Issues of Recreating the Californian Innovation System in Latin American Countries

Franco-Bermudez, Juan F
University of Sussex
United Kingdom
j.franco-bermudez@sussex.ac.uk

Franca E-Ribeiro, Amanda A
University of Sussex
United Kingdom
a.franca-e-ribeiro@sussex.ac.uk

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Abstract

This paper analyses the issues in attempting to replicate the Californian Innovation System (IS) in Latin American contexts. We try to establish the parallels for Latin American countries by identifying the fundamental elements and feedback loops that were necessary to the emergence of Silicon Valley and their strengths in the technology and software industry. We compare three scenarios through analysing their technological change trajectories: Silicon Valley, Colombia and Brazil. Using theoretical frameworks relevant for innovation studies such as path dependence on technical change trajectories, accumulation of technological capabilities, national and regional IS, Pavitt's taxonomy, and supply-chain trade; we explain why Latin American countries and policymakers should not try to pursue the same path as Silicon Valley trying to catch-up in the technology and software industries. Moreover, we propose some recommendations for policymakers. Hence, countries can exploit their own accumulated capabilities and tacit knowledge from their particular technological trajectories or scout new trajectories unexplored by other nations. Latin American countries must take advantage of their complementary assets and regimes of appropriability to obtain profits from innovation. We suggest that megadiversity could represent a new trajectory where those countries are likely to globally stand out. Finally, we

highlight some reflections in terms of specific elements that can be promoted through science, technology and innovation policies to leverage Latin American IS. Such as being driven by inclusive approaches, retaining the human capital, fostering the academia-industry relationships, and embedding the policy evaluation stage as a fundamental part of the policy process.

1. Introduction

Since the middle of the 20th century, California has been positioning itself as one of the world's most innovative regions. Particularly, the Silicon Valley region went through several processes of technical change that gave rise to critical technological developments and the birth of many technology firms (Ferrary & Granovetter, 2009). Silicon Valley became a highly productive cluster in terms of knowledge and technology, enabling it to uphold essential economic growth and development (Moore & Davis, 2004). California produces around 14% of the gross domestic product (GDP) from the United States. The region holds a GDP per capita higher than countries such as Japan and Germany (Bureau of Economic Analysis, 2019).

According to Fagerberg (2004) *"countries or regions that wish to catch up with the innovation leaders face the challenge of increasing their own innovation activity towards leader levels"*. Hence, policymakers in developing countries often seek benchmarks and try to replicate dynamics taken from the Californian innovation system (IS), with the expectation of achieving similar benefits to their countries' economy, profiting from the technology industry. However, it is not as simple as copying their industries, actions and policies (Etzkowitz, 2019).

In this paper, we discuss the issues for Latin American countries in promoting the technology industry and replicating the Californian IS outside its original context. We compare the Californian trajectory to the Brazilian and Colombian contexts. We start by presenting the historical overview of these three IS. Then, we discuss the issues about said imitation using concepts and frameworks such as path dependence on technical change trajectories, accumulation of technological capabilities, national and regional IS, Pavitt's taxonomy, and supply-chain trade. Finally, we conclude that such reproduction is not implementable to Brazil and Colombia, addressing some elements that can guide policymakers and giving some recommendations for a more pertinent science, technology and innovation (STI) policy.

2. Historical Context - Different Technical Change Trajectories

2.1 Californian IS

One of the most important milestones that made possible the emergence of the Californian innovation system was the development of silicon transistors; this would later give rise to the first microprocessor and eventually to the entire software industry; being at the frontier of knowledge was fundamental for these disruptive innovations to occur (Pavitt & Bell, 1993). The Second World War had led the United States to allocate significant amounts of money to R&D activities in the technology field (Jasanoff, 2005), configuring a technical change trajectory and accumulating specific capabilities (Pavitt & Bell, 1993). This led to strengthening universities and technology companies in the eastern part of the country, such as the Massachusetts Institute of Technology and Bell Labs. Their members would be influential for Silicon Valley emergence (Rosenberg & Nelson, 1994).

Towards the 1950s, Stanford University, located in California and the most prominent engineering school in the region, started creating initiatives such as "Stanford Research Institute", in charge of collaborating with technology firms in R&D; and "Stanford Industrial Park", where students could create start-up firms focused on the technology market, counting on the university advice and venture capital sources. Given these synergies, several businessmen and researchers from the East began moving to California to try to meet the demand for electronic devices required during the cold war (Adams, 2005; Moore & Davis, 2004).

Fagerberg (2004) argues that *"Innovation tends to cluster in certain industries/sectors, which consequently grow more rapidly".* Therefore, this region would be born supported by the technological growth that the university entailed, enabling the emergence of companies in the technology sector. This dynamic created a positive feedback loop (Akbar et al., 2018), attracting more venture capital industries (Armour & Cumming, 2006), more entrepreneurs and technology firms, and triggering other universities such as the University of Berkeley to enforce engineering and technological programs (Adams, 2009; Rosenberg & Nelson, 1994).

2.2 Colombian IS

Throughout its history, Colombia has set out a different trajectory, not focusing on the technology industry but in the extractive industry, both at the mining-energy and agricultural level. Analogously to Silicon Valley, mining activity at the beginning of the 20th century attracted investors and venture capital industries for creating start-up firms. Consequently, this leveraged the growth of universities such as the National School of Mines, today attached to the National University of Colombia and the most important engineering faculty in the country (Cubides, 1985; Meisel-Roca, 2005).

The wealth obtained from mining would trigger another positive feedback loop: the opportunity for creating manufacturing, steel and food companies appeared, and the School of Mines would introduce programs such as chemical, industrial and mechanical engineering, whose graduates would create and manage said companies. Later would emerge a cluster of companies in the mining-energy and food sector in the region of Antioquia (Mora, 1984). However, the administration of said capital was deficient due to cultural issues and political ideologies, it passed from the hands of the engineers to the hands of politicians, significantly slowing progress and causing several companies to fail (Cubides, 1985; Mora, 1984).

The relationships and cooperation between firms and universities in Colombia are minimal. Companies that collaborate with universities in R&D are exclusively those of the mining-energy sector, and most of STI policies have been oriented towards the exploitation of these markets (Robledo, 2019). According to Pavitt and Bell (1993), when a nation embarks on a trajectory of technical change, this determines the accumulation of specific technological capabilities; consequently, Colombia would obtain a different set of capabilities at not promoting technology and software industries.

In later years, the progress has been predominantly institutional. Towards the 90s, it was officialised the national system of STI (Moncayo-Jiménez, 2018). In 2019 the Ministry of STI was created, and in 2020 Colombia was admitted to the Organization for Economic Cooperation and Development (Minciencias, 2021). However, these institutional signs of progress have not generated desired impacts on the realities of companies, universities, markets, society, and the country's economic growth.

2.3 Brazilian IS

Similarly to Colombia, the Brazilian technological trajectory has not been focused on high-value-added electronic goods. Technological change in Brazil has followed a hectic trajectory, marked by short and occasional cycles of growth, commonly underpinned by protectionist state-led measures, which have made the economy excessively inward-looking and insulated from external competitors (Arbix, 2019). As a result, Brazil demonstrates a poor performance when it comes to the innovative activities from its companies, both in-process and products innovation (de Negri, 2018).

For many decades, the country's industry relies on the manufacture of food products and automotive vehicles (internally consumed) and on the extraction of oil, natural gas and metallic minerals (largely exported) (IBGE, 2020). According to de Negri (2018), despite some sparse initiatives, Brazil is lagging in terms of catching-up with industrialized economies.

In 2003, the Brazilian government launched the Industrial, Technological, and Foreign Trade Policy (PICTE), the first policy to add innovation to the Brazilian industrial agenda (Arbix, 2019). PITCE was steered to boost areas such as semiconductors, software, capital goods, pharmaceuticals and medicines and *"future-oriented activities"*, i.e., biotechnology, nanotechnology, biomass and renewable energies (Salerno & Daher, 2006). However, the lack of coordination among stakeholders within the National Government involved in PICTE constrained this policy to achieve its full potential (Arbix, 2019).

In the last 30 years, Brazilian science grew above global averages, however, in terms of university-industry collaboration, the desired interactions are not effective for innovation purposes (de Brito, 2019).

3. Discussions and Analysis

Understanding at a general level the trajectory of each region, the first argument to consider is path dependence: the chosen technological trajectories by each country determined the technological capabilities accumulation and these trajectories built over more than 50 years are difficult to reverse (McEvily & Zaheer, 1999; Stirling, 2010). For Brazil and Colombia aiming to catch-up and stand out in markets where there are much more expert regions would be disadvantageous because *"developing complex technologies requires technology-specific, accumulated expertise, that takes time to acquire, can be difficult to articulate, is typically passed on by face-to-face mentoring, and is learnt through practice"* (Nightingale, 2014). These differences of capabilities have several implications that make Brazil and Colombia unlikely to compete in the technology market.

Consequently, the second argument is the accumulation of capabilities. According to Freeman (1995) and Robledo (2019), technological capabilities are those skills, knowledge and resources that enable innovative agents to exploit different innovation opportunities in a competitive environment. Actors accumulate capabilities through processes of learning which demand time and resources; maintaining these capabilities is also costly (Lundvall & Johnson, 1994). Learning processes also trigger tacit knowledge accumulation, a fundamental component for operating and adopting technology (Nightingale, 2014; Pavitt & Bell, 1993). For Brazil and Colombia to start learning processes, acquire new capabilities and tacit knowledge demand significant efforts and coordination.

Smith and Babbage (Nightingale, 2020) identified that the division and specialization of labour was a differentiating factor in obtaining efficient processes and better outcomes from technology. By analogy, orienting learning processes to the specialization in specific capabilities and supplying the missing capabilities through associations with other agents is fundamental for exploiting innovation opportunities (Ruiz-Castañeda, 2016). However, specializing requires skilled professionals capable of transforming tacit knowledge into codified knowledge (aggregation capability) and improving technologies incrementally (Geels & Deuten, 2006), while building networks requires strong intermediation capabilities (Franco-Bermúdez & Ruiz-

Castañeda, 2019) such as diffusion and bonding (Howells, 2006) that Brazil and Colombia still lack.

Converging previous ideas, the third argument brings us to the emergence of IS. These dynamics in a competitive environment where innovation opportunities emerge, and heterogenous innovative agents make decisions, associate, specialize, catch up (or fail), determine what is known as regional and national IS (Freeman, 1995; Lundvall & Borrás, 2006). Within IS, the environment, technologies and knowledge evolve and mutually adapt, generating better outcomes over time (Nightingale, 2014).

To determine the required effort, Brazilian and Colombian IS lack such dynamics. Both countries would require starting a new technical change trajectory and implementing policies to promote an IS emergence. Later, they require accumulating capabilities, approximating the technological frontier and training skilled people aiming high levels of specialization. Subsequently, they need to build networks with leader countries. Unfortunately, this is not still sufficient to catch-up in the technology industry; a key element that impacts on who gets profits from innovation opportunities, and comes as the fourth argument are the regimes of appropriability (Teece, 1986).

Taking Teece's ideas (1986) about appropriability, there are two determinant factors to obtain economic benefits from innovation. The first one is owning complementary assets that enable commercializing the innovation and favour more efficient market exploitation. The second one is related to the nature of technology in terms of being easily imitable. In accordance, there are necessary effective mechanisms of intellectual property protection.

According to Pavitt's taxonomy (Nightingale, 2020), another factor to consider is the competitive advantage for which actors aim to stand out. It could be the price by obtaining technology from suppliers aiming economies of scale and scope (Teece, 1993); or performance by product and process design, engineering, and investment in R&D (Pavitt & Bell, 1993).

Brazil and Colombia are unlikely to profit from the technology industry through performance, by investing in R&D or design to find technological discoveries. Other countries are already at the technological frontier for easily copying, adapting, and improving possible technological innovations. Leader countries own complementary assets due to their technical change trajectories and successful learning experience in this industry. On the side of the price, adapting technology from suppliers is complex, it requires diffusion and production capabilities besides skilled engineers for adapting and improving foreign technologies (Pavitt & Bell, 1993), especially requires a high absorptive capacity (Fagerberg, 2004) and knowledge in the field. Hence, Brazil and Colombia are unlikely to stand out in the technology market neither for price nor performance.

As the fifth argument, both countries would struggle to participate in international trade networks (Pavitt & Bell, 1993) and the supply-chain trade dynamics. The current trend is that high-tech firms take advantage of low-wage labours in developing countries to get economies of scale and scope becoming more competitive in the international market (Baldwin, 2012).

Expanding this idea, they face three main barriers: First (1), considering big firms (Teece, 1993), they lack companies in the technology industry with know-how, capabilities and resources to consider expanding to international markets and outsourcing their manufacturing processes. Secondly (2), the logistics infrastructure prevents them from having an efficient supply-chain for re-importing and re-exporting dynamics as the only mode of transport is through highways, and the mountainous geography makes transporting goods within the country particularly expensive (Gonzalez et al., 2007). Finally (3), as supply-chain trade is regional, not global (Baldwin, 2012), the neighbouring countries play a prominent role. Unfortunately, in Latin America, there are no countries that stand out for their R&D, production or marketing capabilities in the technology industry, so close alliances are unlikely to help exploit this market.

One last difference is related to entrepreneurship dynamics and a qualified workforce. The availability of venture capital and certain regulatory freedom facilitated a bottom-up emergency of firms in Silicon Valley, favouring the positive feedback loops and attracting highly-skilled professionals (Armour & Cumming, 2006).

In both Brazil and Colombia, the entrepreneurs face significant institutional barriers, and tax burdens can be impeditive for emerging firms (Rubach et al., 2015). Most entrepreneurs are driven by necessity (Puente et al., 2019); thus, venture capital is scarce (Acs & Amorós, 2008). Additionally, the digitization of certain jobs has contributed to a brain drain dynamics, causing a shortage of qualified workforce in technology areas (Gazabon et al., 2015).

4. Conclusions and recommendations

Finally, it is evident that Latin American countries lack many pieces of the puzzle to catch-up in the technology industry. Innovation is not about investing in R&D and imitating leader countries. Also, we explained several arguments that show Silicon Valley did not emerge and succeed fortuitously. Many specific factors and decisions converged in California, facilitating a technical change trajectory and accumulation of technological capabilities that gave birth to an IS challenging to imitate for practically any country.

However, the discussions above provide key elements for policymakers to understand innovation dynamics better and formulate more appropriate STI policies. Some of these elements are: identifying technical change trajectories for taking advantage of tacit knowledge, capabilities and experience that are already accumulated, training skilled engineers to be able to adapt and improve technologies, taking advantage of learning processes and specialization, correctly managing regimes of appropriability and guarantying complementary assets besides just innovating, protecting innovations if they are easy to imitate, building valuable networks and partnerships with neighbours to participate in dynamics of supply-chain trade, technology transfer, and economies of scale and scope, among others.

The past technical change trajectories in Brazil and Colombia limited the countries to stand out in the most profitable industries. A recommendation if they want to be leaders taking advantage of its resources and capabilities is starting a new trajectory based on their biodiversity. Brazil and Colombia are "Megadiverse" countries since each of them is home to more than 70% of the world's biodiversity. They are wealthy in fauna, flora, climate, ecosystems, landscape and part of the resources counts with initial elements to take advantage of them such as tacit knowledge and complementary assets. This is an unexplored trajectory where no country has significantly progressed or take the lead, and as in the case of California, it is something difficult to imitate.

A more inclusive approach is needed due to the high inequality in Latin American contexts (Audretsch, 2021). Retaining human capital is also recommendable bearing in mind that the external sources of human capital are one of the main dependencies that Silicon Valley currently faces (Etzkowitz, 2019).

Finally, we highlight two recommendations for STI policymakers: the first is strengthening the academic sector and the permeability of academic boundaries (Etzkowitz, 2019). Although there are constraints for developing a direct academy-industry relationship in Latin America (Arocena & Sutz, 2001), the extant literature highlights the fundamental role of universities in the emergence of successful technological clusters (Adams, 2009; Mowery & Sampat, 2009). The second is embedding policy evaluation as a crucial part of the policy learning process (Meseguer, 2005).

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