CORVINUS UNIVERSITY of BUDAPEST

International Relations Multidisciplinary Doctoral School

THESIS SUMMARY

Dániel Vértesy

Cycles of Economic and Technological Change in Latecomer Aerospace Industries

Ph.D. Dissertation

Supervisor:

Dr. András Blahó, CSc
university professor

Budapest, 2015

Department of World Economy

THESIS SUMMARY

Dániel Vértesy

Cycles of Economic and Technological Change in Latecomer Aerospace Industries

Ph.D. Dissertation

Supervisor:

Dr. András Blahó, CSc
university professor

Budapest, 2015

Table of Contents

I. Background and motivations

This dissertation aims to describe and explain the forces behind catch-up and eventual changes in industrial leadership through the case of the aircraft industry. It addresses the long-term transformation of developing countries intro advanced industrialized ones and the entry and catch-up of latecomer companies. Such processes bring about a change in the global distribution of labour, in the interdependence of economies, expand and deepen technological capabilities of the world, and reshuffles centers of global political power. The aircraft industry lies at the center of these processes in all its aspects: it is a capital- and knowledge-intensive, strategic sector, characterised by high value added and high incomes (Prencipe, 2013).

The investigation relies on various strands of literature: on the seminal works addressing latecomer industrialization and the role of the state in this process, and on neo-Schumpeterian studies of technological change and innovation.

One of the central questions of development economics is whether a latecomer industrializing economy or company enjoys advantages over forerunners. The idea that economic backwardness may be an asset for latecomer industrialization has been at the center of debates on economic development. According to the catch-up or convergence hypothesis of Alexander Gerschenkron (1962) (who was building on the work of Veblen (1919)[1]), technologically backward countries (businesses) can apply already existing technologies at much lower costs than those who developed them. Catch-up occurs as productivity increases due to more advanced technology and the income difference narrows between countries. The larger the initial

[1] To do justice to the cited work it should be noted that Veblen's view was in many ways sharply different from Gerschonkron's thesis, e.g. considering technology transfer as a more automatic mechanism possibly driven by market forces.

productivity gap (or the greater the distance to the technological frontier), the greater is the potential for growth. This happens because latecomers can enter directly into large-scale production in the most dynamic industries and make advantage of their lack of institutional inertia. The tension spanning between the promises of economic growth that was demonstrated by the leading countries and the reality of stagnation is an important motivating factor for institutional change in the follower. However, institutional obstacles can (Gerschenkron referred to serfdom or the lack of political unity) preclude the emergence of such a tension. Based on 19th century historical evidence, Gerschenkron points to an interventionist role for the state to boost capital and entrepreneurship in nascent industries. In industrializing France or Germany state intervention compensated for (or substituted) the insufficient (or inadequate) physical, human and technological resources required to catch-up. To successfully *substitute* the missing prerequisites, setting up appropriate institutions and organizations was crucial. One example was the creation of the German development bank in the late 19th century, as in the example of Gerschenkron, or the Ministry of International Trade and Industry (MITI) in Japan, as others have pointed out.

The rapid development of many East Asian economies in the second half of the twentieth century (Hong Kong, Singapore, South Korea or Taiwan) testify the possibility of reaping latecomer advantages by providing evidence at the firm and sectoral levels in industries such automobile, electronics, semiconductor (Kim 1980, 1997, 1998, Kim and Nelson 2000, Fagerberg 2000, Hobday 1995, 2003, Amsden 1989, 2001, Mathews 2002).

Others argued that latecomers' disadvantages create vicious circles. Incumbent companies in a sector have already established close connections with suppliers and consumers, and may have exclusive access to

technology, can enjoy economies of scale and their market power (Hobday, 1995; Ferrier et al, 1999). For latecomers, accumulating a critical mass of technological, investment and organizational capabilities is a lengthy and costly process. Without these capabilities, they cannot pose a challenge to the established market structures (Ames and Rosenberg, 1963; Abramovitz, 1986; Lall, 1992; Nelson and Pack, 1999). The outcome of this learning process is uncertain, which deters investors in less developed economies, which may justify state intervention (Lall 2001, 2004). Nevertheless, the success of capabilities accumulation depends largely on the efforts of companies and other institutional actors. To convert disadvantages into advantages, Mathews (2002, 2006) is optimistically arguing that latecomer firms are not bound by organizational inertia. This allows them to shift quickly from being imitators to innovators, by making benefit of the 3 Ls: linkage, leverage, learning in the age of globalization, which enhances their dynamic capabilities (*Linking* up to global value chains, offering lower costs and gaining access to knowledge, technology, or markets. The gains exceed their inputs, offering firms greater *leverage*. As they do this strategy in a sustained way, they *learn*.) This is evidently in contrast with industrialization strategies of many Latin American countries following inward looking recipes of 'de-linking' and 'import substitution industrialization'.

In a broader context, it was found that industrialization was a primary source of accelerated growth for advanced economies and emerging countries alike. Szirmai (2005) concludes that no developing country achieved successful economic development without industrialization. Verspagen and Fagerberg (1999) present evidence showing that manufacturing was an engine of growth in East Asia and Latin America. Using empirical data on structural change and comparative levels of total

factor productivity, Timmer (2000) shows that investments not necessary lead to catch-up if it is not associated with assimilation of more advanced technology, in the case of China, Indonesia and India. The experience of slow catch-up and the East Asian crisis of 1997 cooled down the optimism of many observers, spurring continuous debate on how to translate the catch-up hypothesis into actual policy measures.

A central problem for the latecomer literature is to define the role of the state and private actors in the industrialization process. The same historical development paths of East Asian countries have been read in very different ways depending on the spectacles observers were looking through. On the one hand, according to the neoliberal view summarized in a widely cited World Bank (1993) report, the success of governments was their ability to providing a stable macroeconomic environment. This entailed limited inflation, rarely appreciating real effective exchange rate, only brief instances of import substitution industrialization, and earnings from export motivating technological upgrading in trading sectors. Additionally, public measures were concerned with human capital formation, established openness to international trade and a strong bureaucracy that relied on contests when making selective supporting measures. On the other hand, both sectoral level and macro level studies (Amsden 1989, Wade 1990, Hobday 2003) found historical evidence of strong state intervention.[2] Amsden (2001) showed that "getting the control mechanisms right" was the key to the successful "Rise of the Rest". Recently Chang (2003) and Cimoli *et al* (2009) further argued along the lines of Gerschenkron and emphasized that no backward country has ever developed without a relatively high degree of government intervention to facilitate technological accumulation

[2] Also, studies on the Gerschenkron hypothesis in a regional context show that national level convergence might even increase regional inequalities. See more on the 'Williamson effect' in Blahó (2005).

and change the organization of production. Reinert (2009) showed how protecting infant industries in areas at the forefront of technological progress helped latecomers emulate the richer leaders of their time and reduce the asymmetries in knowledge and technological capabilities, and made technology transfer profitable. Only after symmetry is achieved could partners specialize and trade according to their comparative advantages and could (neo-)colonialist structures be prevented. This reconfirms the theses of Friedrich List who argued that latecomers need protectionist measures to raise infant industries and new competitors, because free trade hampered progress by freezing existing trading structure. At the same time, a number of authors have pointed out the fact that public financing has been a crucial source for innovations also in the most advanced economies (Ruttan, 2006; Mazzucato, 2011).

Recent trends of globalization and the expansion of transnational companies in the world economy has created new kind of opportunities for latecomers. Late industrializers that connect to lower tiers in the **global value chains** possess required capabilities and devise adequate strategies may upgrade to higher value added activities. What these capabilities and strategies are, and what kind of state intervention may be necessary to support them, remains an area of heated debate (Gereffi et al, 2001; Humphrey, 2004; Schmitz, 2004; Szalavetz, 2013).

In sum, the theoretical framework to apply needs to be comprehensive, encompass firm and government actors, should help understand the co-evolution of the accumulation of technological capabilities, innovation, competitiveness, and politics. Innovation and technological capabilities have been found to play a crucial role in gaining and sustaining competitiveness (Freeman, 1995; Nelson és Mowery, 1999; Malerba és

Mani, 2009). At the same time, there is no agreement in the literature ont he source of long-term competitiveness. We argue that a multi-actor, multi-level systems bound together by a complex web of interactions of various nature can be best understood by applying an innovation system perspective (Nelson, 1993; Freeman, 1995; Edquist, 1997).

Given the lack of empirical data, another key aim of the study is to make rigorous, evidence-based comparison possible, in combination with a historical-institutional, qualitative investigation.

There are many **practical applications** of a study of this industry at the intersection of world economy and politics. First, due to its size: with 1,300 new aircraft sold anually and a 77% growth over the past two decades, the industry shows its strenth despite downturns. Its growth perspectives are also promising, driven by the growing demand for fuel efficient jets. This is likely to put a price pressure on the current duopoly characterizing the large civil aircraft market and on producers along the supply chain, and pull technological development (Deloitte, 2014). At the same time, the market segment for shorter range regional jets has witnessed significant turbulence in the past decades, with the Brazilian Embraer taking over the market and new players entering mainly from Asia: Comac of China and Mitsubishi of Japan, alongside the Russian Sukhoi. In order to understand and predict these dynamics, it is essential to study the modes of innovation that characterise the industry. Furthermore, developing aircraft production capacities is, due to the dual-use nature of the products, is often seen as a source of political strength with repercussions on international relations and the global balance of power.

It is just as important to understand the drivers of development of the industry from a European perspective, as aerospace generates high-income and jobs, and attracts foreign direct investments (FDI), also in research and

development. This is central to the European strategy aiming for structural change towards high-tech, high-value-added industries that fosters competitiveness and growth. The innovation competition apparently takes place at multiple levels, in which companies and governments are important actors. Thus, understanding the processes of innovation in the industry will help understand the global political and economic developments in our multipolar world and supports the design of adequate innovation and industrial policies, as well as company strategies.

II. Methods applied

The dissertation investigates the following three main research questions:

- How did the international division of labour change in the global aircraft industry in the past half a century, and what are the main patterns of internationalization?
- Why have some countries succeeded while others failed to catch-up in aircraft manufacturing – in particular, what strategies did governments follow in emerging economies that fostered sustained growth in the sector?
- At the level of companies, in the regional jet segment, what have been the drivers of successive catch-up and leadership changes?

The three questions are connected by the overall aim of investigating the same phenomenon – change in the global aircraft industry – from multiple perspectives. They are distinguished by the different points of entry, their focus on three different aspects and levels of change. In order to establish the boundaries of the research, we introduce a few definitions for central concepts used in this dissertation. This involves addressing four main methodological issues.

The first one is the level of analysis problem. In order to offer a comprehensive study and mitigate potential biases, this dissertation takes multiple points of entry: we study country-dynamics as well as company dynamics. Chapters 2 and 4 have a more macro focus, primarily on countries, while Chapter 5 looks more closely at the factors influencing company strategies as well as their impacts on industry dynamics.

With respect to the second problem of delimitation (time, space and activity), we decided to look at very long term evolution, and start the

statistical overview with the diffusion of the jet technology in the 1950s and follow country growth patterns until as recently as possible, and to cover as many countries as data permits.. This scope serves answering the first two research questions. As the third research question focuses on regional jets, the starting point for this investigation will be the early 1980s, with the emergence of this segment. With regards to selecting the activity in focus, we take the standard international statistical definition of the aerospace industry (that is, the manufacturing of aircraft, spacecraft, their parts and components, including engines and propulsion systems – ISIC Rev.4 class 303) – and not air transport services, and focus on production and innovation activities. Wherever possible, we opt for a product-based approach, that is, if companies host multiple activities, we are only interested in those referring to aircraft. We noted the close link between military and civilian production, as well as the inclusion of space industry in many statistics – where possible, we tried to distinguish both. A product-based approach was also the point of reference for delimiting the aircraft innovation system.

Third, it was a major challenge to overcome the problem of secrecy, confidentiality, and lack of information on the sector when aiming to find long time series, contextual information on systems and information on firm strategies. Our data sources had to be rather heterogeneous, including official statistics, company reports, trade journals and newspapers, secondary analyses, data collected by enthusiasts as well as declassified spy agency reports. We relied on triangulation methods to validate the information.

Below, we introduce a few key concepts applied throughout the dissertation. We argued that the **industry level** is the most appropriate for studying Schumpeterian dynamics. This "meso"-level situated between country

(macro) and firm (micro) levels, is an often neglected field which influences firm as well as country dynamics; it is of course closely linked to the two, thus is influenced by politics.

We consider the aircraft industry as a complex **innovation (and production) system**, with its specific knowledge base, demand patterns, actors (companies and public actors, research institutes) and the institutions that define interactions among those (Malerba, 2002), and which adopts, develops and introduces new technologies and products in order to sustain competitiveness. This we take a multi-actor, multi-level perspective, and focus on long-term evolution of these systems. We build on neo-Schumpeterian evolutionary economics, which opens that "black box" of technological development and considers it also an outcome of economic and social activities; bounded rationality characterizes its economic actors that make decisions amidst uncertainty, limited information and preference to routines. As a result, actors may learn. However, the system is not expected to be bound for equilibrium (Nelson and Winter, 1982; Dosi, 1991).

While there has been a tradition for studies to look at the aircraft industry in a neo-Schumpeterian perspective (Mowery and Rosenberg, 1982), and in a sectoral innovation systems perspective (Malerba and Mani, 2009; Niosi and Zhegu, 2005; Marques, 2004), our choice is driven by the aim to offer a comprehensive and realistic analysis. Many theories focus only on a certain element of the system. International political economy, unlike the neoclassical school, considers political factors influencing economic choices, but its fundamentally macro-level perspective offers less attention to differences across industries, in particular regarding technological development and innovation. Theories of competitiveness similarly tend to disregard these differences (Szentes, 2006). Similarly, we found product life

cycle theories (Vernon, 1966) and the recent theory on complex product systems (COPS, l. Dosi et al, 2003; Hobday et al, 2005) to be useful for studying products, but less applicable for long-term historical dynamics.

By **innovation**, we not only refer to the narrow, technology-based definition of new products and production processes to the market, or opening of new markets. This dissertation considers the institutional and organizational changes that create conditions for technological development (Freeman, 1995). That involves interaction with many relevant actors, which makes innovation only meaningful in a given context.

We define **latecomer** industrializers those companies that (or their predecessors) had little or no production capacities at the dawn of the jet age. Typically, these companies entered the industry in the 1960s, in different ways: as spinoffs from research institutes, through diversification of heavy industry or car manufactures, or were newly established. By catch-up of latecomers, in a broad understanding we consider their increasing market share or productivity increase relative to the industry leader.

Our research design can be summarized in Table 1. In brief, we answer the first research question in Chapter 2 with the help of an empirical study of the industry's evolution based on of statistics compiled by the author on production, value added, trade and innovation, from official sources augmented when necessary in order to obtain comparable time series. Based on the empirical findings in Chapter 2 and on a review of the literature on latecomer industrialization, innovation and capability building in Chapter 3, we answer the two subsequent research questions using qualitative case studies, structured in conceptual frameworks presented in the respective chapters. Chapter 4 focuses on the evolution of sectoral innovation systems, and we conduct a historical-institutional study of country-catch-up using a framework of innovation system dynamics. Next, Chapter 5 discusses

industrial leadership change in the regional jet segment in light of windows of opportunity and preconditions. In this piece of research, all cases of leadership change are studied in-depth, with a focus on companies as well as exogenous and endogenous events that may have triggered leadership change. In order to be comprehensive and objective, we study not only the companies that became the leaders, but also incumbents and other challengers. For both Chapters 4 and 5, we rely on data collected from triangulated sources that include archived company reports, trade journals and newspapers, secondary studies, as well as official statistics. A combination of these sources has proved to be very insightful for the aerospace industry with a highly concentrated company structure, and where other methods, such as surveys are less effective.

Table 1. A schematic overview of the research design (research questions and applied methodology)

Research question, in brief form	Chapter	Unit of analysis (region of focus)	Methodology applied
1. The evolution of the global aircraft manufacturing industry and internationalization	Chapter 2	Country, world region (global)	Harmonizing data from different statistical sources; comparative analysis of descriptive time-series statistics
2. Understanding successful and failed strategies of catch-up	Chapter 4	Sectoral innovation systems (latecomer economies)	Comparative case studies using a framework of "innovation innovation system dynamics" (based on neo-Schumpeterian literature)
3. Industrial leadership changes in the regional jet segment	Chapter 5	Companies (from latecomer and advanced economies)	Case studies based on the conceptual framework of windows of opportunities– strategic response – preconditions

Finally, the conclusions from the studies at the various levels are brought together in Chapter 6, which revisits the research questions and summarizes the results.

In sum, through this multi-level analysis, this dissertation aims to increase our understanding of the constant competitive struggle between incumbents and new entrants, and tries to understand long-term change by disentangling the various sources of incremental and radical system changes.

III. Results of the dissertation

We have observed three distinct forms of cycles that affect the growth and decline of the aircraft manufacturing industry. First, at the level of products, the fortune of companies at the top of the pyramid depends on the sales performance of an aircraft or aircraft family. Sales success is not only necessary to recover the sunk costs in development, machinery, marketing and support activities, but also to enable companies to make further investments in new product development. Production curves can be extended if companies introduce refurbished products and modernize components and subsystems, such as replacing engines with more efficient ones. This pattern is applicable to large civil aircraft and regional aircraft alike, and affects the supply chain.

Second, at the aggregate level of the aircraft industry, we have identified cycles of expansion and contraction, which are closely correlated with business cycles in the world economy and affected by global political events. The oil crises, the increased defense spending during the last decade of the Cold War, the subsequent Gulf War, the 9/11 shock and the most recent global financial crisis are a few key events that made their mark on the evolution of the industry.

Thirdly, between these two levels, we have observed discontinuities in the evolution of aerospace innovation systems. Institutions in innovation systems govern learning, technological capability building and new knowledge production activities. Recurrent events of radical institutional changes that redesign the system and incremental change as actors gradually expand their activities within the system framework create a third type of cycles – albeit cycles that can only be observed indirectly.

The first research addressed the changes in the international division of labor in the aircraft industry, and the main patterns of internationalization. In chapter 2, we have found that the overwhelming majority of commercial aircraft exports, final products as well as intermediate goods, continues to originate from North America and Europe. Their combined exports have more than quadrupled in real terms in the past three decades. The double-digit annual average growth since 1990 which characterises emerging producers is to some part due to the very low initial levels, and also to their gradually increasing production capacity. A more noticeable global trend has been a gradual redistribution of exports between the US and Europe. At the same time, it is important to note that in 2012, two emerging exporters made it to the top 10: Singapore and Brazil, with market shares comparable to that of Japan, Italy or Spain.

Considering the domestic market as well and focusing on value added, we find a more significant global redistribution in the mid-ranks of the top 10 aircraft producers. While the dominant producer by far remains the US (producing more than 2.6 times the amount of the 9 subsequent countries), China has emerged as the second largest aircraft producer by 2010.

We have also noticed a redistribution of R&D activities. The largest business R&D spender in the aerospace industry continue to be the incumbents in the US, Europe and Canada, we have seen the rapid growth of China (today the 5th largest R&D spender) and the gradual growth of India and Brazil and Singapore.

We distinguished two waves of internationalization in which the aircraft industry extended to emerging economies. Although identifying them requires a certain degree of abstraction and the waves, in a few cases overlap, there have been notable differences between the two. We have seen that entry during the second wave of internationalization, occurring in an

era when companies are increasingly specialized along the supply chain (most markedly since the 1990s), new entrants face lower capital and technology barriers than those entering over the 1950s through the 70s, in an era of vertically integrated companies. Therefore, it is not surprising that among the many entrants, the success of Embraer was exceptional. Today, internationalization is fuelled by the pull-force stemming from the shared strategic interests of governments of emerging economies and of incumbent firms in the West. The goals of governments of emerging economies for establishing high-tech, high value added activities and move up along the value chain –national security interests notwithstanding – meet with the company interests in cost saving and access to growth markets. Containing this wave creates a particular challenge for established players in Europe and North America, which fear the loss of high value added jobs. Yet, the scale of threat has not yet been justified; consolidation (mergers and acquisitions), efficiency gains through the use of ICT and reduction in defense spending appear to have been the major source of aerospace jobs reduction in the US and Europe, rather than outsourcing to East Asia. The global aircraft manufacturing industry is still concentrated to North America and Europe (around almost 88% in terms of value added) and faces and expanding market – thus, contrary to what hawks say, it is not a zero-sum game. But comparing the two waves of internationalization, the second one is expected to have more profound effect then the first. While statistics show that the fears of North America losing positions may be exaggerated, European countries face a more direct challenge and need to improve significantly their competitiveness in aircraft manufacturing, attract R&D and high value-added jobs, particularly in niche activities. In the end, innovation systems compete to attract investors, and the number of potential locations has certainly increased – mostly in East and Southeast Asia,

Central America, and potentially, Central Eastern Europe. Yet, there are significant limits to internationalization, as capabilities cannot be accumulated overnight, which require not only advanced training of highly-skilled professionals, but also other modes of less formal learning, i.e. 'learning by doing'. Thus, barriers for latecomer entry remain high, as aerospace manufacturing remains a technology and capital intensive industry.

At this point, it may be relevant to discuss the potentials that the second wave of internationalization brings for companies of Central and Eastern Europe, or Hungary in particular. The region looks back to a century of history in the aircraft industry, typically designing and producing for general aviation; they have experienced challenges of crises and the need for a system transition after the collapse of the former Eastern Bloc. Specialization as component suppliers offers opportunities for these companies with more modest investment capabilities. The question is (and this warrants further investigation), with what activity can they secure the best position in the global supply chain – as assemblers of small planes, or as suppliers of knowledge-intensive subsystems, such as avionics, or developers and producers of composite materials. These companies may capitalize from the proximity of related industries, such as automobile, electronics, precision engineering or chemical sector, and from close ties with universities and research institutes.

The case studies in the fourth chapter of this dissertation showed that while every development trajectory was unique and the local context mattered, a number of general conclusions could be drawn related to latecomer industrialization. First, that only those emerging economies managed to

become aircraft exporters where the key elements of a sectoral innovation system was developed and local research institutes supported the accumulation, adaptation and development of technological capabilities, education of experts, and linking up to international knowledge, product and capital markets. In the years of emergence, governments stepped in to fill the initial lack in these resources, without blocking the execution of business decisions with excessive bureaucracy. Typically a strategic public-private "coalition" supported late industrialization. It is nevertheless important to note that this implied a sensitive balance, which worked out successfully for Brazil and Singapore, but not for Argentina and Indonesia, where the excessive military involvement and lack of oversight over funding, coupled with insufficient entrepreneurship and competitive strategy resulted in a lack of growth.

Furthermore, successful catch-up depended on the ability of innovation system actors to induce a fundamental institutional change in the system with the aim to adjust to new demand conditions. For instance, in the case of Brazil, this included the privatisation of the major state-owned enterprise, the loss of certain local capabilities while joining in global value chain primarily as system assembler.

The historical studies in the fifth chapter showed that economic crises, technological innovations available for companies of the sector, and changes in the regulatory environment have created recurrent windows of opportunity for latecomer companies to design and implement innovation strategies which had a fundamental effect on company demography. In the first instance of industrial leadership change studied, BAe and Fokker, the two incumbents lost leadership to Bombardier, a Canadian newcomer in 1995. In 2005, Embraer of Brazil overtook Bombardier in terms of number of regional jets delivered. The analysis of the two cases of leadership

change showed that more efficient engines and technological improvements in subsystems, changing oil prices, business cycles, liberalization of air transport services, scope clauses and government interventions were the main sources of technological, demand and regulatory windows. The most successful challengers were the ones implementing an innovation strategy and launch a new product family addressing a specific market niche – the 50-seat market in case of Bombardier, and the 100-120-seat market in case of Embraer. The fate of failed challengers and former leaders points to the importance of preconditions, that is, technological and financial capabilities needed for companies to respond to emerging opportunities, as well as the to importance of the timing of windows of opportunity, speedy strategic response, a proper evaluation of future demand and sheer luck, as long lead times and sunk costs entrap incumbents and inadequately responding companies.

IV. Summary of conclusions

A main novelty of this dissertation is the way it jointly analyzes the problems of economic and technological development, competitiveness and the international redistribution of political power. It proposes a new conceptual framework to study sectoral catch-up and innovation dynamics. An important theoretical contribution is the study of Schumpeterian dynamics from a systemic perspective. Scholars of innovation systems generally acknowledge that the structure of a system at a certain point in time reflects the historical evolution of its components (Edquist, 1997; Malerba, 2002). Yet, how exactly long-term evolution unfolds, what are the drivers of gradual or radical change have received less attention in the literature. A key conclusion of the study is that the incremental evolution of system elements is, from time to time (in the case of the aircraft industry, this could take decades), punctuated by radical transformation. Such transformation could be the emergence of new actors (companies, research institutes), a deep transformation of the channels of interaction between actors (new way of finance, exchange of knowledge and technologies, etc.), or a fundamental change in demand conditions. Radical changes are typically triggered by crises. Yet, systems do not necessarily transform in the wake of crises, as successful transition requires that active contribution of key actors (companies, government). It is a real possibility that passive approach will result in stagnation or a crash course of the industry.

The observation that the competitiveness of high-tech industries is closely linked to the performance of the sectoral innovation system means a particular disadvantage for latecomers, where this system needs to emerge. The strengthening of the system is a precondition for sustained growth of the sector, but this is the outcome of a long learning process. However,

crises discussed above may arrive during this emergence period, and the aftermath of crises may present conditions very different from according to which the emerging systems were conceived. Radical changes that are, according to the terminology of Anderson and Tushman (1986) competence destroying, can be particularly damaging for latecomers. This highlights the importance of foresight as well as of the role of chance in successful catch-up. Although according to the Gerschenkronian argument, latecomers are better positioned since they need to acquire existing technology, the conclusions of the fourth chapter show that the length of this learning process is particularly critical, which is in fact the source of what we see as net disadvantage.

The firm-level analysis of leadership dynamics highlighted further factors that drive technological change and the entry and exit of firms in high-tech, capital-intensive sectors in capitalist economies. The findings on how various types of windows of opportunity may trigger radical product innovation and sectoral leadership change points beyond the aircraft industry and suggest that Schumpeterian "creative destruction" can take a more limited form and may occur more frequently within the evolution of an industry. Furthermore, it highlighted the importance to consider, in a comprehensive way, the co-evolution of technology, economics and government, and discontinuities in the various domains. "Steady-state", simplifying growth models may be useful in predicting the short-term future of a sector, but for long-term evolution of the system, such co-evolutionary frameworks seem to be more appropriate.

V. Main References

Abernathy, W. J., & Utterback, J. M. (1978). Patterns of Industrial Innovation. *Technology review, 80*(7), 40-47.

Abramovitz, M. (1989). *Thinking about growth : and other essays on economic growth and welfare*. Cambridge: Cambridge University Press.

Ames, E., & Rosenberg, N. (1963). Changing Technological Leadership and Industrial Growth. *The Economic Journal, 73*(289), 13-31. doi: 10.2307/2228401

Amsden, A. H. (1989). *Asia's next giant : South Korea and late industrialization*. New York: Oxford University Press.

Amsden, A. H. (2001). *The rise of "the rest" : challenges to the west from late-industrializing economies*. Oxford ; New York: Oxford University Press.

Cimoli, M., Dosi, G., & Stiglitz, J. E. (2009). *Industrial policy and development : the political economy of capabilities accumulation*. Oxford ; Toronto: Oxford University Press.

Deloitte (2014) 2014 Global Aerospace & Defense Industry outlook. [URL: http://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-ad-2014-global-ad-industry-outlook.pdf (R: May 2015)]

Dutrénit, G. (2007). The transition from building-up innovative technological capabilities to leadership by latecomer firms. *Asian Journal of Technology Innovation, 15*(2), 125-149. doi: 10.1080/19761597.2007.9668640

Edquist, Charles. 1997. *Systems of innovation : technologies, institutions and organizations*. London; Washington, D.C.: Pinter.

Fagerberg, J. (2000). Technological progress, structural change and productivity growth: a comparative study. *Structural Change and Economic Dynamics, 11*(4), 393-411. doi: 10.1016/S0954-349X(00)00025-4

Fagerberg, J., & Verspagen, B. (2002). Technology-gaps, innovation-diffusion and transformation: an evolutionary interpretation. *Research Policy, 31*(8-9), 1291-1304. doi: 10.1016/s0048-7333(02)00064-1

Ferrier, Walter J., Ken G. Smith and Curtis M. Grimm. 1999. "The Role of Competitive Action in Market Share Erosion and Industry Dethronement: A Study of Industry Leaders and Challengers" *Academy of Management Journal*, 42:4, pp. 372-388. doi: 10.2307/257009

Freeman, C. (1987). *Technology, policy, and economic performance : lessons from Japan*. London ; New York: Pinter Publishers.

Gereffi, G., Humphrey, J., Kaplinsky, R., & Sturgeon*, T. J. (2001).

Introduction: Globalisation, Value Chains and Development. *IDS Bulletin, 32*(3), 1-8. doi: 10.1111/j.1759-5436.2001.mp32003001.x
Gerschenkron, Alexander. 1962. *Economic backwardness in historical perspective: a book of essays*. Boston: Harvard University Press.
Hanusch, H., & Pyka, A. (2007). A roadmap to comprehensive neo-Schumpeterian economics. In H. Hanusch & A. Pyka (Eds.), *Elgar Companion to Neo-Schumpeterian Economics* (pp. 1160-1170). Cheltenham, UK; Northampton, MA, USA: Edward Elgar.
Hanusch, H., & Pyka, A. (2007). A roadmap to comprehensive neo-Schumpeterian economics. In H. Hanusch & A. Pyka (Eds.), *Elgar Companion to Neo-Schumpeterian Economics* (pp. 1160-1170). Cheltenham, UK; Northampton, MA, USA: Edward Elgar.
Hill, H., & Pang Eng, F. (1988). The State and Industrial Restructuring: A Comparison of the Aerospace Industry in Indonesia and Singapore. *ASEAN Economic Bulletin, 5*(2), 152-168. doi: 10.1355/ae5-2d
Hira, A., & Oliveira, L. G. d. (2007). Take off and Crash: Lessons from the Diverging Fates of the Brazilian and Argentine Aircraft Industries. *Competition & Change, 11*(4), 329-347. doi: 10.1179/102452906X239501
Hobday, M. (1995). East Asian latecomer firms: Learning the technology of electronics. *World Development, 23*(7), 1171-1193. doi: 10.1016/0305-750X(95)00035-B
Hobday, Michael , Andrew Davies, and Andrea Prencipe. 2005. "Systems integration: a core capability of the modern corporation." *Industrial and Corporate Change*, 14:6, pp. 1109-43.
Hobday, M., Davies, A., & Prencipe, A. (2005). Systems integration: a core capability of the modern corporation. *Industrial and Corporate Change, 14*(6), 1109-1143. doi: 10.1093/icc/dth080
Humphrey, John. 2004. "Upgrading in global value chains." *ILO working paper* No.28, ILO, Geneva.
Kim, L. (1980). Stages of development of industrial technology in a developing country: A model. *Research Policy, 9*(3), 254-277. doi: 10.1016/0048-7333(80)90003-7
Kim, L. (1997). *Imitation to innovation : the dynamics of Korea's technological learning*. Boston: Harvard Business School Press.
Kim, L. (1998). Crisis Construction and Organizational Learning: Capability Building in Catching-up at Hyundai Motor. *Organization Science, 9*(4), 506-521. doi: 10.1287/orsc.9.4.506
Kim, L., & Nelson, R. R. (2000). *Technology, learning and innovation : experiences of newly industrializing economies*. Cambridge, U.K. New York: Cambridge University Press.
Kimura, S. (2006). Co-evolution of Firm Strategies and Institutional Setting

in Firm-based Late Industrialization – The Case of the Japanese Commercial Aircraft Industry. *Evolutionary and Institutional Economics Review, 3*(1), 109-135. doi: 10.14441/eier.3.109
Lall, S. (1992). Technological capabilities and industrialization. *World Development, 20*(2), 165-186. doi: 10.1016/0305-750X(92)90097-F
Lall, S. (2001). Competitiveness Indices and Developing Countries: An Economic Evaluation of the Global Competitiveness Report. *World Development, 29*(9), 1501-1525. doi: 10.1016/S0305-750X(01)00051-1
Lee, K., & Lim, C. (2001). Technological regimes, catching-up and leapfrogging: findings from the Korean industries. *Research Policy, 30*(3), 459-483. doi: 10.1016/S0048-7333(00)00088-3
Lee. K. & Malerba, F. (2013). Toward a theory of catch-up cycles: windows of opportunity in the evolution of sectoral systems. Paper presented at the *2013 Globelics International Conference*, 2013 September, Ankara, Turkey.
Lundvall, B.-A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter.
Lundvall, B.-Å. (2007). National Innovation Systems--Analytical Concept and Development Tool. *Industry & Innovation, 14*(1), 95-119. doi: 10.1080/13662710601130863
Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy, 31*(2), 247-264. doi: 10.1016/S0048-7333(01)00139-1
Malerba, F., & Mani, S. (2009). *Sectoral systems of innovation and production in developing countries : actors, structure and evolution*. Cheltenham, UK ; Northampton, MA: Edward Elgar.
Marques, R. A. (2004). Evolution of the civil aircraft manufacturing innovation system: A case study in Brasil. In S. Mani & H. Romijn (Eds.), *Innovation, Learning and Technological Dynamism of Developing Countries* (pp. 77-106). Tokyo ; New York: United Nations University Press.
Mathews, J. A. (2002). Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-Up Strategies. *Asia Pacific Journal of Management, 19*(4), 467-488. doi: 10.1023/A:1020586223665
Mazzucato, Mariana. 2013. *The entrepreneurial state: Debunking public vs. private sector myths*. London, New York: Anthem
Mowery, David C. 1987. *Alliance politics and economics: multinational joint ventures in commercial aircraft*. Cambridge, Mass.: Ballinger
Mowery, D.C., Nelson, R.R., 1999. *Sources of industrial leadership: studies of seven industries*. Cambridge University Press, Cambridge, UK ; New York.
Nelson, Richard R. 1993. *National Systems of Innovation: A comparative*

Analysis. Oxford: Oxford University Press.
Nelson, R. R., & Pack, H. (1999). The Asian Miracle and Modern Growth Theory. *The Economic Journal*, *109*(457), 416-436. doi: 10.1111/1468-0297.00455
Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge, Mass.: Belknap Press of Harvard University Press.
Niosi, J., & Zhegu, M. (2005). Aerospace Clusters: Local or Global Knowledge Spillovers? *Industry & Innovation*, *12*(1), 5 - 29. doi: 10.1080/1366271042000339049
Niosi, J., & Zhegu, M. (2008). *Innovation System Lifecycle in the Aircraft Industry*. Paper presented at the 25th Celebration Conference 2008 on Entrepreneurship and Innovation, CBS, Copenhagen, Denmark. http://www2.druid.dk/conferences/viewpaper.php?id=2885&cf=29
Niosi, J., & Zhegu, M. (2010). Anchor tenants and regional innovation systems: the aircraft industry. *International Journal of Technolgy Management*, *50*(3/4), 263-284. doi: 10.1504/IJTM.2010.032676
Perez, C., Soete, L., 1988. Catching up in technology: entry barriers and windows of opportunity, in: Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., Soete, L. (eds.), *Technical Change and Economic Theory*. Pinter, London, New York, pp. 458-479.
Prencipe, Andrea. 2013. "Aircraft and the Third Industrial Revolution" in Dosi, G., Galambos, L. (eds.) *The Third Industrial Revolution in Global Business*, Cambridge: Cambridge University Press.
Romanelli, E., & Tushman, M. L. (1994). Organizational Transformation as Punctuated Equilibrium: An Empirical Test. *The Academy of Management Journal*, *37*(5), 1141-1166. doi: 10.2307/256669
Schumpeter, Joseph A. 1934. *The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle*. Cambridge: Harvard University Press.
Simai, M. (2001). *The age of global transformations: the human dimension*. Budapest: Akadémiai Kiadó.
Szalavetz, Andrea. 2013. *Régi-új világgazdasági jelenségek a globális értékláncok tükrében.* Külgazdaság, 57 (3-4). pp. 46-64.
Tushman, M. L., & Anderson, P. (1986). Technological Discontinuities and Organizational Environments. *Administrative Science Quarterly*, *31*(3), 439-465. doi: 10.2307/2392832
Veblen, Thorstein. 1919. *The place of science in modern civilisation and other essays*. New York,: B.W. Huebsch.
Westphal, L. E. (2002). Technology Strategies For Economic Development In A Fast Changing Global Economy. *Economics of Innovation & New Technology*, *11*(4/5), 275. doi: 10.1080/10438590200000002

VI. List of relevant publications by the author

Books and book chapters in English:

Vertesy, D. (2015). The Contours of the Global Commercial Aircraft Manufacturing Industry. In S. Eriksson & H.-J. Steenhuis (Eds.), *The Global Commercial Aviation Industry* (pp. 1-32). London: Routledge.

Vertesy, D. (2011). The evolution of the Chinese and Argentine aircraft manufacturing industries. In M. Santillán, M. H. & Rubiolo (Eds.), *América Latina y el Este Asiático: Perspectivas desde Córdoba*. Córdoba, Argentina: CIECS-CONICET Universidad Nacional de Córdoba.

Vertesy, D. (2011). *Interrupted innovation: Emerging economies in the structure of the global aerospace industry*. Phd Dissertation, Maastricht: Universiteit Pers Maastricht

Book chapters in Hungarian:

Vértesy Dániel (2008), "Utazás az innovációs rés mélyére", in: Palánkai et al (szerk.) *Három éve az ötven éves EU-ban*, Konferenciakötet, Budapest: BCE.

Articles in peer-reviewed journals in English:

Vertesy, D. (2013). The lion with wings: Innovation system dynamics in the aerospace industry of Singapore. *International Journal of Technology and Globalisation, 7*(1-2), 118-140. doi: 10.1504/IJTG.2013.052027

Vertesy, D., Annoni, P. & Nardo, M. (2013). University Systems: Beyond League Tables. Engines of Growth or Ivory Towers? *Higher Education Evaluation and Development*, 7(1), 21-43. doi:10.6197/HEED.2013.0701.02

Re Articles in peer-reviewed journals in Hungarian:

Vértesy, Dániel (2008), "Mi motiválja Közép- és Kelet-Európa vállalatainak K+F kiadásait?" *Társadalom és Gazdaság*, 30(1), pp.115-137. DOI: 10.1556/TarsGazd.30.2008.1.7

Vértesy Dániel (2006), "Fejlődő feljesztés? Fejlesztési- és támogatáspolitika az ENSZ keretében 1945 és 1990 között" *Grotius – A Budapesti Corvinus Egyetem Nemzetközi Tanulmányok Intézetének tudományos folyóirata*.

Other journal articles in English:

Vértesy, D. (2011). „Global Insider: The Brazilian Aerospace Industry" *World Politics Review*; 10 Jan 2011, p.3.

Muchie, M., Vértesy, D., Baskaran, A., Na-Allah A. A. (2009). Book Reviews *African Journal of Science, Technology, Innovation & Development*, Vol 1, Nr. 2-3, 2009.

Working Papers in English:

Van Roy, V., Vértesy, D. & Vivarelli, M. (2015). Innovation and Employment in Patenting Firms: Empirical Evidence from Europe, *Institute for the Study of Labor (IZA) Discussion Papers*, No 9147.

Vertesy, D. (2014). Successive leadership changes in the regional jet industry *UNU-MERIT Working Paper Series*, 2014-046.

Vértesy, D. & Szirmai A. (2010). Interrupted Innovation: Innovation System Dynamics in Latecomer Aerospace Industries, *UNU-MERIT Working Paper Series*, 2010-059;
újra közölve: *Globelics Working Paper* Nr. 10-02.

Vértesy, D. & Szirmai A. (2010). "Brazilian aerospace manufacturing in comparative perspective: A Brazil/USA comparison of output and productivity", *UNU-MERIT Working Paper Series*, 2010-032.

Conference Publications in English:

Vértesy, D. (2014). Successive Leadership Changes in the Regional Jet Industry presentation paper presented at the conference *Future perspectives on innovation and governance in development*, Maastricht, The Netherlands 26-28 Nov 2014

Saltelli A., Saisana M., and Vértesy D., (2013). Advocacy, Analysis and Quality. The Bermuda triangle of statistics. Presentation at the *What way forward for European and Hungarian Statistics?* conference of the Hungarian Statistical Association, Budapest, 20-21 Nov 2013

Vértesy, D. (2013). Changing leadership in the regional jet industry, Paper presented at the *Conference on Changes in the Industry Leadership and Catch-up Cycles*, Seoul, South Korea 12-13 May 2013.

Vértesy D. (2012). Measuring Innovation, presentation at the 2012 Cyprus Presidency – JRC Conference *Scientific Support to Innovation in the Services Sector*, Nicosia, 13 December 2012.

Vértesy D. (2012). Exploring research performance of countries and knowledge-led growth, *Proceedings of the 10th Globelics 2012 International Conference*, 9-11 November 2012, Hangzhou, China

Vértesy D., Annoni, P., Nardo, M. (2012). "Regional University Systems: Engines of Growth or Ivory Towers?" Paper presented at the *IREG-6 Conference:The Academic Rankings and Advancement of Higher Education. Lessons from Asia and Other Regions.* Taipei (Taiwan) 18-20 Apr 2012.

Vértesy, D. (2011), Charting the Changing Landscape of the Aerospace Manufacturing Industry, Paper presented at the *9th Globelics International Conference*, Buenos Aires (Argentina) 15-17 Nov 2011

Other peer-reviewed studies in English:

Hardeman S., Van Roy V., Vértesy D. and Saisana M. (2013). *An analysis of national research systems (I) A Composite Indicator for Scientific and Technological Research Excellence* EUR 26093. Luxembourg (Luxembourg): Publications Office of the European Union; doi: 10.2788/95887

Hardeman S. and Vértesy D. (2013). *An analysis of national research systems (III): towards a composite indicator measuring research interactions* EUR 26405 EN Luxembourg (Luxembourg): Publications Office of the European Union; doi: 10.2788/50714

Vértesy D. and Van Roy V. (2013). *Update on the Composite Indicators of Structural Change towards a More Knowledge-Intensive Economy* EUR 26409 EN Luxembourg (Luxembourg): Publications Office of the European Union; doi: 10.2788/51665

Vértesy D., Tarantola S. (2012). *Composite Indicators of Research Excellence*. EUR 25488 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2012. doi: 10.2788/45492

Vértesy D., Albrecht D. & Tarantola S. (2012). *Composite Indicators measuring structural change, to monitor the progress towards a more knowledge-intensive economy in Europe*, Luxembourg: Publications Office of the European Union; doi:10.2788/20444

Tarantola, S., Vértesy D. & Albrecht D. (2012). *Composite Indicators measuring the progress in the construction and integration of a European Research Area*, Luxembourg: Publications Office of the European Union; doi: 10.2788/20356