantage) serves the intent of this paper to show the extent that Singapore’s comparative advantages were transformed by policy interventions.

3.2 Product Relatedness

To establish a notion of product relatedness, the output-based proximity measure by Hausmann and Klinger (2006, 2007), rather than vertical input-output relationships\(^9\), is adopted:

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\phi_{k,j,t} = \min\{P(x_{k,t}|x_{j,t}), P(x_{j,t}|x_{k,t})\}
\]

where \(x_{k,t}\) for country \(i\) takes on the value of 1 if \(RCA_{i,k,t} > 1\) (i.e. country \(i\) has a revealed comparative advantage in exporting good \(k\) in year \(t\)), and 0 otherwise. Calculating across all countries in year \(t\), \(P(x_{k,t}|x_{j,t})\) denotes the conditional probability that a country has a revealed comparative advantage in exporting good \(k\), given that it already has a revealed comparative advantage in exporting good \(j\). In other words, two goods are in close proximity if they have a high chance of being jointly exported by countries with comparative advantages in both of them. This output-based formulation avoids the need to comprehensively account for the specific mix of inputs (e.g., land labour, capital), conditions (e.g., geographical, climatic, institutional) and production processes that are required to export different products.

3.3 Product Space Maps

Product space maps pioneered by Hidalgo et al. (2007) are then constructed using export data from Feenstra et al. (2005) (for 1962-2000) and the UN (2014) ComTrade Database (for 2001-2010) under SITC Rev. 2 at the 4-digit level.\(^{10}\) The dataset includes linkages between 1,069 commodities and 260 countries.

A product space map provides a graphical representation of the proximity between products (Figure 1). Each node represents a different commodity and is coloured based on Leamer’s (1984) product classification groups. The size of the nodes is proportionate to the

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\(^9\) Under the input-output framework, similar products require similar inputs. Such a methodology to estimate product relatedness is more challenging for small and highly open economies such as Singapore that draw many inputs from abroad. A detailed sectoral breakdown of imports is unavailable in national input-output tables.

\(^{10}\) One important advantage of using the cleaned data by Feenstra et al. (2005) is that adjustments have been made to account for trade between Singapore and Indonesia (which was not reported by Singapore before 2003). Some 4-digit SITC codes in Feenstra et al. (2005) ended with ‘A’ or ‘X’ if knowledge of the precise commodity exported was unavailable (e.g., 75XX). In these cases, their export values were apportioned to the relevant commodities exported (e.g., 7591 and 7599), with the allocation based on their weights from available export data in the given year.
product’s share in world exports (i.e. the importance of the commodity in world trade). Products that require similar capabilities are clustered, with links between nodes coloured based on their ‘proximity value’ (ϕ) or relatedness between products. Countries with capabilities in core products in the ‘dense’ portion of the product space (including machinery, chemicals and metals) tend to find it easier to transition to the numerous linked products nearby. Conversely, countries with capabilities in ‘peripheral’ products have more difficulties moving towards the ‘core’. In this framework, structural change follows a diffusion process over a network of products, rather than gradual changes in aggregated input variables (Hidalgo & Hausmann, 2008).

Figure 1: The Network Representation of the Product Space

Source: Hidalgo et al. (2007)
By interlacing product space maps with some notion of a country’s comparative advantage (typically denoted by a black node), the maps show how a country’s comparative advantage evolves over time as its export structure changed. If comparative advantage follows a sequential evolution, movements in the product space would typically be to adjacent nodes. If the country ‘defies’ its comparative advantage, it would make jumps in the product space and attain comparative advantage in more distant nodes.

4. Evolution of Singapore’s Product Space

Figure 2 shows Singapore’s product space maps for seven chosen years between 1962 and 2010. In each product space map, 534 to 736 products were represented in Singapore’s export basket. Commodities which Singapore exported with revealed comparative advantage (i.e. RCA > 1) are depicted by black nodes. Appendix A lists the 10 commodities with the highest RCA for the seven years analysed.

In 1962, Singapore’s primary role as an entrepôt meant that it largely re-exported primary products in the region. With a small manufacturing base (11.3% of nominal GDP; DOS, 2015), Singapore’s comparative advantage revolved around the processing and export of raw materials and primary products (e.g., spices, rubber, palm oil and live animals) which occupied peripheral positions in the product space (see Figure 2A). Although Singapore had a small petroleum refinery cluster11 near the north of its product space, the pattern of products with RCA was largely scattered. In many ways, the concentration of productive capabilities on peripheral, rather than core, products in Singapore’s productive space was not dissimilar to the situation faced by present-day Africa.12

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11 Singapore’s comparative advantage in the petroleum refinery industry was a result of Shell’s US$30 million investment in a refinery on Pulau Bukom in 1961. Between 1961 and 1962, the industry’s output jumped 100-fold from S$1.3 million (or 0.1% of manufacturing output) to S$130.5 million (7.6%) (DOS, 1983).

12 See Hausmann and Klinger (2008), Abdun and Felipe (2011) and Hidalgo (2011) who argued that the peripheral nature of Africa’s product space constrained its economic growth.
Figure 2: Evolution of Singapore’s Product Space, 1962-2010

(A) 1962

(B) 1965

(C) 1970

(D) 1980
Between 1963 and 1965, Singapore entered a brief union with the Federation of Malaya, during which its industrial policy tools were stifled (see Kuan, 2015). When
Singapore gained independence in 1965, the dispersed and peripheral nature of its production capabilities in the product space map remained unchanged (Figure 2B). An import substitution regime had consolidated strengths in existing exports and re-exports that served the region, rather than build up new capabilities at the core of the product space.\textsuperscript{13} During this period, the number of products with comparative advantage fell from 112 to 87.\textsuperscript{14} Re-exported primary products such as rubber, spices and palm oil continued to dominate the list of commodities with the highest RCA. Notably, Singapore’s RCA in refined petroleum products strengthened significantly from 9.71 in 1962 to 30.04 in 1965.

Between 1965 and 1970, Singapore embarked on export-oriented industrialisation as its ousting from the larger Federation of Malaya dissipated hopes of a common market. Singapore actively courted FDI using a variety of industrial policy instruments including tax concessions. By 1970, Singapore had made some headway in the electronics and machinery industries by gaining comparative advantage (RCA of 1.07) in ‘miscellaneous electrical machinery’ (SITC 7788) (see Figure 2C). Barely four years earlier in 1966, Singapore had no comparative advantage in the product (RCA of 0.04).

By 1980, Singapore had gained comparative advantages in a number of products within the electronics and garments clusters (Figure 2D). Greater diversification of its trade basket was characterised by a larger number of products with comparative advantage (more black nodes in the product space map) and lower RCA scores for the products with the highest revealed comparative advantage (see Appendix A).\textsuperscript{15} Within a decade, Singapore gained comparative advantage in a number of commodities (e.g., electric motors, portable radio receivers, electric transformers, printed circuits, electronic microcircuits, diodes, transistors) that it did not export earlier.

In 1990, there was a greater concentration of products with comparative advantage within the electronics cluster (Figure 2E). At the same time, Singapore gained comparative advantage in several chemical commodities (e.g., polyethylene, polypropylene, acyclic alcohols, heterocyclic compounds and nucleic acids). As Singapore advanced into these

\textsuperscript{13} Although Singapore gained a slight comparative advantage in exporting footwear between 1963 and 1965 (denoted by the largest black square in the garments cluster in Figure 2B), this proved to be short-lived.

\textsuperscript{14} This also corresponds to a fall in Hidalgo and Hausmann’s (2009) diversification indicator ($k_{c,0}$) which partly reflects the economic complexity of countries. $k_{c,0} = \sum_{p=1}^{N_p} M_{cp}$, where $M_{cp} = 1$ if country $c$ exported product $p$ with revealed comparative advantage (i.e. RCA > 1) and $M_{cp} = 0$ otherwise.

\textsuperscript{15} Arising from the mathematical formulation, diversification tends to reduce the RCA scores of individual products in Singapore’s export basket. Diversification reduces the numerator in the RCA Index (defined as the share of the commodity’s exports in Singapore’s total exports divided by the share of the commodity’s exports in total world exports).
sophisticated products, several commodities in the garments cluster lost their comparative advantage.

By 2000, the garments cluster was void of any product with comparative advantage (Figure 2F). Notably, there was also a visible reduction in the number of scattered black spots in Singapore’s product space as the number of goods with comparative advantage fell by 25% (from 142 to 106) between 1990 and 2000. For the products with comparative advantage, there appeared to be a convergence towards the southern electronics cluster. The list of products with the highest RCA was largely dominated by the petroleum refinery and chemicals industry.

Within a decade, Singapore’s direction to focus on niche areas (see its strategic economic plans such as EPC, 1991; Government of Singapore, 1991) was borne out by a further shrinkage in the number of goods with comparative advantage (from 106 in 2000 to 96 in 2010) (Figure 2G). As the concentration of black nodes around the electronics cluster became weaker, there appeared to be a movement of the black nodes to the cluster’s north (towards goods in the core of the product space such as polymerisation and copolymerisation products, machinery for specialised industries, non-mechanical or electrical instruments for physical analysis, and power hand tools) and south (e.g., aircraft parts, office machines and industrial diamonds).

5. Did Singapore Defy Its Comparative Advantage?

The evolution of Singapore’s RCA in its product space maps between 1962 and 2010 provides insights on whether Singapore conformed to or defied its comparative advantage. Broad readings of the product space maps suggest that new comparative advantages were not always a result of natural transitions. Leveraging on FDI as a source of technological transfers, Singapore traversed the product space rapidly and gained comparative advantages in products that it barely exported a few years earlier. In this section, a new empirical strategy is proposed to identify the specific products that Singapore ‘teleported’ to in the product space.

16 The shrinkage is also partially attributable to the unavailability of data in 2010 for several petroleum refining products at the 4-digit SITC level (e.g., SITC 3341, 3342, 3343, 3344). Singapore appeared to lose comparative advantage in the petroleum refining cluster because RCA scores were unavailable for these products. However, at the 3-digit SITC level, Singapore’s RCA score (3.5) for ‘petroleum products, refined’ (SITC 334) in 2010 showed that Singapore continued to reveal comparative advantage in the petroleum refining industry.
To understand if Singapore ‘defied’ its comparative advantage to acquire new capabilities in each decade, the product space is analysed in two stages. In the first stage, products that gained comparative advantage in each decade (reference years of 1970, 1980, 1990, 2000 and 2010) when no comparative advantage existed in the preceding decade were identified. In the second stage, filters were applied to eliminate false positives and to impose increasingly stricter conditions on the definition of a product that ‘defied’ its comparative advantage.

In the first filter (F1), products that recorded RCA > 1 in earlier periods (i.e. the product lost comparative advantage and then regained it in a later year) were excluded as they do not count as new areas of comparative advantage. As an example, the product ‘audio amplifiers’ (SITC 7642) was picked up in the first stage as it gained comparative advantage by 1990 when it had no comparative advantage in 1980. However, as Singapore had a revealed comparative advantage in the product in 1974 and 1975, it was filtered out by filter F1.

Filters F2A, F2B and F2C removed products that did not represent sustained comparative advantage for Singapore. In F2A, products that were not consistently exported in the following years (i.e. there were no exports in years X+1 and X+2, where X is the reference year) were excluded. In F2B, products that continued to be exported but had a sudden collapse in the RCA scores in the following years (i.e. the average RCA score in years X+1 and X+2 fell below 0.1) were excluded. In F2C, products with a one-off comparative advantage in the reference year (i.e. RCA < 1 in the four years prior to and after the reference year) were excluded.

Filter F3 eliminated products that experienced ‘natural’ transitions in the product space. A natural transition occurred if Singapore gained new comparative advantage in a product when it had capabilities (i.e. RCA > 1) in at least one nearby product in the preceding five years. An additional filter was initially experimented with to remove insignificant products with exports valued at less than US$500,000 in the reference year. Such products could have a RCA score above 1 if total world exports were small. However, this filter turned out to be redundant because the insignificant commodities were picked out by the other stringent filters.

The conditions in these filters represent our best efforts at maintaining the balance between the need for stringent filters and not filtering away products excessively. In filter F2A, a more stringent criterion could have been to exclude products that had no exports only in the year after the reference year (i.e. X+1). However, this may unnecessarily filter away products that had patchy data in one year. A weaker criterion could have been to exclude only products with more than two consecutive years of zero exports. A sensitivity analysis shows that the results remain unchanged even if the condition was set at five consecutive years of zero exports (i.e. X+1, X+2, X+3, X+4, X+5). In filter F2B, a fall in RCA from RCA > 1 in the reference year to RCA < 0.1 in the two subsequent years represents our best assessment of what a collapse in RCA could be. Once again, a two-year period was used to avoid distortions from anomalies in trade data in any given year. In filter F2C, the period of four years before and after the reference year was chosen to sieve out products that only had one year of revealed comparative advantage in almost a decade.

\[\text{\textsuperscript{17}}\text{An additional filter was initially experimented with to remove insignificant products with exports valued at less than US\$500,000 in the reference year. Such products could have a RCA score above 1 if total world exports were small. However, this filter turned out to be redundant because the insignificant commodities were picked out by the other stringent filters.}\]

\[\text{\textsuperscript{18}}\text{The conditions in these filters represent our best efforts at maintaining the balance between the need for stringent filters and not filtering away products excessively. In filter F2A, a more stringent criterion could have been to exclude products that had no exports only in the year after the reference year (i.e. X+1). However, this may unnecessarily filter away products that had patchy data in one year. A weaker criterion could have been to exclude only products with more than two consecutive years of zero exports. A sensitivity analysis shows that the results remain unchanged even if the condition was set at five consecutive years of zero exports (i.e. X+1, X+2, X+3, X+4, X+5). In filter F2B, a fall in RCA from RCA > 1 in the reference year to RCA < 0.1 in the two subsequent years represents our best assessment of what a collapse in RCA could be. Once again, a two-year period was used to avoid distortions from anomalies in trade data in any given year. In filter F2C, the period of four years before and after the reference year was chosen to sieve out products that only had one year of revealed comparative advantage in almost a decade.}\]
Two products were defined to be nearby if they had first-order linkages in the production connection networks of Hausmann et al. (2011) (i.e. they were in adjacent nodes). For instance, in 1990, computer peripherals (SITC 7525) in Singapore had 11 direct linkages to other products such as CPUs, printed circuits and optical lenses (Figure 3A). As another example, knitted outerwear (SITC 8451) in Singapore had 21 direct linkages with other products such as men’s shirts, women’s suits and dresses in 1990 (Figure 3B).

Filter F4 removed products that had insufficient data points to test the RCA relationship between nearby products based on filter F3. Filter F4 had the largest impact on products that gained comparative advantage in the 1960s as many of them did not have at least 5 years of data in the preceding years to analyse the comparative advantage of nearby products. Under this filter, products that did not have visualisation of their product connections were also excluded.

Table 1 summarises the results of the number of CA-defying products in each decade. As Singapore expanded its share of manufacturing in the economy, it introduced CA-defying products to its export basket (particularly in the 1970s and 1980s). Singapore developed comparative advantage in 26 new products in the 1970s and 13 new products in the 1980s that were not related to existing capabilities.

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19 The choice of five years is somewhat arbitrary, but it represents a reasonable duration that capabilities can be retained in the economy to build new, related areas of comparative advantage. Additional sensitivity analyses indicate that reducing the duration by a year leaves the results unchanged, while increasing the duration by a year only filters out an additional product.

20 Second-order linkages were excluded in the definition of ‘nearby’ products because they represented a jump over the intermediate product.

21 Our definition of distance served as a stricter filter than defining distance as the inverse of the density of the product (e.g., Felipe, 2012). The density of product k ($\omega_k$) refers to the sum of the proximities between product k and all exported products with revealed comparative advantage, scaled by the sum of all proximities leading to product k (i.e. $\omega_k = \frac{\sum_j \phi_{jk} x_j}{\sum_j \phi_{jk}}$, where $x_j = 1$ if $RCA_j \geq 1$; $x_j = 0$ if $RCA_j < 1$; $\phi_{jk}$ is the proximity between product j and k). Under this definition, a product’s distance is measured from the general capabilities of the whole economy (i.e. a product may have a nearby product with revealed comparative advantage, but it will register a larger ‘distance’ if the majority of products in the economy with revealed comparative advantage are far away). Using our filter, we removed products as long as they had at least one nearby product with revealed comparative advantage, regardless of whether the overall economy had more distant capabilities.

22 In Figure 3, coloured nodes denoted products that Singapore had a comparative advantage in. In 1990, Singapore revealed comparative advantages in 9 of the 11 products directly linked to computer peripherals and 5 of the 21 products directly linked to knitted outerwear.
Figure 3: Product Connections for Computer Peripherals and Knitted Outerwear in Singapore, 1990

(A) Computer Peripherals (SITC 7525)

(B) Knitted Outerwear (SITC 8451)

Notes:
(1) Coloured nodes denote products which Singapore had a revealed comparative advantage in (i.e. RCA > 1) in 1990.
(2) The colours of the fonts and nodes reflect the categories used by Hausmann et al. (2011) for the products.

Source: Hausmann et al. (2011)
Table 1: Number of Comparative Advantage-Defying Products, 1970-2010

<table>
<thead>
<tr>
<th>Number of products with comparative advantage compared to the preceding decade</th>
<th>1970</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>(F1) Excluding products which lost comparative advantage before the preceding decade</td>
<td>47</td>
<td>97</td>
<td>58</td>
<td>36</td>
<td>44</td>
</tr>
<tr>
<td>(F2A) Excluding products which were not consistently exported in the following 2 years (i.e. X+1 and X+2)</td>
<td>45</td>
<td>71</td>
<td>37</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>(F2B) Excluding products which experienced a collapse in the RCA in the following 2 years (i.e. X+1 and X+2)</td>
<td>43</td>
<td>71</td>
<td>35</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>(F2C) Excluding products with one-off revealed comparative advantage (i.e. no comparative advantage in X+1, X+2, X+3, X+4, X-1, X-2, X-3, X-4)</td>
<td>43</td>
<td>70</td>
<td>33</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>(F3) Excluding products which had nearby products with revealed comparative advantage in the product space in the previous 5 years (i.e. X-1, X-2, X-3, X-4, X-5)</td>
<td>29</td>
<td>30</td>
<td>14</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>(F4) Excluding products with insufficient data points to analyse nearby products in the previous 5 years (i.e. X-1, X-2, X-3, X-4, X-5)</td>
<td>8</td>
<td>26</td>
<td>13</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Share of comparative advantage-defying products (F4) in total number of products with new comparative advantage (F2C) (%)</td>
<td>18.6</td>
<td>37.1</td>
<td>39.4</td>
<td>44.4</td>
<td>38.5</td>
</tr>
</tbody>
</table>

Notes:
(1) Products with comparative advantage had RCA > 1. Products with ‘new’ comparative advantage did not have comparative advantage (i.e. RCA ≤ 1) in the preceding decade (i.e. 2010 was compared with 2000; 2000 was compared with 1990; 1990 was compared with 1980; 1970 was compared with 1962 as trade data was unavailable for 1960).
(2) Year X refers to the reference year.

Source: Author’s estimates

Corroborating past findings of the relationship between economic discovery and economic development (e.g., Klinger & Lederman, 2004), the number of CA-defying products rose before subsequently declining as Singapore attained higher income levels. This pattern was consistent across all the filters used. Since the 1970s, the inducement of comparative advantage has continued to play an important part of economic discovery in Singapore. In each reference year from 1980, the share of CA-defying products in exports with new revealed comparative advantage consistently exceeded 37%.

The numbers reflect a lower bound of the number of CA-defying commodities. In other words, Singapore likely defied its comparative advantage in more products than what was found in the analysis. First, when in doubt, the analysis erred on the side of being more stringent in the filters used. Second, commodities that gained and lost comparative advantage between the reference years were not captured in the analysis. As an example, Singapore had
comparative advantage in the product ‘photo and movie equipment’ (SITC 8813) between 1972 and 1979. Although it conformed to the characteristics of a CA-defying commodity (i.e. it had no capabilities in adjacent products in the product space in the five years before it gained comparative advantage), it was not picked up in the analysis as it did not have comparative advantage in the reference year 1980.

Third, transitions between seemingly-related comparative advantages may also not occur so naturally, particularly for small economies such as Singapore with binding resource constraints. In generalising the relationships between commodities, product space maps adopt a neutral approach towards countries with different characteristics (e.g., level of development, size, quality of institutions and governance, political conditions). This is viewed as a strength because product space maps do not need to make judgements about which characteristics are more important than others. However, for small countries such as Singapore that face restricted economic conditions, some CA-defying transitions may be underrepresented. For instance, although the transition of capabilities from petroleum refining products to certain petrochemical products may appear ‘natural’ based on the experiences of larger countries, Singapore lacked the natural resources (i.e. natural gas and land) that characterised other successful petrochemical industries.

Figure 4 maps the CA-defying products on Singapore’s product space. The dispersed nature of CA-defying products in 1970 verified that Singapore was initially less discriminate in the manufacturing investments it sought given the urgency to arrest the high rates of unemployment in the 1960s. Reflecting the sentiment then, former EDB Chairman Ngiam Tong Dow said, “We didn't talk about high-tech, low-tech or whatever. Anybody who was prepared to put some money in and create jobs for Singaporeans was very welcome” (cited in Chua, 2010, p. 51).

In 1970, the diverse mix of CA-defying products included ‘margarine’ (SITC 0914), ‘cotton’ (SITC 2634) and ‘miscellaneous agricultural machinery’ (SITC 7219). However, the subsequent decades were marked by CA-defying products that targeted nodes that were closer to the core of the product space. These products included ‘transmission belts’ (SITC 6282), ‘medical furniture’ (SITC 8212), ‘control instruments of gas or liquid’ (SITC 8743) and ‘metal chains’ (SITC 6992) in the 1970s; and ‘metal office products’ (SITC 8951) and phenoplasts (SITC 5821) in the 1980s.

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23 Naphtha from refineries is the primary feedstock used to produce ethylene and propylene in the petrochemical industry.
As Singapore introduced new CA-defying products closer to the ‘core’, it moved more rapidly into other parts of the product space. As such, the CA-defying products influenced both the pattern of new comparative advantages and the speed at which Singapore acquired new comparative advantages in subsequent years. Of the 77 products with new comparative advantage that was based on ‘natural’ transitions between 1980 and 2010, 33 of them (or
42.9%) were linked to previously-induced capabilities from CA-defying products. For example, Singapore drew on knowledge gained in the 1970s from manufacturing the CA-defying ‘miscellaneous electrical machinery’ (SITC 7788) to grow comparative advantage in the 1980s in four related-electronics products (calculators [SITC 7512], electrical resistors [SITC 7723], telecom parts and accessories [SITC 7649] and miscellaneous power machinery [SITC 7712]). Capabilities in ‘calculators’ and ‘electrical resistors’ in turn contributed to the development of comparative advantage in the 1990s in ‘miscellaneous data processing equipment’ (SITC 7528).

6. Industrial Policy in Singapore

Industrial policy played a key role in the structural transformation of Singapore’s economy (see Kuan, 2015). Among the CA-defying products, there was a close concordance with four strategic industries (electronics, chemicals, biomedical manufacturing and aerospace) that were actively promoted by Singapore’s Economic Development Board (EDB) (Table 2).

Table 2: Comparative Advantage-Defying Products in the Electronics, Chemicals, Biomedical Manufacturing and Aerospace Industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>CA-Defying Product (SITC Code)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics</td>
<td>Diodes, transistors and photocells (SITC 7763), electronic valves and tubes (SITC 7762), electrical transformers (SITC 7711), circuit breakers and panels (SITC 7721), analog navigation devices (SITC 8741), electric heating devices (SITC 7758), clocks (SITC 8852), cameras (SITC 8811), movie cameras and equipment (SITC 8812), machinery for specialised industries (SITC 7284), miscellaneous agricultural machinery (SITC 7219), miscellaneous electrical machinery (SITC 7788)</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Ethers and acetals (SITC 5161), cyclic alcohols (SITC 5122), synthetic organic luminophores (SITC 5312), phenoplasts (SITC 5821), polypropylene (SITC 5832), photographic chemicals (SITC 8821), scented mixtures (SITC 5514), phosphatic fertilizers (SITC 5622), miscellaneous colouring products (SITC 5331)</td>
</tr>
<tr>
<td>Biomedical Manufacturing</td>
<td>Vitamins (SITC 5411), antibiotics (SITC 5413), medical instruments (SITC 8720)</td>
</tr>
<tr>
<td>Aerospace</td>
<td>Aircraft parts and accessories (SITC 7929), aircraft tires (SITC 6253), miscellaneous gas turbines (SITC 7148)</td>
</tr>
</tbody>
</table>

Source: Author’s results based on analysis of transitions in Hidalgo et al.’s (2007) product space.

24 Of these 33 products with new revealed comparative advantage, 20 products were directly linked to the CA-defying products (i.e. first-order linkages), 11 products were linked to the 20 first-order-linked products (i.e. second-order linkages) and 2 products were linked to the 11 second-order-linked products (i.e. third-order linkages).
Established in 1961, the EDB served as the “midwife” of industrialisation (Low, 2006, p. 47) in an economy with a comparative advantage that was heavily skewed towards services such as trading and commerce. In 1968, the EDB’s responsibilities for industrial financing and the development of industrial estates were respectively transferred to the newly-formed Development Bank of Singapore (DBS) and the Jurong Town Corporation (JTC). Nonetheless, it retained its investment promotion functions and continued to play an active role in Singapore’s industrial policies.

Over the years, Singapore relentlessly sought to move its industries up the value chain. To boost investments in strategic industries, the government adopted a discretionary approach in administering fiscal incentives such as tax concessions to ‘pioneer companies’. In the electronics industry, Singapore only had two locally-owned firms (Setron and Roxy) manufacturing monochrome televisions before 1968. Despite the lack of skilled labour and domestic supply of inputs, electronics transnational corporations (TNCs) such as National Semiconductor, Texas Instruments, Philips and Seagate were enticed to invest in Singapore as tax concessions were extended under the 1967 Economic Expansion Incentives Act.25 Pioneer status was also granted to Sundstrand’s US$250,000 (S$750,000) investment to make sanding discs for the furniture industry in 1971 even though the project fell below the minimum investment prerequisite of S$1 million and was the lowest-value manufacturing activity in Sundstrand’s business. Over the next few years, the EDB actively courted Sundstrand’s high-technology activities, which eventually led to the birth of Singapore’s aerospace industry in 1974 when Sundstrand invested US$60 million to manufacture aircraft equipment in Singapore.

Through state entrepreneurship, the government took on a leading role in catalysing the growth of strategic industries. For instance, although Singapore had become the largest producer of hard disk drives in the world by the 1980s, the government still sought to upgrade its comparative advantage to higher-value electronics by undertaking joint ventures in the wafer fabrication (with Sierra Semiconductor and National Semiconductor to form Chartered Semiconductor) and dynamic random access memory (DRAM) semiconductor chip (with Texas Instruments, Hewlett Packard and Canon to form Tech Semiconductor) industries. In the 2000s, the biomedical manufacturing industry benefited from these public-private joint ventures (e.g., Merlion, ES Cell International and S*Bio).

25 Another decisive factor in attracting electronics investments was the quick speed at which factory space was prepared by the EDB. In 1969, the S$6 million Texas Instruments plant at the Kallang Basin industrial estate was established in just 50 days.
Education and manpower training policies were geared towards nurturing a labour force that could meet the needs of targeted industries. The emphasis on vocational and technical education (and subsequently engineering in universities), through the expansion of infrastructure and government subsidies, raised the industrial capabilities of Singapore’s workforce. Vocational institutes also boosted the supply of skilled workers (e.g., welders and machinists) in specific industries such as oil refinery, electrochemical and electromechanical. Additionally, Singapore formed strategic partnerships with foreign TNCs (e.g., Tata, Rollei and Philips) and governments (e.g., Japan, France and Germany) to establish government training centres that enhanced the skills of workers in targeted areas of interest (e.g., electronics, precision engineering, electrical fitting, machine maintenance, tool and die design, and robotics).

By leveraging on its significant ownership of land (87% in 2013), the government possessed a strong mandate to undertake land-related industrial policies through land allocation and clustering decisions. Contiguous land was set aside and specialised infrastructure was developed to grow clusters for the electronics (Woodlands, Pasir Ris and Tampines Wafer Fabrication Parks), chemicals (Jurong Island), aerospace (Seletar Aerospace Park) and biomedical (Tuas Biomedical Park and Biopolis) industries.

Notably, Jurong Island marked a remarkable example of government-led efforts to transform the economy’s comparative advantages by altering the surface configuration of land. To build a petrochemicals hub in the mould of Germany’s Ludwigshafen, the government initially invested S$7 billion (US$4.9 billion) to reclaim 22 km$^2$ of land around seven small islands to triple and amalgamate their land mass from 1995. The EDB began wooing foreign chemical investors based solely on the government’s vision of a well-integrated chemicals hub as the physical land and common infrastructure were still non-existent. Yet by its official opening in 2000, Jurong Island had successfully attracted S$20 billion (US$11.6 billion) of investments from 60 leading petroleum and petrochemical companies.

7. Concluding Remarks

In its static form, comparative advantage is “like a compass – it is absolutely necessary in finding out where you are but it does not tell you where to go or how to get there” (Chang, 2013, p. 42). The structural transformation of economies is too important to be left to the natural workings of market forces for several reasons.
First, economic development through the ‘stages approach’ to comparative advantage is too gradual and slow in a rapidly-changing globalised world economy. As comparative advantage is a relative concept that does not merely depend on the evolution of a country’s absolute strengths, it is influenced by the speed at which other countries are gaining technological capabilities through industrial policy.

Second, natural transitions between each stage can incur substantial costs. In reality, factors of production are not as perfectly mobile as assumed in neoclassical models. When the ‘tipping point’ of comparative advantage is reached and industrial restructuring occurs, the transition is necessarily painful for the factors of production involved in the previous rung of the ‘technological ladder’.

Third, countries differ in their abilities to adjust to global disruptive forces and cannot merely depend on natural evolutions of their economic structures. For instance, smaller economies such as Singapore may be less able to assimilate new technologies to upgrade their economies if significant scale economies in production or R&D are required.

Drawing on Singapore’s experience, this paper proposed a new empirical strategy to analyse whether countries conformed to or defied their comparative advantage at the detailed product level. Contrary to neoclassical interpretations of Singapore’s economic development, the diversification of its production and export baskets towards more sophisticated and complex products did not always follow ‘natural’ evolutions of its comparative advantage that was exploited by the private sector. It was also due to the relentless search for new capabilities – particularly in uncharted and targeted areas – that was engineered by the government.

Singapore leveraged on a diverse suite of industrial policies to build productive capabilities and move rapidly to new areas in the product space. As the results in this paper show, industrial policies in Singapore were not just ‘pro-market’, ‘market-conforming’, ‘market-anticipating’ or ‘market-accelerating’ as commonly described (e.g., Lim, 1995, p. 228). They were also ‘market-defying’ in many instances.

Despite initially following a straight service economy trajectory in the early 1960s, Singapore successfully industrialised by creating comparative advantages in many new manufacturing products. Its dramatic jumps in the RCA scores for numerous commodities within a few years required changes in technologies and factor endowments that went beyond the gradual evolutionary process envisaged in traditional neoclassical models of comparative advantage. CA-defying products were responsible for 43% of ‘sequential’ transitions to new
comparative advantages from 1980 and played an important role in accelerating the speed at which Singapore traversed the product space.

The product space analysis in this paper showed that countries – even small ones like Singapore – have the ability to shape their comparative advantages. Countries need to manage the balance between being realistic and risk-taking with regard to new industries. Although conforming to comparative advantage achieves allocative efficiency from a static perspective, countries can potentially benefit from adopting a dynamic view to assess how best to gain capabilities in ‘distant’ products that can more rapidly induce structural change and accelerate the process of economic development. As such, comparative advantage should be viewed as a dynamic concept that can be actively and adroitly shaped by judicious policies, rather than an immutable, deterministic law that is broken to the detriment of countries.
References


### Appendix A: Singapore’s Top 10 Products
with Highest RCA, 1962-2010

<table>
<thead>
<tr>
<th>SITC</th>
<th>Description</th>
<th>RCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0750</td>
<td>Spices</td>
<td>51.36</td>
</tr>
<tr>
<td>2320</td>
<td>Natural rubber latex; rubber and gums</td>
<td>27.31</td>
</tr>
<tr>
<td>2923</td>
<td>Vegetable plaiting materials</td>
<td>21.53</td>
</tr>
<tr>
<td>0014</td>
<td>Poultry, live</td>
<td>21.07</td>
</tr>
<tr>
<td>6872</td>
<td>Tin and tin alloys worked</td>
<td>21.01</td>
</tr>
<tr>
<td>0751</td>
<td>Pepper of ‘piper’; pimento of ‘capsicum or pimenta’</td>
<td>19.69</td>
</tr>
<tr>
<td>6924</td>
<td>Cask, drums, etc, of iron, steel, aluminium, for packing goods</td>
<td>15.43</td>
</tr>
<tr>
<td>0752</td>
<td>Spices, except pepper and pimento</td>
<td>15.18</td>
</tr>
<tr>
<td>2710</td>
<td>Fertilizers, crude</td>
<td>13.70</td>
</tr>
<tr>
<td>6618</td>
<td>Construction materials, of asbestos-cement or fibre-cements, etc</td>
<td>13.59</td>
</tr>
<tr>
<td>2320</td>
<td>Natural rubber latex; rubber and gums</td>
<td>46.00</td>
</tr>
<tr>
<td>751</td>
<td>Pepper of ‘piper’; pimento of ‘capsicum or pimenta’</td>
<td>39.24</td>
</tr>
<tr>
<td>3340</td>
<td>Petroleum products, refined</td>
<td>30.04</td>
</tr>
<tr>
<td>2923</td>
<td>Vegetable plaiting materials</td>
<td>24.63</td>
</tr>
<tr>
<td>4242</td>
<td>Palm oil</td>
<td>21.79</td>
</tr>
<tr>
<td>2711</td>
<td>Animal or vegetable fertilizer, crude</td>
<td>14.15</td>
</tr>
<tr>
<td>752</td>
<td>Spices, except pepper and pimento</td>
<td>13.78</td>
</tr>
<tr>
<td>9110</td>
<td>Postal packages not classified according to kind</td>
<td>13.45</td>
</tr>
<tr>
<td>589</td>
<td>Fruit prepared or preserved, nes</td>
<td>12.83</td>
</tr>
<tr>
<td>2483</td>
<td>Wood, non-coniferous species, sawn, planed, tongued, grooved, etc</td>
<td>12.69</td>
</tr>
<tr>
<td>4240</td>
<td>Other fixed vegetable oils, fluid or solid, crude, refined</td>
<td>55.96</td>
</tr>
<tr>
<td>2320</td>
<td>Natural rubber latex; rubber and gums</td>
<td>51.57</td>
</tr>
<tr>
<td>4242</td>
<td>Palm oil</td>
<td>40.92</td>
</tr>
<tr>
<td>2923</td>
<td>Vegetable plaiting materials</td>
<td>35.43</td>
</tr>
<tr>
<td>4230</td>
<td>Fixed vegetable oils, soft, crude refined or purified</td>
<td>34.32</td>
</tr>
<tr>
<td>2920</td>
<td>Crude vegetable materials, nes</td>
<td>27.48</td>
</tr>
<tr>
<td>751</td>
<td>Pepper of ‘piper’; pimento of ‘capsicum or pimenta’</td>
<td>27.07</td>
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<tr>
<td>3340</td>
<td>Petroleum products, refined</td>
<td>22.23</td>
</tr>
<tr>
<td>2711</td>
<td>Animal or vegetable fertilizer, crude</td>
<td>19.59</td>
</tr>
<tr>
<td>129</td>
<td>Meat and edible meat offal, nes, in brine, dried, salted or smoked</td>
<td>17.11</td>
</tr>
<tr>
<td>2470</td>
<td>Other wood in the rough or roughly squared</td>
<td>25.26</td>
</tr>
<tr>
<td>7764</td>
<td>Electronic microcircuits</td>
<td>24.01</td>
</tr>
<tr>
<td>2923</td>
<td>Vegetable plaiting materials</td>
<td>18.10</td>
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<tr>
<td>3340</td>
<td>Petroleum products, refined</td>
<td>17.73</td>
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<tr>
<td>2320</td>
<td>Natural rubber latex; rubber and gums</td>
<td>17.22</td>
</tr>
<tr>
<td>7628</td>
<td>Other radio receivers</td>
<td>16.05</td>
</tr>
<tr>
<td>4311</td>
<td>Processed animal and vegetable oils</td>
<td>15.95</td>
</tr>
<tr>
<td>4200</td>
<td>Fixed vegetable oils and fats</td>
<td>15.25</td>
</tr>
<tr>
<td>7649</td>
<td>Parts, nes of and accessories for apparatus falling in heading 76</td>
<td>14.47</td>
</tr>
<tr>
<td>4230</td>
<td>Fixed vegetable oils, soft, crude refined or purified</td>
<td>14.07</td>
</tr>
</tbody>
</table>
### Appendix A (cont’d): Singapore’s Top 10 Products with Highest RCA, 1962-2010

<table>
<thead>
<tr>
<th>SITC</th>
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<tbody>
<tr>
<td>7524</td>
<td>Digital central storage units, separately consigned</td>
<td>18.33</td>
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<tr>
<td>2923</td>
<td>Vegetable plaiting materials</td>
<td>13.97</td>
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<tr>
<td>3345</td>
<td>Lubricating petroleum oils, and preparations, nes</td>
<td>13.54</td>
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<tr>
<td>7511</td>
<td>Typewriters; cheque-writing machines</td>
<td>12.33</td>
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<tr>
<td>7622</td>
<td>Portable radio receivers</td>
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<tr>
<td>3343</td>
<td>Gas oils</td>
<td>9.87</td>
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<tr>
<td>2480</td>
<td>Wood, simply worked, and railway sleepers of wood</td>
<td>9.13</td>
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<tr>
<td>1120</td>
<td>Alcoholic beverages</td>
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</tr>
<tr>
<td>141</td>
<td>Meat extracts and juices; fish extracts</td>
<td>7.48</td>
</tr>
<tr>
<td>3342</td>
<td>Kerosene and other medium oils</td>
<td>6.93</td>
</tr>
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**1990**

<table>
<thead>
<tr>
<th>SITC</th>
<th>Description</th>
<th>RCA</th>
</tr>
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<tbody>
<tr>
<td>5157</td>
<td>Sulphonamides, sultones and sultams</td>
<td>15.43</td>
</tr>
<tr>
<td>7524</td>
<td>Digital central storage units, separately consigned</td>
<td>10.55</td>
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<tr>
<td>3343</td>
<td>Gas oils</td>
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<tr>
<td>2714</td>
<td>Potassium salts, natural, crude</td>
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<td>Fuel oils, nes</td>
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<tr>
<td>5982</td>
<td>Anti-knock preparation, anti-corrosive; viscosity improvers; etc</td>
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<tr>
<td>5154</td>
<td>Organo-sulphur compounds</td>
<td>5.24</td>
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<td>2923</td>
<td>Vegetable plaiting materials</td>
<td>5.20</td>
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<tr>
<td>3342</td>
<td>Kerosene and other medium oils</td>
<td>5.05</td>
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<tr>
<td>8974</td>
<td>Other articles of precious metals or rolled precious metals, nes</td>
<td>4.82</td>
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</table>

**2000**

<table>
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<tr>
<th>SITC</th>
<th>Description</th>
<th>RCA</th>
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<tr>
<td>7131</td>
<td>Internal combustion piston engines, for aircraft, and parts, nes</td>
<td>13.95</td>
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<td>7768</td>
<td>Crystals, and parts, nes of electronic components of heading 776</td>
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<tr>
<td>5146</td>
<td>Oxygen-function amino-compounds</td>
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<tr>
<td>5157</td>
<td>Sulphonamides, sultones and sultams</td>
<td>8.58</td>
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<tr>
<td>2771</td>
<td>Industrial diamonds</td>
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<tr>
<td>5851</td>
<td>Modified natural resins etc; derivatives of natural rubber</td>
<td>7.96</td>
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<tr>
<td>7764</td>
<td>Electronic microcircuits</td>
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<tr>
<td>5982</td>
<td>Anti-knock preparation, anti-corrosive; viscosity improvers; etc</td>
<td>5.75</td>
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<tr>
<td>6871</td>
<td>Tin and tin alloys, unwrought</td>
<td>5.51</td>
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<tr>
<td>8991</td>
<td>Articles and manufacture of carving, moulding materials, nes</td>
<td>3.81</td>
</tr>
</tbody>
</table>

**Note:** Although ‘silk’ (SITC 2610) had the highest RCA (78.32) in Singapore in 1980, it was excluded from the list because the RCA was artificial inflated by its insignificant value in world exports. In 1980, Singapore exported US$5 of the total US$8 world exports of this category. Most silk was exported in the ‘raw silk’ (SITC 2613) category (US$259,377 of global world exports).

Source: Author’s estimates based on data from Feenstra et al. (2005) and UN (2014)