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Spatial Re-Localisation in Global Value Chains and Global Production Networks: Path Creation Perspective

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Abstract: *The article provides insights into the drivers of spatial re-localisation within the production networks of the solar photovoltaic (PV) industry. In doing so, we combine the perspectives of Global Value Chain (GVC), Global Production Network (GPN) and institutional path creation perspective to analyse the relocation and upgrading of multinational corporations (MNCs) in Malaysia using interviews and trade data. Our findings show that institutional path creation has helped to promote the completeness of the entire solar PV value chain in Malaysia, with the state actively intervening and creating new pathways by learning from the experience of the electronics industry, especially in the pre-foundation phase. Nevertheless, the path creation is also limited in that they have only been able to open windows of investment and trade opportunities within the different segments of the GVC without doing much to promote technological learning and spillover effects as the governance structure of the value chain is integrated. We find that other factors are less helpful in promoting local spillovers – export-oriented policies, energy policies and domestic industry dynamics due to lack of policy coordination. The results draw attention to some important issues that deserve closer consideration and contribute to the theoretical discussion within the GVC and GPN literature. First, path creation occurs at both levels - at the level of institutions and at the level of firms' strategic decisions. Second, institutional path creation acts as exogenous shocks to firm path creation leading to different strategic choices, and the two reinforce each other. In other words, we have shown the complexity of path creation in the context of GVC and GPN. Third, institutional path creation is subject to dynamic coordination among agencies, without which path formation is constrained.*

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1. Introduction

The theoretical contribution to the study of investment activities of multinational corporations (MNCs) has come a long way – from the study of the push and pull factors for such investment decisions or the motives for internalisation activities, such as the eclectic paradigm of Dunning (1977, 2001), to the use of a global value chain (GVC) perspective (Gereffi et al., 2005; Gereffi & Lee, 2016; Gereffi, 2018, Gereffi, 2019) and a holistic perspective of examining the entire ecosystem across the global production network (GPN) (Henderson et al., 2002; Ernst & Kim, 2002; Coe et al., 2007; Coe, et al., 2008; Coe et al., 2017). The GVC perspective is more limited in the sense that it looks at the network or, more deeply, the governance structure to understand the inter-firm relationships. On the other hand, the more recent use of GPN and its extension, called GPN 2.0, as a relational framework (Yeung & Coe, 2015) has been attractive in many ways as it involves various actors, called the network, in understanding relational dynamics – the interconnected operational functions and transactions. Thus, the framework brought together the complexity in analysing the relationship, for it requires that one not only examine the linear relationships, but also in many other directions.

We argue that while these frameworks are useful, they would add more value if the perspectives of institutional path-making creation as well as institutional dynamics within the governance structure and GPN were considered. Indeed, one criticism of the literature to date is that institutional factors within the framework are not analysed in depth (Coe et al., 2008; Yeung, & Coe, 2015; Yeung, 2016), which needs to be explored further to draw some policy lessons. Similarly, in the literature on industrial relocation, studies assume common characteristics (availability of resources and markets) for firms' location decisions without examining the dynamic network relationships between actors as well as firms' own path creation perspectives. We argue that it is crucial to explore the issues of agglomeration and concentration in industry (Faggio et al., 2017; Steijn et al., 2022) using the GVC and GPN approach together with the path creation

perspective, as forward and backward linkages are crucial for knowledge spillovers and upgrading. Mathieu et al. (2022) argue that the determinants of location choice have changed and show that knowledge spillovers are becoming increasingly important, especially in the more technology- and capital-intensive sectors. However, we argue that this also depends on institutional efforts to create a new pathway in developing countries, which mostly opt for export orientation and foreign direct investment (FDI) as a strategic choice for industrial development. Indeed, the location and rebalancing of markets become crucial in the context of these strategic choices.

Against this background, this paper aims to explore the role of institutional path-making creation within the GVC and GPN approach to explore industrial spatial location choices and their impact on upgrading. The paper also explores the limitations of these types of path creation and explores the ways in which industrial policy can be reorganised for emerging sectors. In doing so, we take the solar photovoltaic (PV) industry as a case study as this industry has been targeted as one of the key industries in exploring the creation and promotion of new growth and emerging industries in Malaysia. The role of institutions has been crucial in exploring the various value chains of the solar PV industry to support the development of the Malaysian economy. It is imperative to understand what has contributed to this success and why and how the production of the global solar PV industry has increasingly shifted to Malaysia.

In other words, the main objective is to make a theoretical contribution to the drivers of the spatial relocation of the regional production centre and its impact on upgrading. We show that, in addition to the existing theoretical discussion on spatial relocation, few unique factors contributed to the decision to relocate. Indeed, these factors differ within each segment of the GVC, leading us to question previous studies that have used a uniform set of factors to examine the industry. Unlike the quantitative empirical studies that aggregate the impact of factors influencing the decision to relocate for the entire industry segments, our study shows a more detailed analysis that would help policy makers attract different types of industries within the GVC and GPN. It offers much more policy insight than the aggregate analyses, which are very much subject to the problems of heterogeneity. Indeed, the theoretical added value of the paper lies in the combination of the GPN perspective with the concept of ‘path creation' from evolutionary economic

geography. The latter is used to argue that the increasing relocation of global production of solar PV cells and modules to Malaysia depends not only on the traditional localisation factors described in the GPN literature for the decision of MNCs to relocate their production, but also on the technological and workforce relatedness of the existing electronics industry and the larger geopolitical considerations of recent times.

Thus, the development of the industry through relocation in GPNs was strongly influenced by the existing skills and industrial base in specific locations. The relocation path is also strongly influenced by the ownership structure of the MNCs in different ways. For Chinese manufacturers, the relocation is not only technologically motivated, but rather motivated by the conquest of the Asia-Pacific market in the face of restrictions in the more developed market and the diversion of export flows due to tariff and anti-dumping issues. In this sense, the political economy of international trade plays a crucial role in Malaysia's strategy of export- and foreign investment-led development.

This paper is further structured as follows. The next section discusses the literature on GPN and GVC and sets out our arguments for creating institutional pathways within this framework. Section 3 discusses the methodology, while Section 4 presents the results of the study and Section 5 presents the conclusions and implications.

2. GVC, GPN and Institutional Path Creation Perspectives for Re-localisation and Upgrading

GVC and GPN offer the framework for analysing the activities of MNCs and are interrelated, although they have different focuses in terms of approach and analysis. GVC focuses on the value chain within the industry and the governance structure that shapes the value chain. The seminal work on producer- and buyer-driven commodity chains (Gereffi, 1994; Gereffi, & Korzeniewicz, 1994) and the extension to the interfirm governance typology (Gereffi et al., 2005) form the basis for analytical work on internationalisation activities. The focus is on the leading firm that has adequate capabilities to fully organise, coordinate and manage the value chain in different geographical spaces. The choice of governance structure is largely determined by the complexity of the transactions, the ability to codify the transaction and the capabilities of the supply base in the host

country (Gereffi et al., 2005). While the framework allows for dynamism or change in the organisational choices of GVC governance, possibly due to technological advances and other factors, the core assumption here is that the global leader in question is in a dominant position to shape it.

However, new developments have taken place. First, emerging multinational enterprises (EMNEs) are evolving in emerging economies and may change the position of governance. Second, the increasing demand for social and environmental aspects or the focus on sustainability plays a growing role for institutions. Third, governance structure can also be influenced by geographical space. More specifically, the geographical space shaped by the institutional context of the host country, which changes the development of the sector and the strategic choices it makes. Since the institutional context is dynamic as it evolves over time, conditions can change (as opposed to the conditions that existed when the location was chosen), ultimately influencing the decisions and path that firms take. Critics of GVC argue that the GVC approach is incomplete given the non-static nature of industrial governance, which is rather dynamic and evolutionary, and the neglect of institutional dynamics (Yeung & Coe, 2015).

Building on the GVC approach, and to account for the complex nature of interaction, the GPN approach emphasises a broader approach that examines the economic geography of internationalisation activities and incorporates networks of complex interactions of different actors between firms and other organisations (Dicken et al., 2001; Henderson et al., 2002; Coe et al., 2008, 2017; Yeung, 2009). It is designed as a relational framework to describe the interconnected activities through networks in a particular space. To understand value creation and its economic impact, the focus is on different actors, leading firms, suppliers and other types of network configurations outside firms. More recently, however, an improvement of the framework (called GPN 2.0) has been proposed because the complexity of analysing networks poses operationalisation problems for researchers (Yeung & Coe, 2015).

The GPN 2.0 focuses on the actor-specific strategies that are dynamic in shaping industry configurations. It also depends on the cost-capability ratio, market imperatives, financial discipline, and risk environment (Yeung & Coe, 2015). We argue that these dynamic conditions also depend on the institutional setting in a particular locality. Based on these arguments, we include the arguments of institutional path creation, in which we define

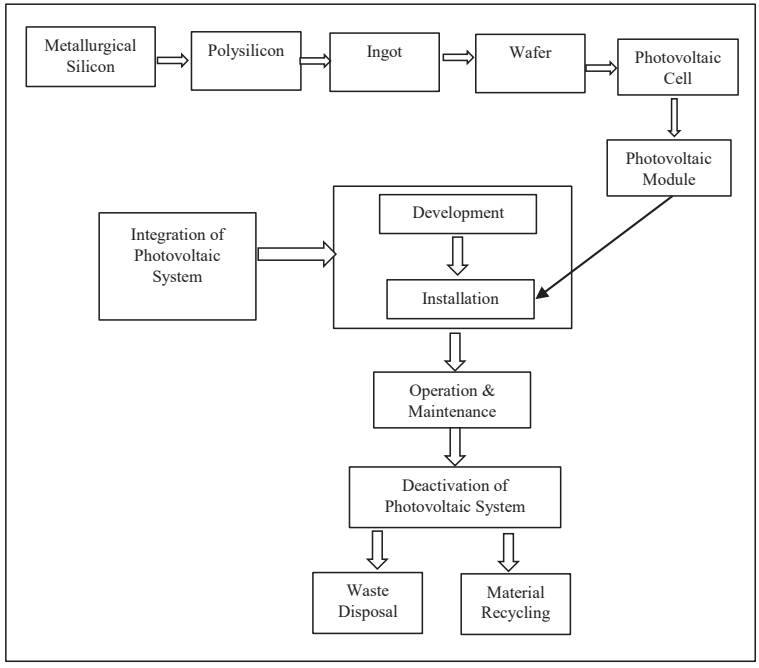
"institutions" as rules of the game that determine the behaviour of actors, e.g. lead firms, in engaging with the dynamic conditions. The notion of path creation has been studied in various aspects, whether in a geographical sense (Binz et al., 2016; Dawley 2014; Neffke et al., 2011; MacKinnon, et al., 2019a, 2019b) or in terms of understanding the strategic choices of firms in relation to technology, capability development and innovation (Teece et al., 1997; Garud & Karnoe, 2001; Garud & Karnoe, 2010). As MacKinnon (2019b) argues, path creation refers to the development of new industrial trajectories that have growth potential. The path creation has gained prominence in the economic geography literature (Martin, 2010; MacKinnon et al., 2019a, 2019b; Njøs, et al., 2020; Panori, et al., 2022), building on the idea of location specific legacies and conditions that favour the emergence of new industry pathways. There is, of course, an interrelation between the emergence of path creation, institutions, GVCs and GPNs.

Yet, there is limited empirical evidence (Boschma 2017; MacKinnon, et al., 2019a) that provides adequate insights into the interplay of path creation in emerging industries and particularly in developing countries. In this study, we seek to understand these constructs and build a framework to analyse the progress of the solar PV industry in Malaysia. We find that the constructs are interrelated and provide a better understanding of how a country builds its industrial policy to promote specific target sectors. We apply this framework to examine the emergence of the solar PV industry in Malaysia. In developing the narrative, we have focused on two main actors: the institutions and the firms to which they are beholden in their decisions. We examine the different position of firms using ownership structure so that these types of heterogeneity can be well captured. Similarly, we use a broader definition of institutions that includes not only the host state but also the policies and regulations and the international political agenda that shape industry structure and firm behaviour.

By bringing together this literature, we create an analytical framework specific to the solar PV industry, as shown in Figure 1, to assess the development of the solar PV industry in Malaysia. The solar PV industry value chain consists of upstream industries (metallurgical silicon, polysilicon, ingots, and wafers), midstream industries (cells and modules) and downstream industries (system integrators and balance of systems). To apply the arguments of GVC, GNP and institutional path creation to the value chain of the solar PV industry, one needs to analyse the following

points: (1) GVC governance structure (power relations and types of governance for upgrading) (2) GPN - the network structure and dynamic network (GPN 2.0) and the role of creating new pathways. The creation of institutional pathways can be important to improve cost-capability ratio, market imperatives, financial discipline, and the risk environment, as outlined by Yeung and Coe (2015), especially in the energy market, which is highly regulated. Similarly, firms can take advantage of institutional path creation and develop their own path-making to secure the market. We analyse both pathway creation efforts. This makes the GVC and GPN framework more dynamic as the relational ontology is constantly changing based on the past, present, and future expectations. This also affects the configuration of the GVC framework. It has been vividly argued and acknowledged that GVC/GPN is a dynamic framework, but an attempt to capture this dynamic was not well constructed.

Figure 1: Value Chain of the Solar Industry



Note: The value chain of the industry is subjected the governance structure (GVC), the network structure (GPN) and institutions.
Source: Authors.

3. Methodology

There are an increasing number of proposals to study path creation efforts using simulations, experiments, and counterfactual approaches. Nevertheless, we choose a qualitative approach to study this topic, consisting mainly of interviews and company observations based on secondary data, as well as field visits, as the study of past, present, and future creation requires unfolding the dynamics in real time. We argue that these quantitative methods have little ecological validity and may limit scholars to a select group of verifiable parameters. Instead, we propose to study GVC, GPN and real-world pathway creation by combining a comprehensive longitudinal research design with a focus on 'real-time' observations (as events unfold) and narrative (Rae, 2005; Sonday et al., 2020) accounts of actors imagining and iterating past, present and future to create, shape or track viable pathways. Therefore, we observed the actors and their decisions along a different time horizon, ranging from 2010 to 2022, to capture how the PV industry is evolving.

Using our framework and information gathered from interviews (Fontana & Frey, 2005), we create narratives and case studies that serve as a foundational approach to understanding the dynamics of actors' positions within the GVC and GPN. We discuss this at the macro, meso and micro levels to better understand how these dynamics work. For this study, we interviewed four institutions/agencies responsible for investment and trade promotion at the federal level (two agencies at the federal level) and at the state level (two at the state level, in Penang and Kulim). We also interviewed 10 firms (one in the upstream value chain, four in the midstream value chain and five in the downstream value chain). The interviews lasted between 45 and 60 minutes. In terms of time horizon, the interviews were conducted in 2011, 2018 and 2022. We also worked with industry associations on an ongoing basis. This allowed us to understand the evolution of the industry in different time periods. We also conducted four focus group discussions with industry stakeholders and policy makers, as well as several site visits that were relevant for observational and participatory engagement. We also use trade data from UN Comtrade.

4. Findings

4.1 Development of the Solar PV Industry in Malaysia

Before discussing the role of institutions and firms in creating pathways, we have examined the configuration of the value chain by assessing the key actors in the value chain in Malaysia. Malaysia is home to the key actors in the solar PV industry and the export contribution of the industry increased from USD 2.6 billion in 2010 to USD 4.8 billion in 2021 at an average annual growth rate of 6.5%. Table 1 shows the key firms within the different segments of the solar PV industry. In the upstream segment, metallic silicon. and polycrystalline silicon, PMB Silicon in Sarawak manufactures metallic silicon and growth is driven by demand in the solar PV sector, while OCIM, a subsidiary of OCI in Sarawak, manufactures polysilicon and has acquired the Tokuyama polycrystalline silicon plant in Malaysia. The acquisition is mainly due to OCI's technological advancement over Tokuyama, which improves efficiency and makes OCI the world's second largest producer of polycrystalline silicon present in Malaysia. In 2021, OCIMSB entered into a long-term polysilicon supply agreement with LONGi Solar of China until 2024 (OCI, 2021). Also, in a bid to expand production capacity, PMB Silicon entered into an agreement with state-owned Sabah Oil & Gas Development Corp Sdn Bhd in March 2022 for the lease/sale of 200 acres of land to develop and operate a new silicon metal production plant. We observed that as of 2022, the industry has produced 70,000 metric tonnes of metallurgical silicon and 35,000 metric tonnes of polycrystalline silicon.

Table 1: Key Firms within the Value Chain

Upstream				**Mid-Stream**		**Downstream**	
Mg-si	**Poly-si**	**Ingot**	**Wafer**	**Cell**	**Module**	**Balance of System**	**System Integrators**
PMB Silicon	OCIM	LONGi	LONGi	LONGi QCELLS Jinko Sunpower Risen JASolar	LONGi QCELLS Jinko Sunpower Risen FirstSolar NanoPac	ETI Tech Huber+Suhner ABB Malaysia Scheider Electric Innotech Synergy Crystal Aluminium Superspan Barysaol Leonix	Around 200 firms and mostly local firms.

Note: At the early stages of development Epsilon Silicon operates in the upstream segment and Panasonic in the wafer, cell and module segments.

Source: Authors.

In the ingot and wafer segment, Comtec Solar and Sun Edison operated in the Samajaya Free Industrial Zone in Kuching. Due to continued losses, LONGi Green Energy Technology acquired both companies. LONGi has built a fully integrated, high-efficiency monocrystalline module manufacturer that produces ingots through to the module in a vertically integrated facility. In the cell and module segments, most firms operate in an integrated governance structure. The firms include LONGi (monocrystalline cells and modules), Hanwha Q- CELLS (multicrystalline cells and modules), Jinko (monocrystalline cells and modules), SunPower (monocrystalline cells and modules) and Risen Solar (monocrystalline cells and modules), which produce cells and wafers. JASolar produces multicrystalline cells, while First Solar and NanoPac are active in thin-film modules. In terms of production capacity, First Solar is one of the largest manufacturers in Malaysia and Nanopac is a locally established company that produces non-toxic, transparent and flexible modules using nanomaterials. In terms of the global market, crystalline silicon-based modules account for almost 95% of global production, while thin-film technology accounts for the rest (IEA, 2022). As of 2022, 500MW of ingot, 500MW of wafer, 13,380MW of cells and over 11,880MW of modules will be produced in Malaysia. The lead firms in the entire value chain are the solar PV manufacturers.

Over time, we have also observed that other local module manufacturers that existed during the pre-forming phase, such as MSR and TS Solar Tech, have closed their operations due to price competition (including lack of bargaining power in sourcing raw materials) in the market and the segment, as of 2022, is fully foreign owned and dominated by China. As a result, there is a critical spatial and market rebalancing within GVC and GPN. With the economies of scale and influx of Chinese investment into the global market, solar prices have been depressed and local companies have been pushed out of the market in Malaysia. We have also observed that firms, such as Flextronics, Panasonic Energy, PV HiTech and Promelight, are no longer active in the cell and module segments in Malaysia. Globally, China has expanded its capacity between 2010 and 2020, increasing its production capacity in the module and wafer segments to more than 70%. In the cell and wafer segments, China has a production capacity of 85% and 95% respectively (IEA, 2022). Malaysia has become home to the largest Chinese lead firms in the solar PV industry. In terms of governance structure, it is evident that the upstream and midstream segments have both a captive and

hierarchical structure. Captive in the sense that the relationships between producers and buyers within the segments are determined by the lead firms. For example, between cell producers and modules. Similarly, some firms have a more integrated structure, which could be called a hierarchical governance structure, as in Gereffi et al. (2005), within the value chain to break the captive governance structure and secure the supply of materials.

In the downstream segment, Balance of System (BOS) is involved in manufacturing equipment such as batteries, inverters, circuit breakers, cables, and mounting structures, which include all the equipment that a PV system needs besides the PV modules. There are some well-known BOS equipment suppliers in Malaysia, such as ABB, Schneider, and Siemens. The BOS segments can supply the required BOS equipment, especially for utility-scale solar-systems, drawing on their experience in supplying large-scale power plants. The system integrators deal with the development of technologies and tools for the installation of solar PV systems onto the grid to increase the reliability and efficiency of the grid. There are nearly 200 actors in this segment of the market, most of which specialise in grid-connected systems. The development of the solar PV industry requires supporting industries, such as chemicals and raw materials, equipment and machinery, industrial gas and manufacturing inputs. Malaysia has a strong supporting industry as the electronics industry has been well established for decades. The supporting industries consist of foreign and local companies. The inclusion of the two industries in the GVC and GPN is in support of solar PV and the domestic solar technology market. They are also closely linked to the development of the electronics industry.

4.2 Institutional Path Creation for Promoting New Industrial Sectors, Linkages and Upgrading

The shift in creating new pathways in institutions was the result of the government's search for new sources of industrial growth. Since the late 1998s, the contribution of the manufacturing sector began to decline, prompting the government to explore new industrial growth areas. Thus, the solar PV industry was identified as a strategic sector. As mentioned earlier, Malaysia was able to develop a complete ecosystem for the solar PV value chain. Creating new industrial pathways for developing countries as a source of growth is crucial for the survival of industrial sectors as they provide

the necessary impetus for growth and employment. The role of institutions in the broader sense is now widely recognised, at least in terms of shaping industrial development through active industrial policy. Institutions can help or hinder the promotion of certain industries. Binz et al. (2016) argue that new path creation requires the generation of knowledge, the formation of markets, the mobilisation of investment and the legitimisation of technologies. And in general, institutional path creation for all segments of the value chain in Malaysia is driven by investment and trade policies. However, we also argue that there are peculiarities in some segments that undermine efforts to create new pathways. Investment incentives in the form of tax exemptions and holidays in the form of investment allowances, export promotion strategies through industrial zones, favourable import duties and 100% shareholding in the enterprises were crucial in this regard (Chandran et al., 2022). More importantly, these institutional arrangements reduce costs in the context of optimising cost-capability ratios (Yeung & Coe, 2015) as most leading firms vertically integrate their operations, allowing institutional to create pathways for new industries to emerge. The increasing relocation of global production of solar PV cells and modules to Malaysia depends not only on the traditional localisation factors described in the GPN literature for the decision of MNCs to relocate their production, but also on the technological relatedness of the existing electronics industry. Thus, industry development through relocation in GPNs is strongly influenced by the existing skills and industrial base in specific locations. Penang and Kulim, for example, are becoming attractive as a production and manufacturing centre, especially for module manufacturers.

Path creation using vertical policy instruments has not been so successful. For example, research and development (R&D) policies to help firms move up the value chain have not been helpful. This is due to the lack of coordination between institutions, as it is administered by different institutions. There has been little take-up of the tax incentives for R&D. In addition, the policy of using local content was not favoured as local companies lacked capabilities. From the perspective of cross-sectoral upgrading, therefore, there is no evidence of the creation of institutional pathways. While policies are crucial, the institutional path creation goes beyond policy. At the state level, attempts are made to strengthen supply chain integration into the value chain production network by identifying local enterprises that are able to integrate into other segments of the chain.

In the initial phase, this was successful as there were few local enterprises in the module segments. However, fierce competition and the inability to compete on the basis of cost drove these companies out of the market.

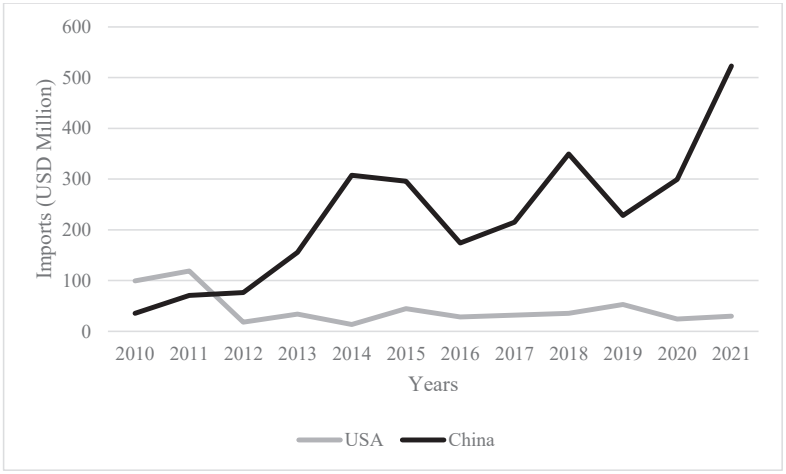
Path creation patterns also differ in the various segments of the value chain. A unique key factor for the competitiveness of the upstream segment is not only investment incentives, but also the low cost of electricity provided by the state. For example, electricity accounts for almost 40% of the production costs for polysilicon (IEA, 2022). The power relations with the state that ensure a favourable environment for the operation of the plants are crucial. As argued by Yeung and Coe (2015), the missing element of enterprise capability is also crucial. In other words, firm's path creation is important, especially in technology discovery. As seen in the silicon segment, the creation of pathways by the firm is crucial due to technological advantages (by acquisition) and the institutional role in creating new pathways by providing resources. However, in the upstream segment of the value chain, the institutional capacity to create pathways for inter-firm linkages in other segments of the value chain is limited. Path creation by the lead firm in the form of acquisitions was more critical. Given the enabling institutional environment, pathway creation for firms involves learning and scaling up investments and markets, most of which are global market driven given the export-oriented industrial strategies. In other words, the firm's path creation in discovering market destinations is subjected to the institutional settings.

In terms of spatial re-localisation, spatial policy was instrumentalised through the creation of economic corridors in Malaysia, which further benefited businesses through positive economic externalities. The upstream segments were mainly focused on the Sarawak Corridor of Renewable Energy (SCORE) and benefited from the low electricity tariffs provided by large hydropower plants. SCORE is an economic corridor designed to attract investment by harnessing clean renewable energy (hydropower) for energy-intensive industries. Support for the corridor includes federal government tax incentives such as tax exemptions for pioneers, investment allowances and more, and state government incentives such as competitive land prices, electricity, and water tariffs. In this context, we observe the dynamic process of strategic coupling (Yeung, 2009) with the convergence of cooperation that aligns relational assets between lead firms and the state.

While investment and trade policies play an important role during the industry's development, the dynamics change significantly as firms' strategic choices and the external environment shape the segment's structure in the midstream segment of the value chain. The political economy of trade such as the trade war between China and the United States (US) has changed the structure of the value chain in Malaysia. The influx of foreign investment from China into Malaysia has shaped the future direction of industrial development. While China has exploited the cost advantages in Malaysia, the spatial relocation of Chinese firms is mainly due to their desire to avoid tariffs and anti-dumping investigations. Malaysia and the other Association of Southeast Asian Nations (ASEAN) were the main production locations for Chinese firms to export to the US. Interviews indicate that investment agencies took a wait-and-see approach to anti-dumping regulations in the early stages, which in turn benefited Malaysia. Mostly, the rules apply to companies that try to circumvent US anti-dumping and countervailing duties by only slightly processing Chinese-made cells and modules before exporting them to the US. Despite the imposition of tariffs and anti-dumping duties, exports of solar PV from Malaysia have soared. The recent decision by the US government to suspend will also benefit Malaysia.

Despite a complete value chain for modules, institutional path creation has not helped to optimise the links between supply and demand at each stage of the value chain that could increase the overall value and competitiveness of the solar PV industry. This is because path creation in these aspects requires different institutional frameworks related to long-term supply contracts, investing party requirements, certification criteria, product specifications, and consideration of quality and cost. Also, from the GVC perspective, governance structures are mostly integrated companies that leave less room for creating new pathways for upgrading. The interviews show that any attempt to explore new ways to diversify the solar PV industry in Malaysia is limited given the cost structure. For example, Chinese firms can produce almost 10% to 30% cheaper than other companies. Chinese firms prefer imports from China to ensure lower production costs. In fact, almost all solar PV manufacturers rely on inputs from China. With the entry of Chinese companies into the market, we have observed an increase in Malaysia's imports in the solar PV industry. In 2010, Malaysia's imports from China amounted to US$35 million and have increased to US$ 522 million by 2021 (see Figure 2). This changes the whole structure for upgrading.

Figure 2: Malaysia's Imports of Solar PV from US and China, 2010-2021



Source: Computed from COMTRADE.

Trade flows within segments are dynamic by nature. For example, while China remains the largest producer with growing demand, it is also the largest importer of polysilicon, wafers, cells, and modules, including from Malaysia. The dynamics can also be seen in the governance structure. Given the export-oriented industrialisation strategies, wafer production, for example, is not offered on the domestic market but imported from abroad for cell and module production. Even in PV equipment manufacturing, China's dominance (previously Germany, the US, Switzerland, and Japan dominated 90% of the market) has led to a drastic shift in the governance structure in Malaysia, favouring imports over local manufacturers. In China, there are 10 top equipment manufacturers that accounted for 45% of the market share in 2021. The institutional path creation in linking actors within the value chain is subjected to dynamics in which lead firms make their decision based on cost structure and preferences. Economies of scale are critical and without these, the creation of institutional pathways to diversify key players within the solar PV ecosystem is limited. Therefore, institutional path creation in Malaysia by reducing other costs such as energy, labour, investment, and capital costs therefore has its limitations. In addition, future path creation also depends on bankability, financial incentives, and other support. Financial institutions and incentive systems need to be revamped if Malaysia is to

promote other new industrial development pathways.

In the downstream segments, the crucial tools for institutional path creation are the creation of a domestic solar PV market. Since most of the investment is domestic, firms operating in this segment do not benefit from investment and trade incentives. In contrast, renewable energy (RE) incentives, more specifically RE policies and initiatives, are key to creating new pathways, especially in the system integrator segments. More importantly, it is not the export market, but the domestic market. The emergence of system integrators is due to the use of demand-side policies to promote solar energy. There are more than 200 firms in the system integrator segments. The emergence of these firms began with the introduction of solar energy to the local market. The first step was the MBIPV-Suria 1000 PV programme, which enabled grid-connected PV installation with a capacity of 2.054 megawatt peak (MWp), followed by the Feed-in Tariff programme with a cumulative installation capacity of over 300 MW. Other programmes, such as Net Metering (NEM) and Large-Scale Solar programmes, were important for the development of downstream activities. Given the agenda of Net Zero and sustainability, the demand for solar energy is expected to continue to grow and contribute to solar PV industrial development. Coupling with technology financing encourages the emergence of the industry. For example, the Green Technology Financing Scheme and the Green Sukuk and Bond Market Initiative in Malaysia are crucial (Chandran et al., 2022). Critically, other path creation in these segments is for lead firms to discover themselves and use institutional arrangements such as trade agreements to open new markets in other Asian countries. System integrators have been venturing into Singapore, Indonesia, Bangladesh, and other Asian countries. For example, Ditrolic Energy, founded in 2009, developed the 50 MW Mymensingh project in Bangladesh and owns more than 300 MW projects in Malaysia, Singapore, the Philippines, and Indonesia. The company developed and delivered 100 off-grid systems to India and commissioned a 60 kW system in Indonesia. Another company, Solarvest, which is also expanding into the ASEAN region with its solar energy solutions segment, has been able to increase its income by participating in large solar projects, including operation, maintenance, and production of solar energy power. The industry could continue to thrive if there was strong support to build local markets and the capacity to support the export of system integration services while building capacity and knowledge in

other ASEAN countries. The installation and maintenance services industry could contribute to the integration of the regional value chain if barriers to intra-regional trade are reduced.

Regulatory barriers, uncertainties about market demand and investment risks also prevent the industry from tapping export potential. However, efforts still need to be made in the downstream segment to build a recycling industry. Investment in solar module recycling is crucial. In the local market, unfavourable policy environments such as limited quota allocation due to inclusion of hydropower and lack of flexibility in RE trading such as peer-to-peer (P2P), direct power purchase agreements (PPA) and third-party access constrain the industry's progress. The business environment can increase the availability of upgrading opportunities for the industries by improving the determinants of upgrading such as infrastructure, establishing and facilitating access to supportive markets, improving producers' knowledge of the costs and benefits of different types of upgrading, and communicating to them the importance of forming strong horizontal and vertical linkages and encouraging the development of these linkages.

As for supporting industries, such as the chemical industry and others, local sourcing was encouraged from the outset in the development of the entire solar PV value chain. The institutional path creation in these aspects involves the ability to identify key supporting industries for inclusion in the value chain. However, as they remain trapped in the governance structure, the lead firms have the upper hand in deciding whether to source locally or import. The share of local sourcing varies among lead firms, and we found that the share of local sourcing ranges from none to 60%. Table 2 shows the main sources of input sourcing from the supporting industries by segment. However, in many segments of the value chain, inputs are largely imported. The institutional path creation and firm's self-discovery are urgently needed to ensure that enterprises can integrate into the value chain of lead firms. Competitiveness on the cost side will define the venture and creating pathways in this area is critical.

Table 2: Input Sourcing Across Solar Value Chain Segments

Upstream and Mid-Stream Industry	Inputs	Support Industry	Input Source	
			Domestic	Import
Mg-Si	Raw materials	Quartz		√
		Petroleum core		√
		Charcoal		√
		Woodchips	√	
	Consumables	Electrodes	√	√
		Parts and components	√	√
	Equipment	Furnaces		√
Poly- Si	Raw materials	Mg-Si		√
		Chemicals	√	√
		Industrial gases	√	√
	Consumables	Parts and components	√	√
	Equipment	Poly-Si processing system		√
Ingot	Raw materials	Poly-Si		√
		Chemicals	√	√
		Industrial gases		√
	Consumables	Parts and components		√
	Equipment	Ingot pullers		√
Wafer	Raw materials	Ingots	√	√
		Chemicals	√	√
		Industrial gases	√	√
	Consumables	Parts and components	√	√
	Equipment	Wafer-slicing machines		√
	Production support	Packaging	√	

Upstream and Mid-Stream Industry	Inputs	Support Industry	Input Source	
			Domestic	Import
Cell	Raw materials	Wafers	√	√
		Gas	√	
		Metals	√	
		Soldering wire	√	
		Chemicals	√	
		Inks		
	Consumables	Targets	√	
		Screens		√
		Parts and components	√	√
	Equipment	Semiconductor processing		√
	Production support	Injection-moulded plastics	√	
		Rubber gloves	√	
		Office supplies	√	
		Safety equipment	√	
		Plastic packaging	√	
		Rack forms	√	
		Polyester tape	√	
		Packaging	√	
	Facility service	Wastewater treatment	√	
		Electrical projects and services	√	

Upstream and Mid-Stream Industry	Inputs	Support Industry	Input Source	
			Domestic	Import
Module	Raw materials	Cells	√	√
		Al frames	√	√
		Glass	√	√
		Encapsulants	√	
		Silicon	√	
		Back sheets		√
		Wiring		√
		Junction boxes		√
		Cord plates	√	
		Adhesives	√	
		Gas	√	
		Chemicals	√	√
	Equipment	Injection-moulded plastics		√
		Fabrication/jigs/fixtures		√
		Equipment and parts		√
		Module-processing		√
	Production support	Packaging	√	
		Pellets	√	
	Facility service	HVAC/water treatment	√	
		Assembly, logistics, servicing & maintenance	√	√

Source: Based on MIGHT (2015) and updated from interviews.

4.3 Limits of Institutional Path Creation

Our observation reveals a peculiarity of the GVC/GPN of solar PV in Malaysia. Upstream and midstream development is driven by foreign investment and export-oriented industrialisation strategies, while downstream industrial progress is highly dependent on domestic market development. Creating convergence pathways between the two approaches is critical for the future development of the ecosystem, especially from an upgrading perspective. Firstly, as Malaysia is a small open economy, reliance on exports as a source of income is crucial and only possible through the active participation of MNCs. The MNCs located in the export processing zones ensure that production is exclusively for export, so that they cannot penetrate

other segments of the GVC where the scope for learning seems to be very large and limited. In other words, the actors in the upper stream can move vertically to the downstream activities and not vice versa. A downstream actor that produces innovative solar modules describes that he must buy the components for production abroad due to the export orientation and then refine them locally. This in turn drives up the price and makes the product less cost-efficient on the market. Currently, the only solution is to source components from other emerging markets to ensure that costs remain within acceptable limits. The apparent "home market bias" was highlighted as a cause for concern by local manufacturers, including local manufacturers in the module segments. The domestic market is an important testing ground for local manufacturers before engaging in export markets. This bias towards the domestic market is not only caused by the preferential treatment of foreign investments, but also reinforced by the presence of national energy companies that justify and protect their existence on their own account. The current energy market structure limits participation of downstream actors as installation is subject to energy regulations.

The lack of liberalisation and competition in the energy market limits the spread of solar energy. Therefore, efforts to create new pathways for downstream firms are limited. Innovation in the energy market and creating pathways for exporting services can further increase overall segment participation. Malaysia has set a target of 31% renewable energy as a share of installed capacity by 2025; currently the capacity is 25%. These efforts should not only be looked at from the perspective of meeting climate commitments and net zero but should be used as path-breaking initiatives for local firms in the downstream segments. The lack of complementary policies leads to slow upgrading. There is enormous potential for how exogenous forces (e.g. energy-related initiatives) can pave the way for the formation of new emerging industries in the way that policy makers envision. Nevertheless, it appears that it has been left to natural forces to determine the future path of industry – namely, to allow industry to take its shape based on the market and other conditions. There do not seem to be any exogenous forces on the part of the state to drive the creation of new industries within the solar industry – e.g., services and others like solar applications. This is solely due to the lack of policy complementarity, which limits the full potential of exogenous forces to create new pathways for the industry. The lack of policy complementarity not only limits the progress of solar GVC,

but also the progress of other segments that could potentially be linked to the sector. In this effort, energy-related policies and industrial development policies should be scrutinised more closely.

5. Conclusion and Implications

This paper discusses the efforts of spatial relocation along with upgrading in the solar PV industry using Malaysia as an example. The results show that the value chain of the solar PV industry in Malaysia has developed with different governance dynamics due to the different investments made by the leading firms in Malaysia. The findings suggest that the creation of institutional pathways has played an important role in the development of the solar PV industry through active state intervention and the creation of new pathways through learning from the experiences of the electronics industry, especially in the pre-formation phase. However, the path creation is also limited in that they have only been able to open investment and trade opportunities within the different segments of the value chain without doing much to promote technological learning and spillover effects given the integrated structure of the value chain. The study found that other factors were less helpful in promoting local spillovers – e.g. export-oriented policies, energy policies and domestic industry dynamics due to lack of policy coordination.

We draw some theoretical implications from the solar PV that deserve closer consideration and contribute to the theoretical discussion within the GPN and GVC literature. The creation of institutional pathways is crucial for the pre-formation of new industrial growth. And the path creation depends on the governance structure of the industry. Importantly, there can be different governance structures within a value chain and the dynamics are determined by the host country's costs, market, institutions, and economic environment. Similarly, path creation occurs at both levels - at the institutional level and at the level of the firm's strategic decisions. Moreover, institutional path creation acts as an exogenous shock to the firm's path creation, leading to different strategic choices, with the two reinforcing each other. Theoretically, there are more complex dynamics of path creation in the context of GVC and GPN. Finally, institutional path creation is subject to dynamic inter-agency coordination, without which path creation efforts are constrained for new industry formation.

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