Science, technology and innovation for economic competitiveness: the role of smart specialization in less-developed countries.

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5 December 2015

SCIENCE, TECHNOLOGY, AND INNOVATION FOR ECONOMIC COMPETITIVENESS: THE ROLE OF SMART SPECIALIZATION IN LESS-DEVELOPED COUNTRIES

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ABSTRACT:

Smart specialization (SS) is a policy concept that has gained significant momentum in Europe despite a frail theoretical background and implementation difficulties. These challenges become critical in the case of less-developed economies that often lack regional autonomy, a strong STI base, and local capabilities to identify and sustain such SS strategies. Combining elements from evolutionary economics and the export-led literature, I propose a framework that anchors the role of SS in the national innovation policy of such laggards, as a complementary avenue for improving competitiveness and growth. Moreover, to assist policy makers in lagging regions or countries, I advance a diagnostic tool to identify potential areas for SS, and also address the systemic and the regional-sectoral bottlenecks in these domains. I exemplify the use of this tool in the case of Bulgaria by using a large battery of quantitative and qualitative indicators from publicly available data. This type of investigation may be useful for other less-developed economies to kick-start this process and identify prima facie SS candidates.

Keywords: Smart Specialization; Innovation Systems; Exports; Patents; Scientific publications;

1. INTRODUCTION

International competitiveness is heralded worldwide as the ultimate economic objective of a government (Porter, 1990). While competitiveness is affected by many factors, innovation, in the form of scientific discovery and creation of new technologies, has been widely acknowledged as one of its main drivers (Cameron, 1996; Hall and Jones, 1999; Freeman, 2002; Rosenberg, 2004; Wang et al., 2007; Gibson and Naquin, 2011). This link has become even more important in the wake of the recent economic crisis, as more and more countries seek to secure sustainable sources of economic growth (Aghion et al., 2009). Subsequently, science, technology and innovation (STI) are increasingly targeted by concerted policy efforts (Filippetti and Archibugi 2011), in an attempt to reduce countries' economic reliance on financial or real estate markets (Blanchard et al. 2012).

Among such initiatives, smart specialization (SS) is a recent concept that seeks to rekindle growth in Europe and reduce its productivity deficit vis-à-vis global leaders (Foray et al., 2009; Giannitis and Kager, 2009). Borrowing arguments from trade theory, such as comparative advantage and factor endowments, the SS framework stresses the need for regions and countries to prioritize selected vertical areas (*specialization*) by building on existing strengths and assets (*smart*) as a base for innovation-driven growth (Foray et al., 2011). In particular, this SS process relies heavily on entrepreneurial discovery, and prescribes different innovation strategies for "leading regions" (i.e., develop General Purpose Technologies – GPTs-) and "following regions" (i.e., apply GPTs in their existing core-activities).

Despite its overwhelming success in the European arena, the SS concept has several limitations, which I argue to be particularly salient for less-developed countries. First, while the simplicity of the concept remains the main selling point, its theoretical rifts (Foray et al., 2009) are exacerbated in less-developed settings. Thus, the key role of entrepreneurs in bolstering new areas of excellence (Morgan, 2013), the tacit nature of knowledge involved (Navarro et al., 2011), the missing ties to economic objectives (van Oort et al., 2015), the fuzzy role of central governments (Charles et al., 2012) and foreign firms (Radosevic and Stancova, 2015), all need to be better addressed in the SS debate, as they prove to be remarkable obstacles for a smooth implementation of SS strategies (McCann and Ortega-Argiles, 2016). Second, in less-developed countries, SS efforts are likely to face atypical obstacles, such as lack of a critical STI mass

(Giannitis and Kager, 2009), limited commercialization opportunities (Morgan, 2013), underdeveloped clusters (Bröchler and Kalentzis, 2017), and weak regional autonomy (Healy, 2016). Thus, SS strategies in these contexts are inherently more likely to follow a traditional top-down trajectory (Kominos et al., 2014), given the lack of entrepreneurial ecosystems (Aidis et al., 2008), heavy reliance on public (Krammer, 2009) and foreign (Krammer, 2014) sources of innovation, and the danger of stalling in regional "technological lock-ins" (Giannitis and Kager, 2009). Finally, SS does not account specifically for the systemic nature of innovation (Lundvall, 1992), which mandates coordinated policies to tackle the fragmentation of innovation systems (Edquist, 2011) and the development of clusters (Phillips, Oh and Lee, 2016). Commonly, such actions target systemic issues (e.g., support of scientific and R&D activities, taxation, education, STI collaboration, etc.) are difficult to address at the regional level given the massive level of investments required.

This study addresses some of these limitations and proposes several contributions. First, incorporating insights from evolutionary economics and the export-led growth literature, it provides an overarching framework that maps SS into the regional and national systems of innovation, linking them with downstream economic growth and competitiveness. In this framework, SS strengthens the vertical links between STI and economic actors, translating competitive advantage from the knowledge domain to the economic one through viable commercialization strategies and entrepreneurial efforts. Furthermore, this approach suggests that a mix of complementary policies (i.e., SS prescriptions for regional and sectoral aspects, combined with national initiatives to tackle systemic deficiencies in economic, knowledge and STI domains) is best suited for stimulating innovation-driven growth in less-developed settings.

Second, it proposes a novel methodology to assist policy makers in these countries to identify fruitful (i.e., "smart") areas of specialization, and also address some of the critical challenges in these domains. In doing so, it infers that SS policies must ultimately cater to greater socio-economic objectives (i.e., increased competitiveness, more jobs, higher growth etc.) of the region/country. Given the importance of exports for future economic performance (Hausman and Klinger, 2008), this diagnostic employs a series of quantitative and qualitative analyses to examine the composition and evolution of exports and identifies promising areas for potential SS strategies. It also examines both systemic and SS-specific deficiencies as a basis for first-stage policy prescriptions in these areas, ones that can be further distilled after consultations with all relevant stakeholders (Foray and Rainoldi, 2013).

The empirical part of the paper employs this diagnostic tool in the case of Bulgaria, an EU "laggard" in both economic and STI terms. The results of this exercise show that, despite its heavy reliance on exports (almost 60% of its GDP), Bulgarian competitiveness has virtually stalled over the last decades. Its low-sophistication export basket is a result of weak innovation performance and a significant mismatch between scientific and research capabilities in the country. Examining detailed export potential data, I identify five promising areas for SS in Bulgaria that cover both manufacturing and services, and different technological regimes (from low-, i.e., "Copper and Iron" or "Food", to high-tech industries such as "Pharmaceuticals" or "ICT"). Subsequent analyses examine these SS candidates from several vantage points (i.e., usage of existing STI capabilities, entrepreneurial intensity, regional distribution, strategic opportunities). Incorporating all these insights, I propose several policy recommendations for each SS candidate area that address concomitantly the systemic and region-sector issues. This exercise is informative for Bulgaria to identify or refine its development strategies. Furthermore, it validates the use of this diagnostic tool as a valuable instrument for policy-makers in less-developed countries to start the SS conversation with relevant stakeholders (e.g., firms, civil society, institutes, and universities).

2. THE ROLE OF SMART SPECIALIZATION POLICIES IN THE INNOVATION SYSTEMS-ECONOMIC COMPETITIVENESS NEXUS

Policy makers in both developed and developing nations frequently depict competitiveness as the pinnacle of economic policies. However, despite its apparent simplicity, competitiveness often remains difficult to grasp in practice. While some define it as the ability to secure desirable economic outcomes (e.g., job creation, high living standards, foreign investments, etc.), others see it as local characteristics (e.g., low wages, high-skilled labor force, low inflation, etc.) that form a favourable environment for economic activities. Besides this confusing dichotomous usage of the term, most definitions capture competitiveness in a multidimensional setting, which induces additional problems in identifying what exactly means to *be competitive*, and at which *level* it should be measured. Therefore, the main criticisms in the literature regarding this concept point to issues such as the arbitrary nature of measures employed, aggregation issues, and great conceptual overlap with productivity measures (Krugman, 1994; Jenkins, 1998; Reichel, 2002). Nonetheless, competitiveness indexes and rankings remain extremely popular in practitioners' circles (Acs et al., 2014; Hermann et al., 2012; IMD, 2015; WEF, 2015) as a base for policy interventions to enhance performance both at the micro (firms, entrepreneurs, clusters) and macro (sectors, regions, and economies) levels (Porter, 1990)[1]. However, a clearer method to identify the micro underpinnings of competitive advantage is to examine trade and specialization patterns at the more disaggregated (i.e., product, niche, or industry) levels (Alcala and Ciccone, 2004). This allows us to identify competitive advantage and its subsequent contributions to regional and national performance via productivity effects (Castellacci, 2008a) and economic growth (Imb and Warcziag, 2003; Hausmann and Klinger, 2008).

Innovation, in the form of scientific discovery and creation of new technologies, remains the most important source of economic competitiveness (Hall and Jones, 1999; Freeman, 2002; Rosenberg, 2004; Castellacci, 2008a; Gibson and Naquin, 2011). This fact has become even more salient in the wake of the crisis, when all countries are seeking more sustainable sources of economic growth (Aghion et al., 2009), often in the form of strong innovation systems (IS) that capitalize on superior scientific and technological assets (Filippetti and Archibugi 2011). Nevertheless, spurring innovation performance is not an easy task given its sectoral specificity and systemic nature (Castellacci, 2008a). Therefore, when analyzing the impact of innovation on economic competitiveness one must carefully account for systemic and industrial particularities that affect the creation, diffusion and exploitation of knowledge among different actors in these innovation systems (Todtling and Trippl, 2005; Krammer 2016).

Following these ideas, **Figure 1** synthesizes the main lessons stemming from this literature (Mulder et al., 2001), conceptualized across three distinct dimensions (i.e., *systemic*, *knowledge* and *economic*) and with distinct implications for *policy*.

---------------------------------- Insert Figure 1--

From a *systemic* perspective (see **Figure 1**), innovation can be conceptualized across

[1] These indexes provide a good overview of the competitive position of a country internationally. However, they tend to aggregate subjectively heterogeneous factors (i.e., from quality of institutions to infrastructure), which makes them less useful for regional policy analyses.

different levels of analysis, i.e., national, regional or sectoral (Nelson and Winter, 1977; Dosi, 1988; Malerba, 2002), and as a result of a complex web of interactions between institutions, actors, and supporting infrastructures. All these systems are closely intertwined and exhibit numerous feedback loops to other elements from the knowledge and respectively, economic context. Such links have been extensively documented by prior studies on trade competitiveness (Fagerberg, 1988; Dosi et al., 1990), productivity differentials (Hall and Jones, 1999), firm performance (Melitz 2003) industrial dynamics (Fagerberg et al, 1997; Castellacci, 2008b), external learning (Clerides et al., 1998) and absorptive capacity (Cohen and Levinthal 1990). Besides national and sectoral systems of innovation, regional drivers are equally important for competitiveness (Feldman and Audretsch, 1999; Delgado et al., 2012). Hence, concentration of STI activities (Breschi and Malerba, 2001), knowledge spillovers (Jaffe et al., 1993; Bottazzi and Peri, 2003; Breschi and Lissoni, 2009) and successful industrial clusters (Bresnahan and Gambardella, 2004; Phillips et al., 2016), support the need for regional tailored innovation policies (Cooke, 2001; Tödtling and Trippl, 2005).

Within the *knowledge* realm, research (both basic and applied) is an important prerequisite for innovation (Rosenberg 1990; Pavitt 1991). Hence, increasing the competitiveness of the scientific base yields steady flows of new knowledge and skilled personnel in the economy (Laursen and Salter, 2005). Likewise, applied knowledge in the form of R&D investments or intellectual property (i.e., patents, trademarks) is a major contributor to international competitiveness as reflected in productivity dynamics (Mohnen and Hall, 2013) and export performance (Cassiman and Golovko, 2010). Together, knowledge from basic and applied science serves as an engine for domestic innovation conferring countries/regions a competitive STI advantage. The extent of this advantage is moderated by different technological regimes that affect the knowledge base and potential opportunities for development of new technologies (Pavitt, 1991; Breschi and Malerba, 2001).

Further downstream, within the *economic* realm, innovation in the form of new technologies and knowledge is responsible for greater productivity (Hall and Jones, 1999) and export performance (Dosi et al., 1990) of firms, regions and nations. In addition to these well-established links, entrepreneurship plays a key role in linking knowledge-creation with knowledge-exploitation domains through several mechanisms: (i) identify and often create new lucrative commercial opportunities to exploit existing innovations (Shane, 2003, Dew et al., 2004); (ii) facilitate the transmission of knowledge from scientific to economic actors (Mosey and Wright, 2007; Franzoni and Lissoni, 2010) (iii) serve as intermediaries for fruitful collaborations between STI actors (Radosevic 2010) and (iv) set-off the forces of "creative destruction" that favour radical innovators (Baumol, 2002).

Finally, turning to *policy* options, the complexity of these ecosystems mandates a balanced policy mix that addresses systemic but also regional issues. Hence, systemic instruments have been widely used in the past to stimulate entire innovation systems and tackle contingent problems (Wieczorek and Hekkert, 2012). These tools improve systemic effectiveness in a horizontal fashion, dealing with actors, institutions, compatibility, and infrastructure issues through institutional responses (Wieczorek et al., 2012) or increased involvement of actors (van Mierlo et al, 2010). Complementary, regional/sectoral innovation policies that focus on the vertical dimension seek to impact actors across multiple contexts and areas of specialization with a competitive advantage. Among them, *Smart Specialization* (SS) is a relatively recent, yet popular, innovation-driven strategy that focuses on existing regional strengths (Foray et al., 2011).

Part of Europe 2020, SS is already a premiere innovation policy in the European Union, and a prerequisite for accessing much-needed structural funds in the period 2014-2020 (Foray et al., 2011; RIS3 Guide, 2012; McCann and Ortega-Argiles, 2013). The SS concept rests on two fundamental ideas: 1) regions should focus on few areas where they have a significant impact (*specialization*) and 2) these domains of specialization should make use of existing strengths (*smart*) such as location, resources, or STI capabilities. A significant difference between SS and other policies is the active role of entrepreneurs in discovering new domains for innovation. Although foreseen as a regional strategy, national governments still have an important role in SS (Foray et al., 2009), by managing many macro-aspects of innovation systems (e.g., upgrade STI infrastructure, incentivize entrepreneurs, provide policy support, or invest in complementary assets such as education of training programs) to support regional SS endeavors.

Despite its simplicity and bottom-up appeal, which distinguishes it from prior innovation policies, SS cannot operate outside the many challenges of the innovation paradigm described by prior studies (e.g., lack of incentives, funds, conducive environments and institutions). Moreover, some of these challenges will be more salient for less-developed countries than for their more developed counterparts. Given its mandate and envisioned tools (e.g., entrepreneurial discovery, regional strengths, sustainable strategies), I argue that SS can provide a critical function in the broader systems of innovation, by focusing innovative capacity on few strategic areas, and sustaining competitiveness through commercial success[2]. As a result, SS will play an important role in the policy domain, namely that of transferring competitive advantage from the knowledge context (innovation, basic and applied science, etc.) to the economic one (income levels, exports, productivity, etc.), thereby providing entrepreneurs with new opportunities to capitalize on existing or future STI assets. This could also lead to a minor overlap between systemic and SS policies in the knowledge realm; however, the levels, aims, and tools employed by these two types of policy interventions remain very different. Lastly, a well-functioning SS depends on national policies and strategies to support and coordinate all these actors, especially when regional autonomy is limited and STI capabilities are weak (Healy, 2016; Bröchler and Kalentzis, 2017). Thus, for less-developed countries, this symbiosis backs the idea of a concerted policy mix across different levels of governance to implement and achieve SS in a much more heterogeneous regional context.

Overall, **Figure 1** synthesizes these insights and emphasizes the role of innovation systems in supporting and determining the competitive position of regions, industries and countries within the global economy. Moreover, it documents a complex web of interactions between these systems, like vertical linkages, entrepreneurial dynamics and technological regimes. Thus, the quality of the innovation system (either national, regional or sectoral) is an important contributor to the creation and sustainability of comparative advantage in STI, and subsequently to production and export patterns.

3. ANALYTIC ROADMAP

Building on the aforementioned ideas, I propose a diagnostic tool that incorporates both systemic STI issues and SS-specifics, with the ultimate goal of spurring competitiveness in less-developed regions/countries. This tool employs a series of quantitative and qualitative analyses as described in **Table 1**.

---Insert Table 1 here---

[2] In Porter's model all four main determinants of competitiveness (firm strategy, structure and rivalry; demand conditions; supporting industries; factor conditions) are subject to governmental policy stimuli.

The first step involves an in-depth analysis of exports to assess the competitive position of a country in the global economy. This will involve using export data at the product/industry level from UN Comtrade and national statistics to select several potential SS candidates based on their current performance and potential for future exports. The second step involves an analysis of domestic and foreign knowledge (applied and basic research, as reflected by international patent data from USPTO and EPO, and respectively, bibliometric databases from Web of Science), and its contribution to the success of potential SS candidates (using science-industry and patent-industry concordance tables). Finally, the third stage will focus on examining these potential candidates from a core SS-perspective (i.e., entrepreneurial involvement, regional spread, future strategic options). The exercise will be concluded with an identification of several policy measures that will include both horizontal (national-systemic) and vertical (region-sector) measures to address salient innovation challenges in less-developed contexts.

4. A PRACTICAL EXAMPLE: SS OPPORTUNITIES FOR BULGARIA

To exemplify the feasibility of this tool, I apply this type of analysis in the case of Bulgaria, a laggard within the EU in both STI and economic terms[3]. However, such an analysis can be easily replicated for other developing economies. Throughout the analyses described in **Table 1**, I will use a reference group of six countries to benchmark Bulgarian performance internationally. These six countries provide a balanced mix of advanced EU economies (i.e., Finland and Italy), similar neighboring countries (i.e., Romania, Croatia and Hungary) and other non-EU, fast-growing economies (i.e., Turkey).

4.1 ECONOMIC CONTEXT

Exports represent a crucial component of the Bulgarian economy (i.e. nearly 60% of its current GDP), with significant increases, even in the aftermath of the recent global crisis (26% in 2011). Despite this performance, Bulgaria remains in the middle of the Eastern European pack, behind

[3] Due to inherent space constraints, the full results of this analysis cannot be presented in this paper.

regional export champions like Hungary[4]. To assess more accurately its international competitiveness, next I will examine its export performance at 2 and 4-digit product level.

Figure 2 presents the Bulgarian export performance of its 15 leading products at 2-digit level in the last decade. The two axes (X-change in the world market share, and Y-annual growth between 2001 and 2011 of all exports) yield four quadrants that characterize the evolution of Bulgarian exports vis-à-vis to the world[5]. We can see that not many products can be labelled as "***Champions***" (only 3 products, compared to 6 before the 2009 crisis), and moreover that their relative contribution to the total export basket is small. The biggest concentration remains, similarly to the pre-crisis period (2009) is in the "***Achievers***" area, where we can find several product groups with higher technological content, i.e., pharmaceuticals, machinery, electrical equipment and chemical intermediates. These sectors have a good chance of becoming export champions in the future, if they benefit from can improve their competitive position, and SS strategies may provide an important boost by providing more focus at the regional level.

-------------Insert Figure 2 here -----------------------

Besides the sheer volume of manufactured exports, I also examine their price- and quality-performance by computing three indicators of quality and sophistication: the *unit value distance* (UVD), product *sophistication levels* (PRODY), and sophistication of the whole export basket of Bulgaria (EXPY), using 4-digit product level export data from UN-Comtrade. These indicators provide additional evidence on how competitive Bulgarian exports are within these niches against international competitors, and are a good predictor for future economic performance (Hausmann and Klinger, 2008). The computational details of these measures are described in **Appendix A1**. Overall, the *unit value distance* reveals that Bulgaria's export basket has made little progress over the past decades (i.e. ranking 71th in 1990, 86th in 2000 and 69th in 2011), as opposed to Hungary or Turkey. Likewise, its EXPY has experienced moderate improvements

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[4] In 2008, Bulgaria had US$3,958 exports per capita, higher than Romania (US$2,781) and Turkey (US$2,378), but below Croatia (US$6,553), Hungary (US$12,549), Italy (US$11,100) or Finland (US$22,664).

[5] The upper-right quadrant (***Champions***) includes top Bulgarian products that enjoy fast growth in world markets. Products in the ***Underachievers*** quadrant exhibit high demand worldwide but Bulgaria underperforms here vis-à-vis the rest of the world and steadily losing market share. Products with dim perspectives for future exports are clustered in the ***Declining*** quadrant while products in the lower-right quadrant (***Achievers)*** are gaining world market share but have not yet seen stellar export growth.

over this time that is in line with Turkey, Romania or Serbia, but below Central European nations and global top-exporters. In fact, only six of its top 15 exports have sophistication levels above the global average supporting a high-sophistication "niche targeting" (i.e., electric current, copper and derivatives). A possible cause for this export un-sophistication is the low share (3%) of high-tech exports, which substantially below the EU-27 average (16%) and signals weak STI systems. Even among their top ten exported goods, only electrical equipment and boilers and machinery possess a high-tech component[6]. This trend has accentuated in the post-crisis period (the overall share of high-tech exports has decreased to 2.59%), raising further doubts on the sustainability of Bulgarian exports.

In terms of service exports, unavailability of such detailed data prevents us from carrying a similar analysis. Overall, according to the IMF statistics, Bulgaria has exported $7,489 million in 2011, in the vicinity of its pre-crisis peak of 2008 ($7,942 mil.), representing about a third of the value of manufactured goods ($28,165 mil.). The export ***Champion*** in services remains Information and Communication Technology (ICT), which is responsible for about 20% of the total services exported in 2011, compared to 12.5% in 2005. ICT is an export-oriented industry (about 60% of its revenues comes from exports) characterized by rapid growth, productivity increases and adaptability to the new market conditions. Many Bulgarian firms are not only outsourcing IT services, but also producing their own items and services, which are successfully traded on the biggest world markets (i.e., EU and USA).

4.2 KNOWLEDGE CONTEXT

4.2.1 Competitiveness of applied research

To assess the competitiveness of applied research, I employ international *patent statistics*, focusing on "new-to-the-world" knowledge (Acs et al., 2002), as reflected by patents granted in the USA (USPTO) and Europe (EPO). To further test the robustness of my conclusions, I also employ data from the Bulgarian patent office (BPO) as a measure of "new-to-the-market" knowledge[7]. Regardless of the measure employed, Bulgaria exhibits a weak track record in terms

[6] Aerospace, computers, office machinery, electronics, instruments, pharmaceuticals, electrical machinery and armament are considered high-technology sectors.

[7] The latter provides a broader picture of the technologies that are developed in the Bulgarian economy, however, national patenting rates tend to be noisier measures and not suitable for cross-country comparisons.

of patenting (averaging 0.85 US patents per million inhabitants), surpassing Romania (0.24) and Turkey (0.19), but below advanced transition countries such as Hungary (5.16) and Croatia (3.08) and Western European nations (Italy, 27.81; Finland, 137.11).

-------------Insert Figure 3 here -----------------------

When looking in more depth at the Bulgarian USPTO patents, three important trends stand out. First, Bulgaria develops much less commercially viable innovations than it did in the past. **Figure 4** reveals a massive drop in the traditional patenting fields (mechanical, electrical and electronics, chemical) driven by lower investments and lack of technological upgrades (Krammer, 2009). However, the last five years show a positive upturn, with new patents coming from high-tech industries (e.g., communication and navigation technology, data processing, computers, software and memory) driven by R&D efforts of several multinational firms (MNEs)[8]. Second, Bulgarian commercial innovations appear to have benefitted from rapid internationalization. Prior to 1990 almost all patents were the results of "all Bulgarian" teams of inventors coming from large public R&D institutes (Radosevic, 1999). Today international co-inventions (mostly with Western Europe) account for more than half of the country's patents at USPTO, mirroring similar trends in the region (Goldberg et al., 2008). Finally, I examine the potential contribution of applied science to the proposed SS candidates using the concordance tables developed by Schmoch et al. (2003). Overall, the results indicate mismatches in most areas of relative strength, with few exceptions that may be propitious for future SS strategies (**Table 3,** Column 5): ICT, communications, computer components, firearms, and medical products. In contrast, most export performers (e.g., Minerals, Oils, Food, Chemicals, and Pharmaceuticals) appear to lack strong technological competences to further boost their international competitiveness. This finding further supports the need for systemic policies to ameliorate such mismatches.

4.2.2 Competitiveness of basic research

To capture competitiveness of scientific research, I compute several bibliometric indicators using data from *Web of Science*, *Essential Science Indicators* and *Scopus* (Elsevier). Overall, the

[8] Patents granted to Bulgarian inventors declined substantially post-1990, but have seen resurgence thanks to SAP labs, a German IT company.

scientific production has proven to be more resilient than patenting of new technologies, but still insufficient for Bulgaria to retain its pre-1990 position relative to peers. On per capita basis, Bulgaria's scientific production is on a par with Romania, Turkey and Croatia but behind Western (Finland and Italy) and Central Europe (Croatia and Hungary)[9]. In fact, the growth rate of Bulgarian publications is lower than the world's average, and consequently Bulgaria's share of the world publications has decreased from 0.19 (1996) to 0.14 percent (2009).

In terms of strengths, science and engineering remain some of the main sources of international publications. Bulgaria does well in Physics (Optics, Applied, Condensed Matter and Multidisciplinary), Chemistry and Engineering (Materials Science, Electrical and Electronics), but its scientific impact in these core-areas is still dimming. As a result, Bulgaria has currently no scientific area of excellence at the world-level (**Figure 4),** and exhibits an average H-index[10]: Bulgaria scores 97 between 1996 and 2009 (i.e. it has 97 papers with at least 97 citations in this interval), similar to Romania and Croatia, but again, below Turkey, Hungary or Poland.

-------------Insert Figure 4 here -----------------------

A positive development is the increased scientific collaborations between Bulgarian researchers and peers from other EU countries, USA, and Russia[11], which could increase knowledge flows and visibility in the global research arena (Figg et al. 2006; Inzelt et al. 2009). Nevertheless, Bulgaria's specialization in terms of basic science does not seem to be particularly supportive of its priorities stemming from its export profile (**Table 3**). Particularly, its resource-intensive sectors (e.g., Minerals, Oils, Food, etc.) seem to lack domestic knowledge in Engineering, Metallurgy and Food sciences (Laursen and Salter, 2005). Nevertheless, some of the "Achievers" are well represented (Pharmacology, Medical Equipment, Telecommunications, and Electronics), recommending these sectors (i.e., Pharmaceutical, ICT, Electronics) as favorites for SS strategies.

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[9] Its global share of scientific publications is 0.14%, similar to Romania (0.22%) and Croatia (0.18%), but behind bigger countries (Turkey- 1.17%, Italy - 3.27%) or more prolific ones (Hungary -0.38%, Finland -0.65%).

[10] This measure was developed by Jorge Hirsch, and equals h if a country publishes h papers each of which has been cited by others at least h times in the considered time frame.

[11] The overall share of co-authored publications with foreign scientists has increased tremendously, from 16% in the communist era, to 35% in the 1990s, and over 50% in the present.

4.3 POLICY CONTEXT

This section examines some of the core-rationales of smart-specialization (i.e., entrepreneurial discovery, regional characteristics and strategic nature) in the context of the 5 proposed priority areas identified by the diagnoses of Bulgarian economic and STI environment.

4.3.2 Entrepreneurial landscape

First, in terms of SMEs (small and medium enterprises) the Bulgarian landscape roughly mirrors the EU average (99.8% of firms are SMEs with less than 250 employees). Yet, it accounts for more jobs (76%) and value-added (62%) than the EU (68% and respectively, 58%). Bulgarian SMEs are more active in trade (as opposed to services) than the European average (46% versus 30%) although the low share of employment (33%) and value-added (27%) suggests lower productivity and lack of economies of scale. This conjecture is supported by the higher percentage of SMEs active in low-tech industries (31%) as opposed to the EU average (24%). Most SMEs are found in Services such as Retail (10,601), Real Estate (1,985), Hotels (1,799) and Transport, ICT and Communication (1,456), while Manufacturing and Construction account for only 15% of the new firm creation in the economy (Eurostat).

Entrepreneurship appears to be of peripheral importance to economic activities in Bulgaria, and the existing institutional framework does not favor such endeavors, posing high entry costs and various bureaucratic barriers (SBA Factsheet). Bulgarian entrepreneurs are much less likely to start up a business in order to exploit existing opportunities (38%) than their Western European peers (50%). Despite some advancement in few areas (e.g., the cost and time to start a business and transfer property) the regulatory framework requires improvement[12]. Finally, three areas (Innovation and skills, Environmental activities, and International expansion) are clearly the weak points of the Bulgarian entrepreneurs, as reflected by consistently lower than the European average scores in these areas. Together these trends diminish significantly the effectiveness of a SS strategy in any Bulgarian region.

[12] For example, closing a business in Bulgaria takes more than three years as opposed to two years in the EU, and the burden of tax handling is more than double (500 hrs.) to that of the EU (206 hrs.).

4.3.3 Regional strengths

Second, a core-principle of SS is its regional, rather than national, orientation (Foray et al., 2009). To assess the regional strengths and weaknesses of the proposed areas for SS, I map their regional distribution using employment data across the six NUTS-2 regions in Bulgaria, and present a regional mapping that covers the three growth principles (smart, sustainable and inclusive) of SS (see **Figure 5**)[13]. In terms of regional distribution of SS candidates, Copper and Iron are predominantly present in the South East and South West regions (66%), Machinery, Electronics and Vehicles in the North Central and South East (47%), while ICT (57%) and Pharmaceuticals (82%) are heavily concentrated in the South West region, which includes the capital (Sofia). As expected, the Food processing sector is more balanced across all regions, with a greater concentration however, in South Central (34%) and South West (27%).

-------------Insert Figure 5 here -----------------------

Moreover, there is great regional heterogeneity in terms of STI capabilities, population demographics and industrial characteristics (**Figure 5**). According to the latest Regional Innovation Scoreboard, only South West and South Central regions qualify for a Modest-medium ranking, while the other four regions are all in the lowest (Modest-low) innovation tier of European regions. Only the South West region qualifies as knowledge-driven, given its high concentration of universities, research institutes and high-tech industries (Pharma and ICT); South-East and South-Central fit best in the Industrial production category, while the rest are characterized by agricultural and resource extraction activities. Overall, these require very heterogeneous SS strategies for these regions, and implicitly, a significant degree of autonomy.

4.3.4 Strategic evaluation of existing options

Lastly, SS relies heavily on strategic forward-looking orientation. To map strategic options for all SS candidate areas, I carry out a SWOT exercise (see **Table 2**) that draws on the previously employed data on exports and STI, complemented with regional data (Eurostat SBS), firm–level

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[13] According to the latter, regions can be broadly classified according to their smart status (STI or non-STI driven), sustainability (rural/urban/coastal) and the evolution of population (growing or declining; migratory inflows or outflows).

data (World Bank Enterprise Surveys), and qualitative assessments from reputable sources (World Bank 2012a, and 2012b; AT Kearney, 2011).

---Insert Table 2 here---

In terms of strengths, the proposed SS candidates benefit from higher-than-average FDI inflows, a relatively strong but outdated scientific base, and diversified export markets that balance both developed (EU) countries and high-growth emerging ones (Middle East, CIS countries). However, there is little evidence that SS strategies are already in place, the two exceptions being Machinery, Electronics and Vehicles where there is a leaping strategy in place towards higher value-added related products, and ICT where significant R&D efforts from MNEs can contribute significantly to the rise of a globally-relevant IT cluster in Bulgaria. Most weaknesses point out to structural (e.g. low R&D intensity) and systemic issues (i.e., lack of linkages between STI actors; lack of qualified human capital) that are specific to former communist economies. There are also some indications for significant opportunities from technological upgrades (via transfers or spillovers) and related diversification (into upper value-added products) that would further strengthen the Bulgarian competitive position in these areas. However, most of these sectors are also vulnerable to a variety of threats, ranging from dependence on global commodity prices to increased competition from Asia and loss of human capital ("brain drain") in key areas.

4.3.5 Policy recommendations: a first take on SS in the Bulgarian context

In terms of policy prescriptions SS relies on four core concepts (4Cs), namely competitive advantage, priority areas, critical mass, and collaboration between STI actors and businesses (RIS, 2012). Subscribing to these priorities, these results convey several policy recommendations for Bulgaria following its specific needs identified in the diagnostic analysis. These include actions to invigorate all three areas of knowledge (creation, diffusion and exploitation) by combining traditional with experimental measures (OECD, 2011). Moreover, these measures exhibit both a horizontal (national-systemic) and a vertical (regional-sector) dynamic, as envisioned in **Figure 1**, and denoted below as [NS] and respectively [RS].

<u>Copper and Iron</u> (Regions: South West, South Central, South East)

- Stimulate (via research or product development grants) diversification into related products for exports with higher value-added and cross-fertilization with other identified SS candidates (e.g., alloys for electrical equipment, transport or medical use) [NS, RS]
- Support local innovation (via incentive schemes for domestic R&D) and technological upgrades (via licensing of foreign technologies) [RS]
- Provide financial support for small experimental innovation projects of SMEs [RS]
- Retain and upgrade the existing human resources in the industry through investments in vocational training, lifelong learning courses, and other talent attraction schemes [RS]
- Create knowledge centers in metallurgy and link them with existing research institutes to reduce the mismatch between basic and applied science in this domain [NS]

<u>Food</u> (Regions: South West, South Central)

- Finance through low-rate loans external technology upgrades for the production process [RS]
- Reduce fragmentation of the supply chains via industrial policies [NS]
- Connect different STI in this sector through a set of incubators targeting promising market niches (e.g., wine, dairy, organics) [RS]
- Improve the ability of firms and other STI actors to absorb EU-funds for R&D by providing free or subsidized training and consultancy on grant writing and application [NS, RS]
- Support connections to international production networks via regional agencies for business development [RS]
- Introduce innovation and entrepreneurship courses in the agricultural education curriculum [NS, RS]

<u>Machinery, Electronics and Vehicles</u> (Regions: North Central, South East)

- Improve the availability of skilled human capital (incentive for more S&E graduates, upgrade education curriculum to international standards) [NS]
- Support R&D efforts in new promising niches (e.g., mechatronics, precision hydraulics, automotive components) that could tap more easily into export markets [NS, RS]

- Stimulate collaborations and technology transfer between universities and private firms through nationally-financed programs [NS]
- Increase public procurement for domestic niche-products [NS, RS]

Pharmaceuticals (Regions: South West, South Central)

- Streamline the approvals process for generic drugs in the domestic market [NS]
- Stimulate collaboration between firms and universities through large competitive grants [NS]
- Provide incentives for MNEs to open R&D centers that focus on new drug development [NS]
- Stop / reverse the brain drain of medical personnel though various incentive schemes (e.g., tax breaks, other non-monetary benefits) [NS]

ICT (Regions: South West)

- Improve the availability and skillset of existing human resources (develop more ICT programs; focus on applied/niche ICT education) [NS]
- Reduce and reverse the brain drain of IT professionals (e.g., tax breaks, non-monetary benefits, scholarships, grants for research) [NS]
- Streamline the regulatory framework for ICT companies (special fast-track for spin-offs and entrepreneurs) [NS, RS]
- Provide competitive funding for development of support technologies through co-invention of IT related applications to other SS candidates (e.g. Food, Electronics, etc.) [NS, RS]
- Support collaboration and technology transfer between domestic firms and MNEs [NS]
- Improve infrastructure (broadband) and incentives (tax breaks, regional support) for a more balanced distribution of ICT activities across regions [NS, RS]
- Support entrepreneurship and university spin-offs (business-plan competitions, venture capital incentives, courses in entrepreneurship) [NS, RS]

These recommendations provide a sound baseline for SS in Bulgaria, and cover several high and low-tech niches that have emerged from prior analyses. These recommendations can be further enriched via cross-fertilization (e.g., application of ICT to Food or Machinery sector), regional redistribution (towards South-East which lacks s strong STI and industrial base), or related diversification strategies (e.g., food and wine-based tourism) through consultations with regional stakeholders. Lastly, there is a stringent need for coordination at the national level to identify the areas of competitive advantage and maximize the SS benefits by harmonizing regional and national responses.

5. CONCLUSIONS, LIMITATIONS AND FUTURE AGENDA

Smart specialization is a recent innovation policy that has rapidly gained traction in the European space as the avenue to increase competitiveness of European countries and regions. The concept comes with a significantly different approach (i.e., regional orientation, bottom-up focus, entrepreneurial discovery) than previous waves of innovation policies. Yet, these very elements are also some its most notable weaknesses, especially in less-developed countries and regions. These environments provide a far-less-than-ideal setting for implementing SS by suffering from low entrepreneurship rates (Carre and Thurik, 2008), weak systems of innovation (Krammer, 2009), limited technological opportunities (Krammer, 2016), significant institutional heterogeneity (Krammer, 2015a), lack of significant regional autonomy (Charles et al., 2012) and market-driven clusters (Bröchler and Kalentzis, 2017). Together, all these issues raise significant concerns regarding the successful implementation of SS strategies for such "laggard" regions or countries, particularly when targeting techno-economic development (Phillips et al., 2016).

Focusing on these limitations, this study starts with the idea that, although SS remains a regional, bottom-up approach, the national contexts remains equally important in the context of less-developed countries. As such, combining elements from several literatures (innovation systems, evolutionary economics, export-led growth), I discuss a conceptual approach that distills the role of SS in the greater innovation-growth nexus, as a mechanism to better translate competitive advantage from the STI domain to the economic one. Subsequently, I propose an analytical tool for policy makers to identify fruitful areas for SS, which can be easily implemented as a first-stage diagnostic of the SS process, following the steps described in Table 1. Finally, I exemplify the use of this diagnostic tool in the case of Bulgaria, a laggard in economic and innovative terms within the EU, and a country with significant regional disparities. The results of these analyses may serve as inputs for policy corrections, which target region-sector issues in the spirit of the SS concept, as well as systemic STI and economic problems.

Overall, the Bulgarian case fit well with some of the SS fallacies foreseen by prior work in the innovation literature. Specifically, the driving forces of SS (i.e., entrepreneurial activities and regional strength) are not sufficiently developed in Bulgaria. Thus, most entrepreneurial endeavors are driven by necessity rather than business opportunities, face significant institutional barriers, and are highly skewed towards domestic activities (e.g., financial intermediation, real estate, wholesale and retail) with limited potential to contribute to the international competitiveness of the country. Moreover, Bulgaria exhibits several important regional STI and industrial disparities (e.g., the highest concentration is in the Southern regions, which include the capital, Sofia) and suffers from systemic deficiencies that impede its overall development. With few exceptions, the contribution of domestic knowledge base to economic outcomes has been consistently decreasing, and access to external knowledge has been rather limited. In turn, this triggered a prolonged decay of international competitiveness.

Using the proposed diagnostic tool, I identify and analyze five candidate areas for SS (Copper and Iron, Food, Machinery, Electrical Equipment and Vehicles, Pharmaceuticals and ICT) that show potential for benefitting from STI links and align well with the smart, sustainable and inclusive growth principles of the SS. Interestingly, all these priority areas (except one) are also found in the recent S3 agenda for Bulgaria (http://s3platform.jrc.ec.europa.eu/regions/BG) finalized in 2015[14], which supports the feasibility of the proposed SS diagnostics tool. Finally, both theoretical and empirical considerations recommend a multi-level mix of SS (region-sector) and systemic (national) instruments as best for dealing with Bulgaria's complex challenges in the economic and STI domain (Krammer, 2015b).

While this study proposes several contributions to the literature on national and regional innovation policy, it is not exempt from limitations. First, it focuses only on exports as a valid representation of international competitiveness, while in reality the competitive landscape can encompasses other different factors, such as human capital, investment climate, institutions, productivity, foreign investments, etc. On the other hand, incorporating too many dimensions (e.g. employing aggregated competitiveness indexes a la IMD, WEF) can diminish dramatically the effectiveness of policy prescriptions for an SS exercise. Second, due to limitations of export data in the UN Comtrade database, the analysis does not include a similar in-depth examination

[14] The identified priority areas are: ICT, Biotechnology, Machinery (Mechatronics and Clean Technologies) and Creative industries.

of the service sectors. To overcome this issue in the Bulgarian example, I have examined its service exports from available national statistics. However, availability of this data is rather limited. Third, the assessment of STI competitiveness relies heavily on patent and bibliometric indicators. While these metrics are widely employed in the literature, they also suffer from well-known limitations that have been discussed by the extant literature. Finally, past lessons in terms of innovation policy suggest that there is a complex trade-off between diversification (traditional) and specialization (cluster-based) strategies (Phillips et al., 2016). As a result, even when applied properly, SS can only offer transitory advantages to a region in terms of competitiveness. Maintaining and expanding these advantages would require an increasing reliance on entrepreneurial discovery, complemented by significant policy flexibility at the regional level. Thus, current efforts in less developed countries to spur SS strategies should account for more long-term dynamic objectives in terms of creating such capabilities.

Given these caveats, future extensions may want to consider different or additional economic objectives (e.g., productivity or FDI) as basis for selection of SS candidates, testing empirically these assertions. Moreover, it would be equally interesting to apply this diagnostic tool to a developed economy with strong STI and economic clusters, and assess its potential to contribute to the SS debate in the context of developed, well-functioning economies with strong regions. Another interesting addendum, if data permits, would employ detailed service export data and develop concordance tables with contribution of different scientific fields to the productivity of these service sectors. This would greatly enhance our understanding of knowledge-driven service economies, and provide additional avenues for spurring SS (e.g., Bulgarian firms specializing in ICT technical service to German customers by combining strong linguistic and ICT skills in tailored educational programs).

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Table 1. Analytic roadmap

Context	Issue	Questions	Diagnostic tools	Objectives	Data sources
ECONOMIC	Competitivenness of exports	1. What is the general evolution of exports? (over time, vis-a-vis other countries)	a. Exports per capita; Comparisons with benchmark countries; Temporal dynamic analyses	1. Provide an overview of competitive position of exports	UN COMTRADE
		2. What are the most successful export products and how competitive are they?	b. Export competitiveness analysis		
		3. What are the opportunities for these products (sustainability)?	c. Qualitative assessments	2. Identify potential candidates for SS	
		4. What are the reasons for this success/failure of export products?	d. Export sophistication; Technological content; Unit value gaps;		
KNOWLEDGE	Competitiveness of applied research	5. What is the general evolution of applied research? (over time, vis-a-vis other countries)	e. Patents per capita; Comparison with benchmark countries; Temporal analysis.	3. Identify the competitive position of applied and basic science	USPTO; EPO ; National Patent Office; SCOPUS; ISI Web of Science; STI-Industry Concordance tables
		6. What are the most successful areas of applied research and who leads them?	f. Breakdown of patents by technological classes and assignees		
		7. What are the foreign sources of applied research?	g. Co-inventions; Domestic and international patenting by foreign entities		
	Competitiveness of basic research	8. What is the general evolution of basic research? (over time, vis-a-vis other countries)	h. Scientific publications per capita; Comparison with benchmark countries; Temporal analysis.	4. Examine the contribution of applied and basic science to the candidates for SS	
		9. What are the most successful areas of basic research and who leads them?	i. Breakdown of scientific publications by field and institutional ownership; Specialization index; Relative scientific impact.		
		10. What are the foreign sources of basic research?	j. Co-authored publications with foreign scholars		
SYSTEMIC	Systemic effectiveness	11. Actors?	k. Qualitative/Quantitative assesments of the barriers to produce applied and basic science	Assess specific hurdles of the main STI actors	WB Enterprise surveys; Qualitative assessments of systemic issues (11-14)
		12. Institutions?	k. Qualitative/Quantitative assesments of the barriers to produce applied and basic science	Assess potential institutional frictions and bottlenecks	
		13. Interactions?	l. Networks/connections/fit between STI components	Map collaborations and main sources of knowledge	
		14. Infrastructure?	m. Transport and IT/communication	Assess the existing infrastrcture	
POLICY	SS agenda	11. What are the entrepreneurial dynamics and opportunities in the country?	n. Entrepreneurial activities, start-ups, success/failures, determinants, and business environment	5. Provide an overview of entrepreneurial activities and obstacles	Entrepreneurship surveys; National statistics; Eurostat; World Bank Enterprise Surveys; Community Innovation Surveys; Qualitative analyses based on interviews with stakeholders
		12. What is the regional distribution of the SS candidates?	n. Quantitative assessments based on employment and value-added	5. Map the regional distribution of the SS candidates	
		13. What are the strategic implications for the SS candidates?	o. SWOT analysis	6. Identify specific strategic issues for the SS candidates	
		14. What are the possible policy commitments?	p. Consulations with stakeholders	7. Set-up of short- and medium-term policy objectives	

Table 2. SWOT analysis of the proposed Bulgarian SS candidates

Strenghts	Weaknesses
Copper and Iron:	**Copper and Iron:**
- Good export performance	- Low R&D intensity
- Strong presence of MNEs (Germany, Canada)	- Slowdown in Construction sector (post-crisis)
	- Increase in environmental standards
Food processing:	**Food processing:**
- Access to major markets (CIS, EU)	- Low R&D intensity
- Strong research tradition	- Weak collaborations industry-academia
- Low labor costs	- Outdated technologies
Machinery, Electronics and Vehicles:	**Machinery, Electronics and Vehicles:**
- Good export presence (CIS, EU, Middle East)	- Insufficient skilled human capital (e.g. Science and Engineering graduates)
- Capacity to attract FDI	- Outdated educational curricula (S&E)
- Initial leaps into higher value-added segments (e.g. automotives, LED lighting, etc.)	- Low R&D intensity
Pharmaceuticals:	**Pharmaceuticals:**
- Strong exports of generics (EU, CIS, Middle East)	- Lack of national funds for R&D
- Strong research tradition	- Limited collaborations between firms and universities
- Good presence of MNEs	- Limited collaborations with foreign entities
ICT:	**ICT:**
- Good innovative performance (patents)	- Inneficient policies regarding IPR (intellectual property rights)
- Good presence of MNEs with local R&D centers	- Insufficient skilled human capital (e.g. IT graduates)
Opportunities	**Threats**
Copper and Iron:	**Copper and Iron:**
- Technology transfer potential from MNEs	- Diminishing supply (estimated for several decades)
- Move to related (e.g., reclamation, recycling) or higher value-added (e.g., alloys for antimicrobial, electrical or transport) segments	- Demand sensitivity to global prices and macroeconomic conditions
Food processing:	**Food processing:**
- Export-led growth (CIS, EU) as a result of technological upgrading	- Export competition (higher productivity in the EU- core markets)
- EU funding programs to target improvements (logistics, technologies, marketing)	- Inneficient supply chains
- New cluster opportunities (organic food and meat, wine, dairy) for niche exports	- Depopulation rural areas
Machinery, Electronics and Vehicles:	**Machinery, Electronics and Vehicles:**
- International partnerships with MNEs in selected niches (e.g. automotives, LED lighting, etc.)	- Increased competition from Asian firms
-Improve S&E training	- Increase in labor costs
Pharmaceuticals:	**Pharmaceuticals:**
- Increase export shares of generics to EU market	- Increased competition from Asian firms
- Incentivise MNEs to open up R&D centers which are not focused on generics	- Brain drain of qualified researchers (low salaries)
ICT:	**ICT:**
- Increase presence in major markets (EU, USA, China)	- Brain drain of qualified researchers (low salaries)
- Bulgarian E-government initiative	- Heavy reliance of foreign MNEs in terms of competitiveness
- Technology transfer potential from MNEs	
- High potential for niche-targeting based on competitive advantage (e.g., field of semantics)	

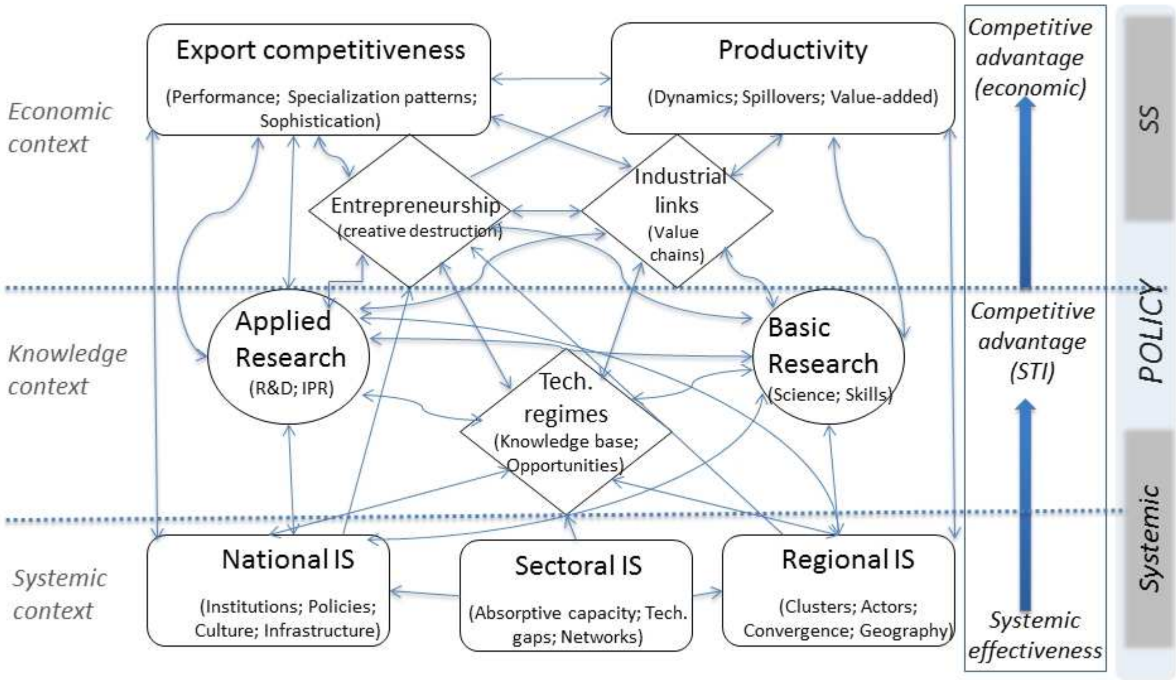
Top 20 Export Products (BG, 2001-2011)	Main scientific contributor	Top 20 Scientific Fields (BG, 2001-2010)	Main contributing tech fields	Top 20 Patent fields (BG, 2001-2010)
Mineral fuels, oils, distillation products, etc.	Geo- Petro- Mining Engineering	Pharmacy	Petroleum (59%)	Communications: Radio Wave Antennas
Copper and articles thereof	Materials Science and Engineering	Medical equipment and materials	Basic metals (34%)	DP: Database and File Management*
Nuclear reactors, boilers, machinery, etc.	Electrical engineering	Food, vine and tobacco industries	Energy machinery (14%)	Internal-Combustion Engines
Iron and steel	Metallurgy	Agriculture	Basic metals (34%)	Memory (Computers)
Electrical, electronic equipment	Physics	Human necessities, sport	Electronic distribution (23%)	Communications: Directive Radio Wave Systems
Apparel, accessories, not knit or crochet	Textile industry	Inorganic chemistry	Textiles (21%)	Firearms
Apparel, accessories, knit or crochet	Textile industry	Organic chemistry and biotechnology	Textiles (21%)	DP: Presentation Processing of Document etc.*
Cereals	Food Science/Nutrition	Transport	Food (67%)	DP: Software Development, Installation etc.*
Articles of iron or steel	Metallurgy	Textile & paper industry	Metal production (20%)	Drug, Bio-Affecting and Body Treating etc.
Oil seed, oleic fruits, grain, seed, fruit, etc.	Food Science/Nutrition	Construction industry	Food (67%)	Liquid Purification or Separation
Plastics and articles thereof	Inorganic and Nuclear Chemistry	Engines, hydraulics	Man-made fibers (21%)	Synthetic Resins or Natural Rubbers
Commodities not elsewhere specified	*NA*	General engineering	*NA*	Radiant Energy
Aluminum and articles thereof	Materials Science and Engineering	Lighting, heating	Mineral products (27%)	Chemistry: Electrical Current Producing Apparatus
Pharmaceutical products	Pharmacology and Toxicology	Weapons	Pharmaceutical (66%)	I/O (Computers and Systems) *
Furniture, lighting, signs, prefabricated buildings	*NA*	Measuring instruments, control and signaling	Consumer goods (55%)	Heat Exchange
Organic chemicals	Pharmacology and Toxicology	Optics, photography, X-ray and plasma equipment	Other chemicals (22%)	Prosthesis (i.e., Artificial Body Members)
Inorganic chemicals, precious metal compound, isotopes	Pharmacology and Toxicology	Computing*	Basic chemistry (43%)	Fishing, Trapping, and Vermin Destroying
Optical, photo, technical, medical, etc. apparatus	Electrical and Electronic Engineering	Telecommunications*	Measuring instruments (49%)	Power Plants
Tobacco and manufactured tobacco substitutes	Food Science/Nutrition	Electronics	Tobacco (72%)	Textiles: Knitting
Glass and glassware	Physics	Electrical engineering	Consumer goods (55%)	Clutches and Power-Stop Control

Table 3. Analyzing the congruity between science, technology (innovation) and economic (export) strengths of Bulgaria

Source: Rankings based on UN COMTRADE, ISI Thomson data; Concordance set using tables from Laursen and Salter (2005) and Schmoch et al. (2003). For column 4, the number in parentheses represents the share of technological fields within a given industrial sector (product, in this case).

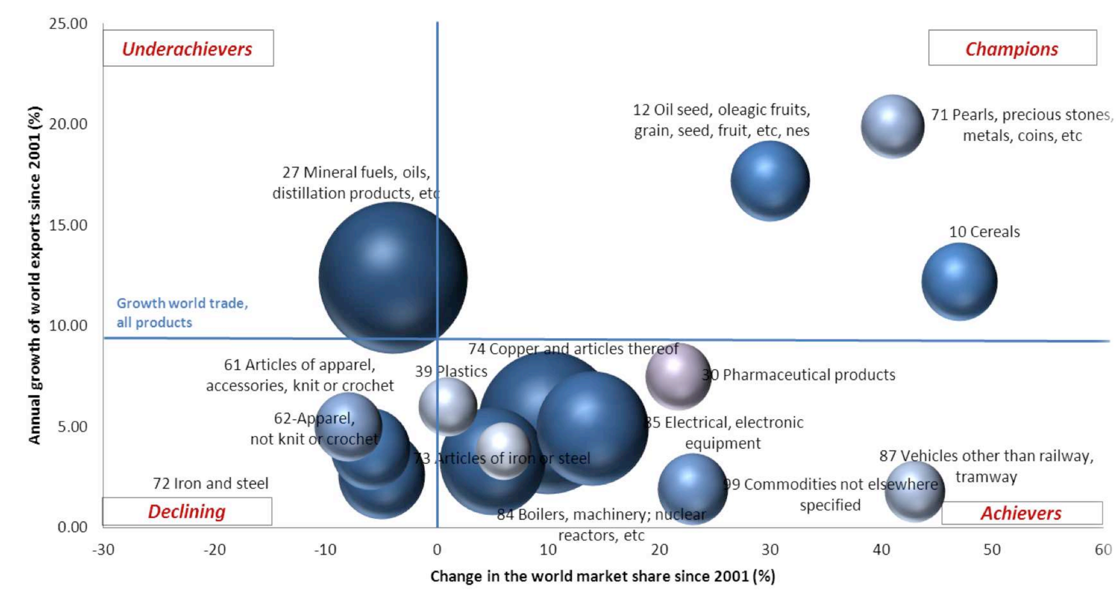
Note: Shaded cells show concordance between exports and technology (gray), and respectively, scientific strengths (yellow). Fields marked with * have been matched with *IT products* that are not represented UN COMTRADE data (e.g. not listed in Column 1 of this table but are top exports of Bulgaria).

Figure 1. Innovation systems and economic competitiveness: the role of Smart Specialization (SS)



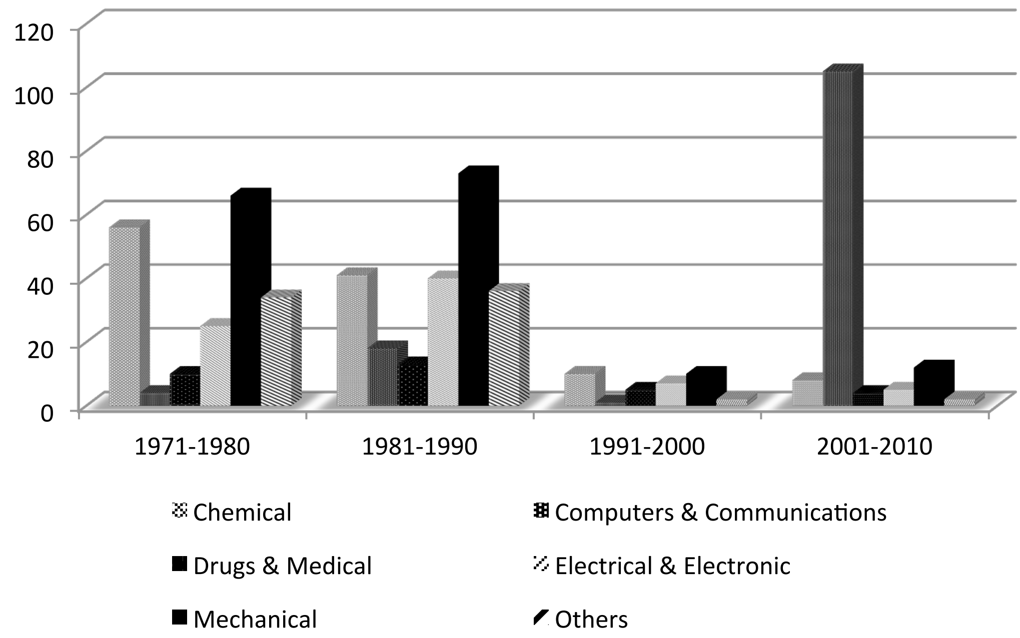
Note: IS refers to Innovation Systems; the length of the arrows and the position of different sub-systems do not proxy for relative closeness or distance between them. Adapted from Castellacci (2008a).

Figure 2. Dynamic profile of Bulgarian top 15 exports (2001-2011)



Source: Own calculations, based on data extracted from UN COMTRADE (http://comtrade.un.org/).
Note: The area of the circles corresponds to the exports in $US mil.; see Footnote 5 for a discussion of results.

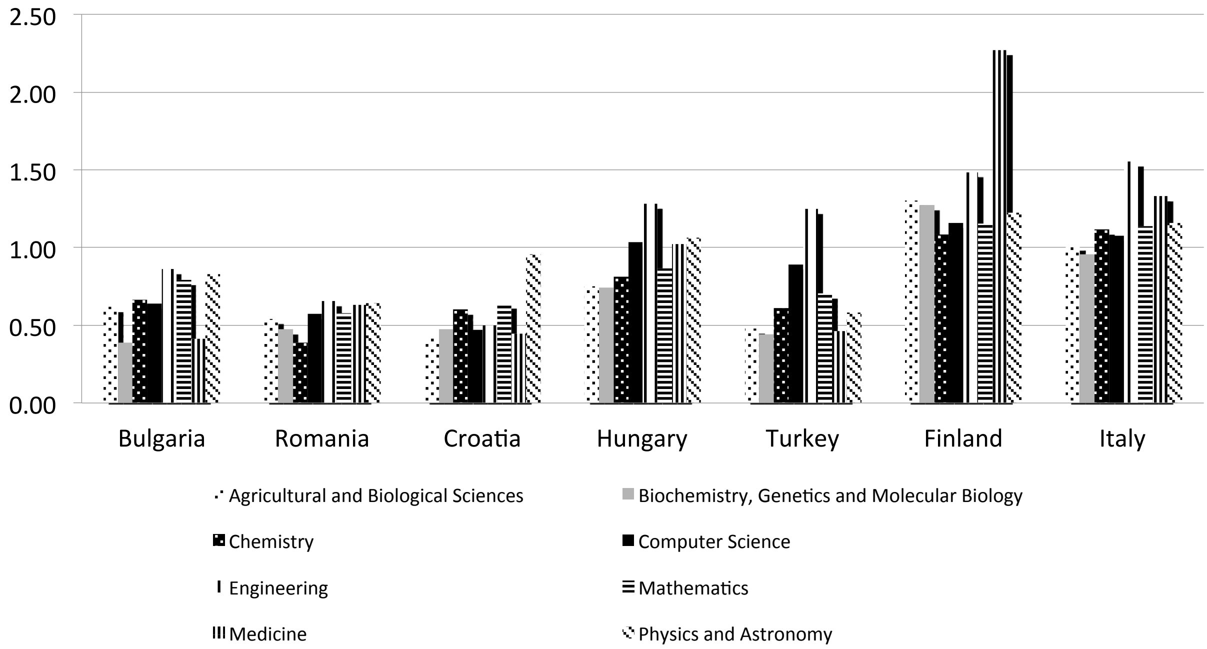
Figure 3. The number of Bulgarian patents granted at USPTO (1981-2010)



Source: Own calculations using the NBER (http://www.nber.org/patents/) and USPTO online patent (http://patft.uspto.gov/) databases

Note: These numbers refer exclusively to the inventions with a Bulgarian first-inventor.

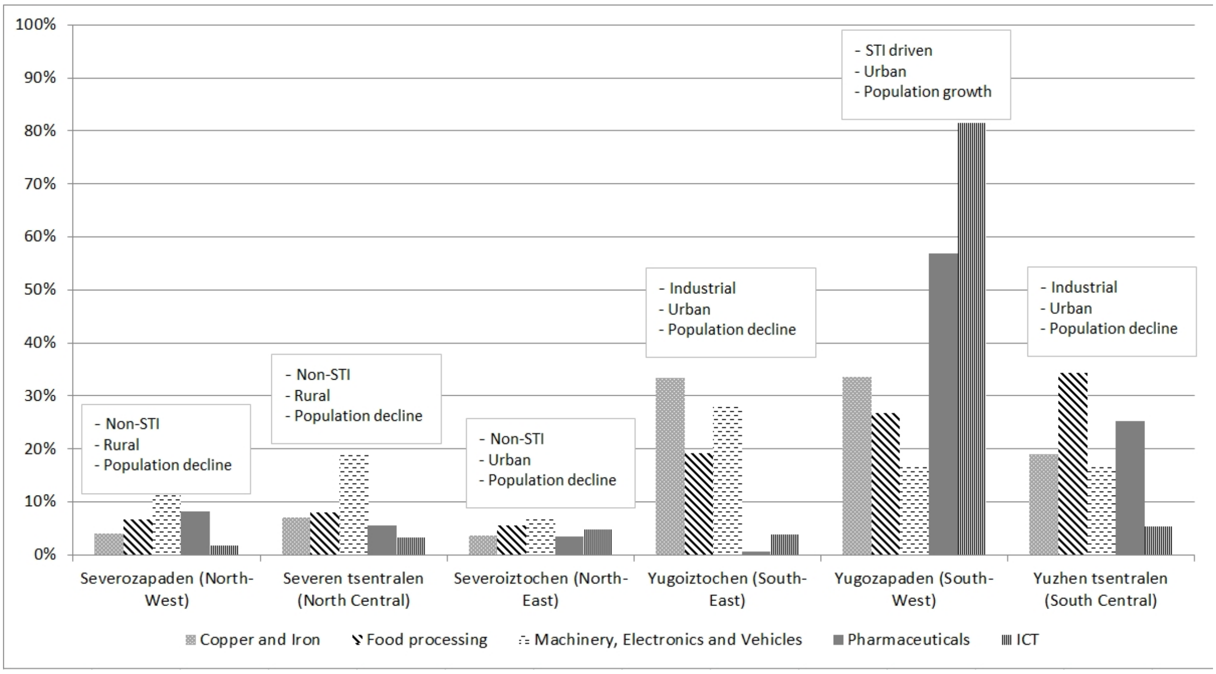
Figure 4. Relative impact index in selected disciplines for Bulgaria vis-à-vis selected benchmark countries



Source: Own calculations based on SCOPUS data (https://www.scopus.com/).

Note: The relative scientific impact index is computed as the ratio of the world share of citations for a country A between 1996 and 2009 to the world share of A's publications in a certain year. A value above 1 indicates that country A received more citations per paper (i.e., more "visible") than the world average.

Figure 5. Regional typology and regional distribution of the SS candidate areas



Source: Own calculations based on employment data from Eurostat SBS 2012 data by NUTS 2 regions and NACE Rev. 2 and the Bulgarian Institute for Statistics - (http://www.nsi.bg/index_en.htm.).
Note: The typology follows the guidelines of the RIS3 Guide (http://s3platform.jrc.ec.europa.eu/s3pguide)

APPENDIX

A1. Export sophistication indicators: computational details

The unit value distance (UVD) is computed as follows:

$$UVD_{c,t} = \sum_i \log(P\max_{i,t} - P_{i,t}) \frac{xval_{i,c,t}}{x_{c,t}}$$

where *c* refers to country, *t* is the time period, P_i is the price of product *i*, $P\max_{i,t}$ is the highest priced export for good *i* worldwide, *xval* and *X* are the total exports of *i*, and respectively of country *c*.
The sophistication measure for the whole export basket of the country (EXPY) equals the weighted average of the sophistication of each of its exported goods (PRODY):

$$PRODY_{i,t} = \sum_c \frac{xval_{i,c,t} / X_{c,t}}{\sum_j xval_{i,c,t} / X_{c,t}} * Y_{c,t}$$

$$EXPY_{c,t} = \sum_i (\frac{xval_{i,c,t}}{X_{c,t}}) PRODY_{i,t}$$

where $Y_{c,t}$ is the GDP per capita, $xval_{i,c,t} / X_{c,t}$ is the value-added share of the commodity in the country's overall export basket of a country *c*.