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Disentangling patterns of economic, technological and innovative specialization of Western economies: An assessment of the Varieties-of-Capitalism theory on comparative institutional advantages

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ABSTRACT

It is one of the central arguments of the Varieties-of-Capitalism (VoC) literature that national institutions determine comparative advantage. While Liberal Market Economies (LMEs) are said to offer comparative institutional advantages to firms that specialize in high-tech sectors based on radical innovation, Coordinated Market Economies (CMEs) offer advantages to firms specializing in medium-high-tech sectors characterized by incremental innovation. Several studies have tested these claims and arrived at contradictory results about specialization in line with institutional advantages. We argue that undifferentiated conceptualizations of the notion of specialization contribute to these inconclusive results. Based on the insights of the innovation literature on comparative advantage, we therefore disentangle the concepts of 1) economic specialization, 2) technological specialization, and 3) innovative specialization. Our analyses of panel data on exports and patents show that the VoC theory is rather weak in explaining patterns of economic specialization but can account for technological specialization. Furthermore, the VoC literature can hardly explain patterns of innovative specialization.

1. Introduction

Ever since the work of Ricardo (1821), the determinants of national comparative advantages have been subject of social science debate. Gradually, economic explanations of comparative advantage based on the production factors labour and capital (Heckscher, 1919; Ohlin, 1933; Vanek, 1968) have given way to accounts of institutions as determinants of comparative advantage (Freeman and Perez, 1988; Porter, 1990; Lundvall, 1992; Hall and Soskice, 2001). From a strategic management perspective, Porter (1990) showed how national institutions, such as a country's education and financial system, can support firms in performing competitive strategies of low-cost or high-quality production. A few years later, the literature on National Innovation Systems (NIS) proposed arguments about the links between national (scientific) institutions and their comparative advantages offered to firms in sectors of diverse innovation intensity (Dalum, 1992; Faber and Hesen, 2004; Herrmann and Peine, 2011). Over the past two decades, the Varieties of Capitalism literature has developed the most comprehensive framework on how labour- and financial-market institutions, as well as institutions channeling inter-organizational collaboration, offer comparative advantages to firms, which lead the latter to specialize in line with the facilitated product, technology, or innovation strategies (Hall and Soskice, 2001; Hancké et al., 2007; Hall and Gingerich, 2009).

The Varieties of Capitalism (VoC) theory concentrates on the Western world and distinguishes two types of countries with different institutional structures: Liberal Market Economies (LMEs) and Coordinated Market Economies (CMEs). In LMEs, economic activities are structured by market-based institutions, whereas coordinating institutions channel the interactions of economic actors in CMEs. Due to these institutional foundations, so the further argument of the VoC scholars, firms in LMEs have a comparative advantage in high-tech production based on radical innovation and, consequently, in so-called high-tech sectors like biotechnology and IT. Firms in CMEs, on the other hand, have an advantage in high-quality production based on incremental innovation and, thus, in medium-high-tech sectors such as automotive and machinery.

Various empirical studies have tested the claims of the VOC literature on corporate specialization in line with institutional advantages, but the results obtained are often contradictory. While

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some studies find, at least partial, empirical support for the specialization theory (Allen et al., 2006; Akkermans et al., 2009; Schneider and Paunescu, 2012), others reject it (Taylor, 2004; Herrmann, 2008a). This is problematic because the VoC arguments on the comparative advantage of nations have become a highly influential explanation for the types of industries that prosper in some rather than in other countries. Furthermore, the VoC arguments are also widely used in policy-making, for example in the strategy document aiming at strengthening the single European market (Monti 2010; Trouille, 2011). At the same time, the persistent academic debate about the empirical validity of this argument casts doubt on the generalizability of the VoC theory.

We argue that these contradicting outcomes largely result from the undifferentiated conceptualizations of comparative advantage and, thus, specialization patterns (Hall and Soskice, 2001; Akkermans et al., 2009; Schneider and Paunescu, 2012). From the innovation literature on comparative advantage, we know that specialization patterns can be conceptualized as *economic* specialization in specific export sectors, as *technological* specialization in distinct industries, or as *innovative* specialization, that is as specialization in a specific type of innovation (Laursen, 2000; Leiponen and Drejer, 2007). If a country excels in a particular sector technologically, it does not necessarily show a high economic specialization in that sector – and vice versa (Laursen, 2000; Schmoch et al., 2003). Similarly, the innovation literature on comparative advantage teaches us that firms in each sector develop both radical and incremental innovations (Mangematin et al., 2003; Leiponen and Drejer, 2007; Kirner et al., 2009).

In order to shed light on the VoC debate about corporate specialization patterns in line with comparative institutional advantages, we distinguish between different specialization concepts. Accordingly, we ask the question whether the VoC theory on comparative institutional advantages can explain patterns of economic, technological and innovative specializations in Western economies.

To answer this question, we test the empirical validity of the VoC claims with the help of panel data of exports and patents. In line with previous VoC studies assessing specialization patterns, we measure economic specialization with export data (Allen et al., 2006; Schneider and Paunescu, 2012), technological specialization with data on patent applications (Taylor, 2004), and innovative specialization with patent citation data (Akkermans et al., 2009). Taking the criticism of the CME-LME dichotomy into account (Streeck, 2010; Thelen, 2012), we follow more recent developments of the VoC literature by distinguishing not only between one broad group of CME and LME economies, but differentiate additionally between CME countries with stable institutions and CME countries that have liberalized (at least some of their) key labour- and financial-market institutions over the past decades (Schneider and Paunescu, 2012). Our analyses show that the VoC arguments weakly predict economic specialization, can account for technological specialization, and are hardly reflected in innovative specialization patterns.

To illustrate our argument, the remainder of this paper is organized as follows. In section two, we lay out the VoC reasoning and discuss the various conceptualizations of comparative advantage in the innovation literature. In section three, we describe the data and analytical approaches used. We present the results of our analyses in section four. Section five concludes with a discussion of the implications and limitations of our results, and points to avenues for further research.

2. Theory

The VoC theory on comparative institutional advantages starts with the observation that the institutions structuring economic relationships within Western political economies differ systematically (Hall and Soskice, 2001). In Liberal Market Economies (LMEs) – including the Anglo-Saxon countries, most prominently, the United States – competitive market-based arrangements constitute the primary mode of economic interaction. Relationships between economic actors are dominated by arm's length interaction based on formal contracting: Labour markets are fluid and allow firms to hire, and fire, employees from one day to the next. As a result, the scientists and workers employed in firms typically have portable rather than firm-specific skills. Since supervisory boards are unknown to firms in LMEs, the top management often has unilateral control over the firm. Firms chiefly rely on equity markets to acquire finance, which is provided based on publicly available information. The case-based common law of LMEs makes firms reluctant to collaborate within the framework of encompassing industry associations as they fear to be found guilty of violating antitrust regulations (Hall and Soskice 2001; Hancké et al., 2007).

In CMEs, by contrast, concerted and collaborative relationships between economic actors are the predominant form of interaction. Powerful unions and work councils combined with restrictive labour-market regulation make it difficult to hire and dismiss employees on short notice. As a consequence, long-term oriented career trajectories within one company motivate scientists and shop-floor workers to gain high and company-specific skills. Supervisory boards including both employee representatives and shareholders grant important control rights to the board members. Therefore, major stakeholders – such as banks, suppliers, employees, or the founding family – also tend to be major shareholders of a company. Finally, the code-based civil law of CMEs gives firms the necessary security that large-scale cooperation within encompassing industry associations will not be considered as violating antitrust legislation (Hall and Soskice, 2001; Hancké et al., 2007).

According to the VoC literature, these institutional constellations offer important comparative advantages to firms in CMEs and LMEs respectively. In LMEs, the institutional setting brings firms to focus on high-tech production based on radical innovation and, consequently, to specialize in so-called high-tech sectors like biotechnology and IT. Thanks to their versatile skills, scientists and shop-floor workers are creative, come up with radically new ideas and are used to cope with the rapidly changing work environments. Since wages are flexible, firms can reward their employees for such outstanding results. Furthermore, shareholders without a voice in a company's supervisory boards chiefly rely on publicly accessible stock market indicators to evaluate corporate performance, because they have only reduced monitoring possibilities to understand how their investments are used. Consequently, firms focus on radically innovative high-tech projects that promise high returns on shareholder value. Since antitrust regulation is suspicious of large-scale firm collaboration, new component standards are developed in small consortia rather than in encompassing industry associations. This helps firms to protect radical innovations from imitation by competitors (Hall and Soskice, 2001, p. 27–33).

The institutional basis in CMEs, on the contrary, brings firms to specialize in high-quality production based on incremental innovation in medium-high-tech sectors such as automotive and machinery. Thanks to their firm-specific skills, employees are less creative, but have the necessary in-depth knowledge to bring the products of 'their' company to perfection. Thanks to the control rights granted to supervisory board members, shareholders have inside information on how their investments are used. In line with their own interests as the company's stakeholders, they thus have a preference for less risky product-improvement strategies even if these promise more limited, but stable, returns on shareholder value. Thanks to the permissive antitrust regulation, suppliers and producers can jointly develop new component standards in encompassing industry associations. This facilitates close cooperation between suppliers and producers on highly sophisticated product components (Hall and Soskice, 2001, p. 21–27).

The relationship between specialization patterns and institutional structure as identified by the VoC theory, is the central hypothesis to be tested in this study. While the VoC arguments on specialization in line with comparative institutional advantages are compelling, empirical tests provide contradictory results. While some scholars find empirical support (Casper et al., 1999; Casper, 2000; Hall and Soskice, 2001), other studies provide mixed evidence (Allen et al., 2006; Akkermans et al., 2009; Schneider and Paunescu, 2012), whereas a third group of studies refutes the VoC claims (Taylor, 2004; Herrmann, 2008b; Lange, 2009).

The innovation literature on comparative advantage hints at a possible explanation of the contradictory VoC results obtained thus far. It suggests that a more refined conceptualization of the notion of “specialization” is needed, namely a distinction between *economic*, *technological*, and *innovative specialization* (Laursen, 2000; Leiponen and Dreher, 2007; Akkermans et al., 2009). Importantly, both economic and technological specialization typically refer to sectoral specialization patterns of countries. However, *economic specialization* is commonly defined as the relative distribution of a country’s economic activity in each sector (see Schneider and Panecsu 2012). Accordingly, it is generally measured with the use of the Balassa index applied to export data (see (Balassa, 1965)). *Technological specialization*, in turn, is conceptualized as “the relative distribution of a country’s inventive activity in each field” (Mahmood and Singh, 2003, p. 1036) and measured with Balassa indices applied to data on patent applications (Soete and Wyatt, 1983). Finally, *innovative specialization* is defined as the relative distribution of different innovation types, namely of radical and incremental innovations, within a country and, more precisely, within different sectors of a country. To classify innovations as either radical or incremental, patent citations are typically used (Akkermans et al., 2009; Schoenmakers and Duysters, 2010; Singh and Fleming, 2010).

By not differentiating between different specialization types, the VoC literature assumes that economic, technological, and innovative specialization are equivalents. According to the VoC logic, many products exported in one sector (economic specialization) automatically implies that many inventions have been patented in this sector (technological specialization), which are all either radically or incrementally innovative (innovative specialization).

Importantly, though, economic, technological, and innovative specialization do not translate one to one into each other (Laursen, 2000; Schmoch et al., 2003; Allen et al., 2006; Leiponen and Drejer, 2007). Various reasons for the disparities between economic, technological and innovation specialization have been identified. For example, a reason for discrepancies between economic and technological specialization is found in the literature on global value chains: Inventions are typically made – and patented – by the R&D departments of companies, while the resulting goods are often produced in separately located production units. Accordingly, (large) multi-national firms may have good institutional reasons to concentrate their R&D activities in just one country, while locating their production facilities in different countries which are, for example, closer to their target markets (Sturgeon et al., 2008; Carlsson, 2006; Sturgeon, 1997;). Consequently, differences between the economic and technological specialization patterns of countries emerge.

Additionally, the VoC theory has been considerably criticized for equating technological specialization in a sector with innovative specialization, i.e. specialization in a type of innovation (Akkermans et al., 2009). The VoC literature assumes that patents registered in high-tech sectors, such as IT, are radically innovative, whereas patents registered in medium-high-tech sectors, such as automotive, are incrementally innovative (Hall and Soskice, 2001, p. 26–44). However, the innovation literature on comparative advantage teaches us that technological inventions can be either radically or incrementally innovative in all types of sectors (Mangematin et al., 2003; Akkermans et al., 2009). For example, Castaldi and Los (2008), using an econometric technique that analyzes patent citations to determine the radicality of patents, find that in the archetypical high-tech sector of biotechnology only 5,75% of the patents were actually radical. Additionally, they also find that 2.76% of the patents in the traditional medium-high-tech sector of motors engines and parts were, as well, radically innovative.

With these conceptual differences in mind, let us return to the arguments of the VoC theory on comparative institutional advantages and, first, relate them to *economic specialization*. The VoC arguments mainly describe how financial- and labour-market institutions, as well as antitrust regulation facilitate technological inventions (Hall and Soskice, 2001, p. 36–44). It is, for example, emphasized how general skills of employees in LMEs foster high-technology inventions, whereas the in-depth knowledge of CME employees enables the latter to make incremental improvements to products, which are of high relevance in medium-high-tech sectors, such as automotive. But, as illustrated above, production facilities are nowadays dispersed around the globe and often located close to the envisaged markets or to cheap sources of input factors. Thus, factors other than the institutional structures identified by the VoC proponents seem to determine the location of production facilities and the resulting exports of goods.

Several empirical studies have assessed if export specialization patterns are in line with the predictions of the VoC theory. For example, Allen et al. (2006) use the OECD sector classifications, detailed at the five- and four-digit level, in order to produce export specialization rankings of various VoC countries. While the authors find that the specialization patterns are overall in line with the VoC predictions, they also identify some notable exceptions. Similarly, Schneider and Paunescu (2012) also use OECD export data, but at a high aggregation level. Accordingly, they only distinguish between a group of high-tech and medium-high-tech sectors in their main analyses, which may have biased their results if these sector aggregates contain one or more sectors that are dominant in terms of their export volume. Schneider and Paunescu (2012) assess the institutional structure of countries empirically, and only observe significant differences between the specialization patterns of LMEs and a core group of CME countries. In a supplementary analysis, Schneider and Paunescu (2012) also perform more fine-grained regressions by disaggregating the OECD data in order to distinguish between four high-tech and five medium-high-tech sectors. While the results obtained reveal differences in economic specialization in line with the VoC predictions, the specialization differences observed are often not significant.

These findings render the VoC reasoning about the link between a country’s institutional structure and its economic specialization inconclusive. In turn, the observed ambiguities justify our empirical test of this particular aspect of the VoC reasoning.

With regard to *technological specialization*, the VoC literature offers elaborate arguments on how specific labour- and financial-market institutions, as well as antitrust regulation influence technological developments in specific sectors (Hall and Soskice, 2001, p. 39–44): Employees in LMEs have the necessary general skill-set for coming up with the type of inventions needed in high-tech sectors, whereas employees in CMEs have the in-depth knowledge needed for inventions in medium-high-tech-sectors. Furthermore, the fluid labour markets of LMEs facilitate a rapid flow of knowledge, while high-risk finance needed for high-tech inventions is more abundant in LMEs. On the other hand, the financial system of CMEs rather offers funding for low-risk inventions that are typical for medium-high-tech sectors. The institutional structure of LMEs and CMEs thus encourages firms to concentrate their R&D activities in those institutional environments which best supports that technological sector in which they are active (Hall and Soskice, 2001, p. 57). This, in turn, leads to pronounced differences in technological specialization patterns between CME and LME economies.

Several studies have investigated the link between the aforementioned institutional constellations and technological specialization patterns. Based on a study of European and US patent data over the period 1963–1999, Taylor (2004) finds technological specializations patterns in line with the VoC theory, but notes that the explanatory power of the VoC theory largely depends upon the inclusion of the US in the LME country group. Using R&D intensity as a measure of technological specialization, Bassanini and Ernst (2002) control for the effects of individual countries, such as the US – and find comparative advantages in line with the VoC predictions. Given the theoretical stringency of the VoC arguments and the findings of the aforementioned analyses, we expect that the VoC hypothesis will be supported when it comes to technological specialization.

With regard to *innovative specialization*, the VoC theory equates inventions in high-tech sectors with radical innovations and inventions in medium-high-tech sectors with incremental innovations. Importantly, though, each sector has traditionally produced both radical and incremental innovations. Given that the VoC literature does not take this possibility into account, it is unlikely that a relationship exists between the institutional structures discussed in the VoC literature and their ability to exclusively produce radical or incremental innovations *within* one sector.

This is clearly reflected in the empirical studies testing the VoC arguments with the use of innovative specialization indicators: Scholars are unanimously critical about the validity of the VoC arguments in this respect (Taylor, 2004; Herrmann, 2008b; Akkermans et al., 2009). Using a database of pharmaceutical innovation projects, Herrmann (2008b) does not find significant differences in the innovation strategies pursued by firms in the UK (LME) and Germany (CME). In a particularly comprehensive study, using various patent indicators, Akkermans et al. (2009) do also not find that firms in LMEs are more radically innovative than firms in CMEs.

In sum, these empirical findings and the inconclusive theoretical reasoning lead us to put the VoC hypothesis applied to innovative specialization under empirical scrutiny.

3. Methodology

To test the proposed link between comparative institutional advantages and different specialization types, we follow the assumptions and indicators used in the VoC and innovation literatures in order to allow for maximum comparability of our results.

3.1. The sample

Our *country sample* is composed in line with the original VoC literature (Hall and Soskice, 2001) and its most important developments: We include 15 of the 17 countries originally considered by Hall and Soskice (2001), excluding Iceland and New Zealand because of their small economic size (see (Schneider and Paunescu, 2012)). The distinction made by Hall and Soskice (2001) between CMEs and LMEs initiated a debate about the heterogeneity of the two country groups (Amable, 2003; Jackson and Deeg, 2006). Most importantly, this debate focused on the liberalization processes of several CME countries, where the institutional structure shifted from a CME towards an LME model over the past decades (Streeck, 2010; Thelen, 2012; Schneider and Paunescu, 2012). Even though the traditional CME-LME dichotomy is still at the basis of both scholarly (Hall and Gingerich, 2009) and policy debates (Monti 2010; Trouille, 2011), we take the recent liberalization debate into account. To this end, we selected the CME 'mover countries' identified by Schneider and Paunescu (2012) as the countries that underwent most institutional change, to assess possible differences in specialization patterns between the different time periods of our study. These countries are the Netherlands, Denmark, Finland, and Sweden and are called "liberalized CMEs" in this study.[1]

Table 1
Country Sample and Its Institutional Classification.

Stable CME	Liberalized CME	LME
Germany	The Netherlands	USA
Austria	Denmark	UK
Belgium	Finland	Ireland
Norway	Sweden	Australia
Switzerland		Canada
Japan		

Table 1 provides an overview of our country sample and its institutional classification.

In order to identify those sectors in which firms in LMEs, as well as in stable and liberalized CMEs, have a comparative advantage, we use the distinction between high-tech and medium-high-tech sectors made by the OECD (2011) industry classification. According to this OECD (2011) compendium, both the high-tech and medium-high-tech sectors include five sub-sectors, which are identified on the basis of the "ISIC REV.3 R&D intensity" classification (OECD, 2011). We decided to focus our analyses on these high- and medium-high-tech sectors for two reasons: First, because they closely resemble the sector dichotomy made in the initial VoC work by Hall and Soskice (2001, p. 42). Second, this distinction was also used in subsequent assessments of the VoC theory on comparative institutional advantages (Schneider et al., 2009; Schneider and Paunescu, 2012). Given that we here intend to shed light on the inconclusive results of previous assessments, it is of utmost importance that we use the same research approaches in order to ensure the comparability of our findings.

Table 2 provides an overview of the sectoral sample analysed and its technological classification in the OECD 2011 compendium.

Furthermore, our study focuses on two *time periods*, namely 1991–1998 and 2000–2007 in order to enable the assessment of possible changes in specialization patterns over time (see Schneider and Paunescu, 2012).

3.2. The data

Following the innovation literature and assessments of the VoC argument on comparative institutional advantages, we measure economic specialization with export data (Allen et al., 2006;

[1] Two of the countries assigned to the CME model in the initial VoC work of Hall and Soskice (2001) are in the study of Schneider and Paunescu (2012) not classified as CME countries for the entire 1990–2005 period: Japan is considered as a hybrid economy and Switzerland as an LME or LME-like economy. Although sometimes referred to as a distinct economy within VoC, most qualitative studies of Japan show the country has institutional structures similar to those of the other CMEs and underwent no major institutional change in the past decades (Jackson and Moerke, 2005; Streeck and Yamamura, 2001; Yoshimori, 2005). Results of other VoC studies show a somewhat more mixed pattern for Switzerland (Hicks and Kenworthy, 1998; Rueda and Pontusson, 2000). This country has wage systems (Oesch and Menés, 2011; Soskice, 1990), and firm networks (Nollert, 1998) largely comparable to those of the other CMEs, but employment protection seems lower (Blaas, 1992), which might be related to large variations in the welfare systems of the Swiss cantons (Armingeon et al., 2004). Based on these studies it was concluded that classifying Switzerland as an LME would not be correct, and because some but no far-reaching institutional change took place in the past two decades (Trampusch and Mach, 2011), Switzerland was classified as a stable *CME* country.

Table 2
Sectoral Sample and Its Technological Classification.

High-tech sectors	Medium-high-tech sectors
Aircraft and spacecraft	Chemicals excluding pharmaceuticals
Pharmaceuticals	Machinery and equipment, n.e.c. (not elsewhere classified)
Office, accounting and computing machinery	Electrical machinery and apparatus, n.e.c.
Radio, TV and communications equipment	Motor Vehicles, trailers and semi-trailers
Medical, precision and optical instruments	Rail and transport equipment n.e.c.

Table 3
Estimated correlations between RCA_{ijt}, RTA_{ijt} and RI_{ijt} (N = 2400).

	RCA	RTA
RTA	0.510**	
RI	0.143**	0.229**

** Correlation is significant at the 0.01 level (2-tailed).

Schneider and Paunescu, 2012), technological specialization with data on patent applications (Archibugi and Pianta, 1992; Taylor, 2004), and innovative specialization with data on patent citations (Akkermans et al., 2009). With regard to the latter, we compare the shares of a country's radical innovations within each sector, i.e. the relative amount of the 10% most cited patents, because patents that are highly cited by follow-up patents have been shown to be of particularly high economic value (Harhoff et al., 1999; Trajtenberg, 1990) and at the basis of numerous future inventions (Albert et al., 1991; Dahlin and Behrens, 2005; Jaffe et al., 1993).

We obtained comparable data on exports and patents from various OECD databases (OECD, 2012a; OECD, 2012b; OECD, 2013a; OECD, 2013b). We downloaded the ***export data*** indicating economic specialization patterns from the OECD BTDIxE database (OECD, 2012a). Data on patent applications used to measure technological specialization, as well as data on patent citations used to measure innovative specialization, were drawn from the OECD patent databases (OECD 2012b; OECD 2013a; OECD 2013b).

Regarding the ***data on patent applications***, several additional decisions had to be taken. First, we decided to focus on *patent applications to the EPO* rather than to other patent offices, most importantly, the United States Patent and Trademark Office (USPTO). Our decision was motivated by the intention to avoid national biases in patent applications, which could occur because firms have a tendency to seek patent protection at their national patent offices in the first place. In this regard, EPO data are advantageous, because the EPO is a cross-national patent office, which exists next to the national offices. Contrary to the USPTO, EPO patent data is therefore not biased by applications of firms from a single country (De Rassenfosse et al., 2013). Furthermore, EPO data is not biased by patent applications of European firms either: As illustrated in detail by the EPO statistics on patent filings, "roughly a third (35%) of the total filings in 2013 came from the EPO member states and two-thirds (65%) from outside Europe." (EPO, 2014). For the USPTO, the division between US and foreign patent filings is less useful for the sake of our study, namely about fifty-fifty (USPTO, 2014). This makes the use of EPO data advantageous over the use of patent data from any other patent office.

Second, the *country of residence of the inventor*, rather than the residence country of the applicant, was chosen as a reference point, because the inventor's address better depicts the country in which the invention was made. For patent applications in which inventors from several countries were involved, fractional counts were used in order to take the residence country of all inventors, and not only that of the first inventor, into account (OECD, 2009).

Third, IPC (International Patent Classification) codes were used to *link patent applications to sectors*. Importantly, the high-tech versus medium-high-tech classification of the OECD, which we use in this study, is based on economic sectors that do not concur with the IPC codes. In order to identify all those patent applications which belong to the respective OECD sectors, IPC concordance tables were used (see Appendix A).[2] Whenever patents had multiple IPC codes, and could thus belong to multiple sectors, fractional counts were applied (OECD, 2009). A patent application with a total number of z IPC codes, of which n IPC codes belong to the same sector, was assigned a fraction of n/z for this sector. To give an example: A patent with 4 out of 5 IPC codes belonging to the German pharmaceutical sector, and with one of its two inventors coming from Germany, was assigned a value of (4/5)*(1/2) = (2/5) for the German pharmaceutical sector.

Akin to the data on patent applications, we also had to decide about which ***patent citation*** data to use in order to enable further calculations of innovative specialization patterns. In line with Akkermans et al. (2009) and Singh and Fleming (2010), we categorized patents as radical if they belong to the 10% most cited patents of their respective sector for a given 3-year period. Patents below this cut-off point of 10% were considered to be incrementally innovative.[3] In line with our above illustrations, we focus our patent assessments on those ten sectors described as high-tech and medium-high-tech by the OECD.

The aforementioned raw data was used to calculate the economic, technological and innovative specialization for the respective countries, sectors and time-spans covered in our sample. ***To determine economic specialization patterns***, we calculated the widely used Balassa index of Revealed Comparative Advantage (RCA), which captures the relative specialization in Exports (Z) of country *i* in sector *j*, at time *t* (Balassa, 1965):

$$RCA_{ijt} = \frac{Z_{ijt}/\sum_{j=1}^{n} Z_{ijt}}{\sum_{i=1}^{n} Z_{ijt}/\sum_{i=1}^{n}\sum_{j=1}^{n} Z_{ijt}}$$

To determine technological specialization patterns, we calculated the equivalent of Balassa's economic index, namely the index of Revealed Technological Advantage. It measures the relative specializations in patent applications (X) of country *i* in sector *j* at time *t* (Soete, 1987)

$$RTA_{ijt} = \frac{X_{ijt}/\sum_{j=1}^{n} X_{ijt}}{\sum_{i=1}^{n} X_{ijt}/\sum_{i=1}^{n}\sum_{j=1}^{n} X_{ijt}}$$

Finally, ***to identify innovative specialization patterns***, we use another equivalent of the Balassa index, which captures the relative specialization of countries in radical innovation within specific sectors (Akkermans et al., 2009). It is here called Radicality Index (RI). Y* denotes the number of radical patents, whereas Y refers to the non-radical patents of country *i* in sector *j* at time *t*.

$$RI_{ijt} = \frac{Y^*_{ijt}/(Y_{ijt} + Y^*_{ijt})}{\sum_{i=1}^{n} Y^*_{ijt}/\sum_{i=1}^{n}\left(Y_{ijt} + Y^*_{ijt}\right)}$$

[2] For eight of ten OECD sectors studied, relevant patent subclasses (four-digit level IPC) were provided in the concordance tables of Schmoch et al. (2003) which are constructed on the basis of expert assessments and firm samples. For the two remaining sectors (*aircraft and spacecraft*, as well as *rail and transport n.e.c.*), the concordance tables of Lybbert and Zolas (2014) based on algorithmic searches of keywords of patents, were consulted.

[3] Even though the 10% cut-off-point is widely used (see (Akkermans et al., 2009; Singh and Fleming, 2010), it is arbitrary. We therefore cross-checked our results on the basis of a 5% cut-off-point. This change in cut-off-point did not substantially change the results obtained.

Table 4
Predictors of economic specialization (Revealed Comparative Advantage) in the high-tech and medium-high-tech sector for 1991–1998 and 2000–2007.

	High-tech sector				Medium-high-tech sector			
	1991–1998		2000–2007		1991–1998		2000–2007	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Stable CME	−0.162	0.00984	−0.169	−0.0765	0.202*	0.361***	0.174*	0.296**
(Ref=LME)	(0.110)	(0.114)	(0.111)	(0.119)	(0.0854)	(0.103)	(0.0862)	(0.0892)
Liberalized CME	−0.0896	−0.0215	−0.110	−0.0781	0.0429	0.106	0.0149	0.0575
(Ref=LME)	(0.105)	(0.108)	(0.124)	(0.126)	(0.0889)	(0.0958)	(0.0899)	(0.0892)
GDP	−0.00644	−0.0240*	−0.00880	−0.0202*	−0.0152	−0.0315**	−0.0317***	−0.0467***
	(0.0107)	(0.0102)	(0.00993)	(0.00850)	(0.0102)	(0.0111)	(0.00759)	(0.00552)
Internationalization	−0.00515	−0.00140	−0.00193	0.00304	−0.00754	−0.00407	−0.00576	0.000768
	(0.00599)	(0.00629)	(0.00645)	(0.00675)	(0.00380)	(0.00407)	(0.00424)	(0.00437)
United States		0.517**		0.490*		0.478***		0.644***
		(0.195)		(0.194)		(0.126)		(0.103)
Constant	0.198	0.254	0.123	−0.00416	0.740	0.792*	1.308**	1.140**
	(0.569)	(0.564)	(0.673)	(0.663)	(0.395)	(0.383)	(0.405)	(0.387)
R^2	0.159	0.222	0.124	0.181	0.189	0.262	0.285	0.425

All models include year and sector dummies. Standard errors are clustered at the country-sector level and presented in parentheses.[5] N = 600. *** p < 0.001, ** p < 0.01, * p < 0.05. High-tech sectors: – Aircraft and spacecraft – Pharmaceuticals – Office, accounting and computing machinery – Radio, TV and communications equipment – Medical, precision and optical instruments. Medium-high-tech sectors: – Chemicals excluding pharmaceuticals – Machinery and equipment, n.e.c. (not elsewhere classified) – Electrical machinery and apparatus, n.e.c. – Motor Vehicles, trailers and semi-trailers – Rail and transport equipment n.e.c.

The Balassa indices obtained from the above calculations range from 0 to 1 for values that indicate comparative disadvantages and from 1 to ∞ for values of comparative advantages. In orde *r to normalize the distribution of values*, we transformed all indices by using the formulae (RCA-1)/(RCA + 1), (RTA-1)/(RTA + 1) and, respectively, (RI-1)/(RI + 1). These transformations result in the confinement of all comparative disadvantages in the range of −1 to 0, and of all comparative advantages in the range of 0–1 (Dalum et al., 1998).

Finally, to limit the impact of outliers contained in the patent application (RTA_{ijt}) and patent citation (RI_{ijt}), data, we calculated 3-year moving averages. Given that the export data (RCA_{ijt}) did not contain major outliers, it was not necessary to use 3-year moving averages.

3.3. Method and models

To investigate the relationship between a country's institutional structure and its economic, technological, and innovative specialization, we use regression analyses based on panel data (see Johnston and DiNardo, 1997)). With country being the unit of analysis, we pool the data for the respective countries over sectors (see Table 2) and years.

To control for explanations of economic, technological, and innovative ***specialization other than a country's national institutions***, we include the following variables in the respective regression models. First, in addition to classifying each country's *institutional constellation* as a stable CME, a liberalized CME, or an LME economy, we include one additional country dummy representing the USA in order to control for its outlier effects within the category of LME countries (see Taylor, 2004). We also include *GDP per capita* as a control variable, because a high GDP may disproportionately stimulate the demand for products of high-tech sectors or of radical innovativeness. Finally, we control for a country's degree of *internationalization* by using the KOF globalization index of Dreher (2006), because some VoC-inspired studies claim that the acquisition of resources from abroad (such as workers or venture capital) enables firms to circumvent national institutions, thereby modifying a country's specialization patterns (Ahrweiler et al., 2006; Jong, 2006; Lange, 2009).

In line with our intention to test the VoC argument as an explanation of economic, technological and innovative specialization, the dependent variables in our regression models are, respectively, the transformed RCA_{ijt}, RTA_{ijt}, and RI_{ijt} for country *i* and sector *j* at time *t*. In all regression models, we regress the same independent variables on these dependent variables namely: First, dummies of the VoC institutional constellations *k* denoting stable CME and liberalized CME countries (*k = 1, 2; where k is the corresponding subset of the countries i listed in* Table 1*; LME countries are taken as reference)*. Second, we also insert the control variables GDP_{it} and degree of internationalization INT_{it} into each model. Third, we include the individual USA dummy to control for its possible outlier effect within the LME country group. Finally, sector dummies and year dummies are added (j = *2,.,5, with 1 as reference, where j refers to each of the high- and, respectively, medium-high-tech sectors listed in* Table 2 *and year dummies* (*t = 1992,. . ., 1998 or t = 2001,. . ., 2007, with 1991 and 2000 as reference).*

Accordingly, the models we estimate by means of the OLS method (Johnston and DiNardo, 1997) can be specified as RCA_{ijt} (RTA_{ijt} and, respectively, RI_{ijt}) being a linear function of the aforementioned independent variables, namely

$$RCA_{ijt} = \sum_{k=1}^{2}\beta_{1k}VoC_k + \beta_2 GDP_{it} + \beta_3 INT_{it} + \beta_4 USA + \sum_{j=2}^{5}\beta_{5j}Sector_j + \sum_{t=2}^{8}\beta_{6t}Year_t + \varepsilon_{ijt} \quad (1)$$

We run the aforementioned model separately for high-tech and medium-high-tech sectors on the one hand, and for the periods of 1991–1998 and 2000–2007 on the other, in order to be able to explicitly test the claims of the VoC logic and assess changes over time. The results obtained for economic specialization (RCA_{ijt}), technological specialization (RTA_{ijt}) and innovative specialization (RI_{ijt}) respectively are reported in Tables 4–6.

4. Results

Before turning to the regression results, correlation analyses of the economic, technological and innovative specialization variables are conducted. The results of these correlation analyses are reported in Table 3.

As can be observed in Table 3, there is hardly a correlation between specialization in radical innovation (RI) on the one hand,

[5] Results with standard errors clustered at the country level (n = 15) yield a similar pattern as the results reported here

and economic (RCA, r = 0.143) and technological specialization (RTA, r = 0.229) on the other hand. This implies that a country that produces relatively many radical innovations in a sector does not necessarily also show high economic or technological specialization in this sector. There is a higher correlation between technological (RTA) and economic specialization (RCA, r = 0.510). This resonates with accounts of technological specialization as a driver of export specialization, in particular for technologically advanced products (Laursen, 2000; Malerba, 2005). All in all, the correlations between RCA, RTA and RI are only moderate, which lends empirical support for our decision to treat them as separate concepts.

The results obtained for the predictions of the VoC theory regarding economic, technological and innovative specializations are presented in Tables 4, 5 and 6 , respectively. To begin with, the *economic specialization patterns* of countries (RCA_{ijt}) only weakly reflect the VoC arguments.[4] In the high-tech sector, the results for the specialization of stable and liberalized CME are not statistically significant. Only the direction of the effects is in line with the expectations of the VoC theory (model 1).

Furthermore, the US dummy variable – added in model 2– is significant. With this variable added, the coefficient for the stable CMEs is not even in the direction of the predictions of the VoC theory in the 1991–1998 period. These results cast doubt on the validity of the VoC theory and lend support to the claim of Taylor (2004) that the United States occupy an outlier position among the LMEs.

In the medium-high-tech sectors, as expected by the VoC theory, stable CME countries have a comparative advantage over LME countries. The liberalized CME countries seem to show specialization patterns in between those of stable CME and LME countries. It is furthermore interesting to note that the US dummy also turns out to be positive for the medium-high-tech sectors. This implies that the US are more specialized in medium-high-tech exports than the other LME economies.

The results obtained for *technological specialization patterns* (RTA_{ijt}) broadly reflect the VoC arguments on comparative institutional advantages (Table 5). The stable CME countries display a statistically significant abstinence from high-tech activities during both observation periods (1991–1998 as well as 2000–2007). In other words, stable CMEs have comparative disadvantages in high-tech sectors. Importantly, the addition of the US dummy variable in model 2 does not alter these results. The liberalized CME countries also show a comparative disadvantage in high-tech sectors, however, this is only significant for the 1991–1998 period.

The results obtained for the medium-high-tech sectors are similar: Accordingly, the stable CME countries have a comparative advantage over LMEs during both observation periods. Again, the liberalized CME countries seem to have specialization patterns in between those of stable CME and LME countries. The addition of the US dummy variable in model 2 also does not change the observed outcomes.

Finally, the results obtained for *innovative specialization* (RI_{ijt}) cast doubt on the VoC arguments, as the observed effects are often not significant or even contradict the VoC logic (see Table 6). The RI indicator measures the extent to which countries are specialized in radical innovation, within sectors. In line with the VoC predictions, stable CME countries are less specialized in radical innovation in high-tech sectors than their LME counterparts. However, these specialization patterns are weakening, even disappearing, over the observation periods, as they are far more pronounced over the 1990s (1991–1998) than in the early 2000s (2000–2007). Furthermore, and contrary to the VoC predictions, the liberalized CME economies have a comparative advantage in radical innovations in high-tech sectors over their LME counterparts during the period 2000–2007.

The results are similar for the specialization patterns in medium-high-tech sectors. During the first observation period (1991–1998), the stable CME countries reveal to have a comparative disadvantage in radical innovations compared to the LME economies. For the second observation period (2000–2007), however, CMEs start to gain a comparative advantage in this area, but this effect is statistically not significant. The specialization patterns of liberalized CMEs display no statistically significant effect for the first observation period, while they are significantly more specialized in radical innovation in medium-high tech sectors than the LMEs during the second observation period. In short, the data hardly reflects the specialization patterns of countries in a type of innovation as predicted by the VoC theory.

5. Conclusions

In this study, we have assessed the empirical validity of the VoC argument on comparative institutional advantages as an explanation of a country's specialization patterns. Our study was motivated by the contradictory results of previous research on this topic (Akkermans et al., 2009; Herrmann, 2008b; Schneider and Paunescu, 2012). Based on the innovation literature on comparative advantage (Laursen, 2000; Leiponen and Dreher, 2007), we have argued that ambiguous conceptualizations of specialization patterns contributed to these disagreements. Accordingly, we have differentiated between economic, technological, and innovative specialization and tested the impact of stable CME, liberalized CME and LME institutions, together with several important control variables, on these three types of specialization.

The results illustrate that the institutions described in the VoC literature (Hall and Soskice, 2001 in particular p. 36–44) are only weakly related to economic specialization patterns of countries. For this form of specialization, the VoC theory only holds in the medium-high-tech sectors. For technological specialization, the VoC theory can explain differences in specialization patterns. Both in the high-tech and medium-high-tech sectors, the specialization patterns of stable CME and LME countries conform to its predictions. Finally, for innovative specialization, the VoC argument on comparative institutional advantages cannot explain the observed specialization patterns. The specialization of countries in radical innovation within sectors is hardly in line with the VoC theory's predictions. This, in turn, indicates that the institutions discussed in the VoC literature actually have a limited impact on the specific innovation strategies adopted by individual companies.

Our results speak to previous assessments of the VoC theory on several noteworthy points. First, in line with Schneider and Paunescu (2012) we find that the VoC theory only applies to a group of core CME countries. The liberalized CME countries tend to have specialization patterns in between those of the LME and the stable CME countries. Our results are also largely in line with the analyses Schneider and Paunescu (2012) perform on exports at a disaggregated level. Second, we find evidence in line with the work of Taylor (2004) that the United States can be an outlier amongst the LME countries. However, the US are not always 'more LME than the other LMEs'. For example, in the case of medium-high-tech exports, the

[4] It should be noted that the export data, used as an indicator of economic specialization, might be flawed by re-exports, especially for small economies with big ports, such as Belgium (Antwerp) and the Netherlands (Rotterdam), because these receive massive overseas imports destined at other European countries. To control for possible re-exports, we ran the same analyses including, and excluding, Belgium and the Netherlands from the sets of stable and, respectively, liberalized CME countries. Importantly, though, the results obtained did not contain major differences, so that we report in Table 4 the results based on the inclusion of Belgium and the Netherlands.

Table 5
Predictors of technological specialization (Revealed Technological Advantage) in the high-tech and medium-high-tech sector for 1991–1998 and 2000–2007.

	High-tech sector				Medium-high-tech sector			
	1991–1998		2000–2007		1991–1998		2000–2007	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Stable CME	−0.232***	−0.201**	−0.175***	−0.151*	0.152**	0.149*	0.235***	0.244***
(Ref=LME)	(0.0538)	(0.0649)	(0.0509)	(0.0575)	(0.0570)	(0.0719)	(0.0483)	(0.0534)
Liberalized CME	−0.165*	−0.152	−0.116	−0.108	0.0292	0.0279	0.0462	0.0493
(Ref=LME)	(0.0791)	(0.0816)	(0.0698)	(0.0714)	(0.0457)	(0.0461)	(0.0544)	(0.0543)
GDP	0.00925	0.00595	0.000584	−0.00250	−0.00481	−0.00450	−0.00687	−0.00799
	(0.00638)	(0.00757)	(0.00420)	(0.00436)	(0.00541)	(0.00708)	(0.00514)	(0.00613)
Internationalization	−0.00354	−0.00285	−0.00142	−0.000081	0.00136	0.00129	−0.000191	0.000293
	(0.00415)	(0.00432)	(0.00350)	(0.00367)	(0.00287)	(0.00315)	(0.00308)	(0.00338)
United States		0.0992		0.132		−0.00935		0.0478
		(0.0993)		(0.0840)		(0.111)		(0.102)
Constant	−0.156	−0.145	−0.0474	−0.0818	−0.134	−0.135	0.0445	0.0321
	(0.409)	(0.408)	(0.378)	(0.381)	(0.233)	(0.233)	(0.290)	(0.290)
R^2	0.272	0.276	0.231	0.243	0.242	0.242	0.378	0.379

All models include year and sector dummies. N = 600. Standard errors are clustered at the country-sector level and presented in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. High-tech sectors: – Aircraft and spacecraft – Pharmaceuticals – Office, accounting and computing machinery – Radio, TV and communications equipment – Medical, precision and optical instruments. Medium-high-tech sectors: – Chemicals excluding pharmaceuticals – Machinery and equipment, n.e.c. (not elsewhere classified) – Electrical machinery and apparatus, n.e.c. – Motor Vehicles, trailers and semi-trailers – Rail and transport equipment n.e.c.

Table 6
Predictors of innovative specialization (Radicality Index) in the high-tech and medium-high-tech sector for 1991–1998 and 2000–2007.

	High-tech sector				Medium-high-tech sector			
	1991–1998		2000–2007		1991–1998		2000–2007	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Stable CME	−0.181***	−0.193**	−0.0380	−0.0646	−0.0669	−0.0908*	0.0368	0.0155
(Ref=LME)	(0.0504)	(0.0649)	(0.0390)	(0.0403)	(0.0351)	(0.0452)	(0.0424)	(0.0527)
Liberalized CME	−0.0148	−0.0198	0.117*	0.108*	−0.0314	−0.0415	0.0971*	0.0896
(Ref=LME)	(0.0705)	(0.0729)	(0.0524)	(0.0516)	(0.0456)	(0.0474)	(0.0466)	(0.0492)
GDP	0.0106	0.0118	0.00614	0.00944	0.00577	0.00826	0.000362	0.00300
	(0.00614)	(0.00740)	(0.00549)	(0.00654)	(0.00442)	(0.00556)	(0.00280)	(0.00335)
Internationalization	−0.00343	−0.00369	−0.00207	−0.00350	−0.00355	−0.00407	−0.00471**	−0.00586**
	(0.00256)	(0.00267)	(0.00174)	(0.00201)	(0.00208)	(0.00213)	(0.00172)	(0.00177)
United States		−0.0370		−0.142		−0.0750		−0.113
		(0.0818)		(0.0792)		(0.0622)		(0.0664)
Constant	−0.297	−0.301	−0.187	−0.151	0.172	0.164	0.361*	0.391*
	(0.309)	(0.310)	(0.189)	(0.184)	(0.209)	(0.207)	(0.163)	(0.156)
R^2	0.206	0.207	0.115	0.126	0.079	0.083	0.114	0.126

All models include year and sector dummies. N = 600. Standard errors are clustered at the country-sector level and presented in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. High-tech sectors: – Aircraft and spacecraft – Pharmaceuticals – Office, accounting and computing machinery – Radio, TV and communications equipment – Medical, precision and optical instruments. Medium-high-tech sectors: – Chemicals excluding pharmaceuticals – Machinery and equipment, n.e.c. (not elsewhere classified) – Electrical machinery and apparatus, n.e.c. – Motor Vehicles, trailers and semi-trailers – Rail and transport equipment n.e.c.

US specialization is more tending towards that of the CME countries than other LME countries. Third, our findings also speak to those of Akkermans et al. (2009) who use various patent-based indicators to assess the distribution of radical innovations among countries. Akkermans et al. (2009) only distinguish between CMEs and LMEs. They find that LMEs are more radically innovative in some high-tech sectors, whereas CMEs are more radically innovative in some medium-high-tech sectors. In our study, it turns out that in particular the liberalized CME countries also have comparative advantages in the production of radical innovations within sectors.

The observation that the VoC theory seems particularly reflected in technological comparative advantage and not always in economic comparative advantage deserves further attention. When turning to the VoC arguments, we indeed find elaborated illustrations of how specific labour- and financial-market institutions, as well as institutionalized user-producer interactions within a country facilitate technological developments. Arguments on how these institutions would influence a company's production decisions are not proposed. In the literature on global value chains for example, it has been shown how production facilities are now located across the globe, while research facilities are still more clustered in certain countries (with a specific institutional structure) (Sturgeon et al., 2008; Carlsson, 2006; Sturgeon, 1997). Second, the VoC theory only makes claims about technology-intensive sectors. Countries with large natural resource or agricultural sectors, which are not particularly technology-intensive, are therefore likely to show specialization patterns that are less in line with the VoC theory's predictions. Finally, in line with the previous assessments of the VoC theory, we used raw export data, which is obviously not a perfect measure of economic specialization. However, because of a lack of data, we were not able to redo the entire export analysis with data corrected for re-exports. Currently various projects are underway to develop datasets with more refined measures of economic specialization, in particular reflecting the increasing international nature of global value chains (OECD, 2015).

Our results also speak to the literature on evolutionary economics. The latter may explain why we found technological specialization to be influenced by institutions, whereas we only find specialization in radical innovations to a limited extent be related to specific institutional structures (Boschma, 1996). Evolutionary economists highlight that there is a considerable chance-element involved in radically innovative breakthroughs (Mokyr, 1990), or that radical innovations may be triggered by events, such as high oil prices, that are not specific to a certain location. In evolutionary terms, there is a large *variety* of locations where radical innovations are made. After this initial *variety*, however, the *selection environment* becomes important. This selection environment determines if the radical innovation will also lead to further technological activity. Apparently, the institutional structures identified by the VoC theory form an important part of this selection environment.

Finally, our findings have implications for economic policies seeking to strengthen technological capabilities of firms. To begin with, policy-makers should be aware that the rigid labour- and financial-market institutions of CMEs facilitate inventions in medium-high-tech sectors such as automotives, whereas the flexible institutions of LMEs are instrumental for making inventions in high-tech sectors such as pharmaceuticals. In order to be effective, it therefore seems wise to design technology policies in such a way that they build on the economy's respective comparative institutional advantages, or explicitly address its comparative institutional disadvantages (cf. (Harcourt and Wood, 2007)). Furthermore, given that technological and economic specialization are not equivalent, economic policy-makers may also want to be aware that policy programs aimed at increasing the technological capabilities of companies do not necessarily translate into economic success, i.e. export growth. And vice-versa: policy programs supporting corporate export growth do not necessarily lead to increasing technological capabilities of firms.

Like virtually all research, our study has its limitations, also providing avenues for further study. First, this concerns our data. As mentioned, it would be worthwhile to further explore economic specialization patterns, once more refined data become available (e.g. OECD, 2015). The same holds for our measurements of radical innovations. This study did not assess the radicality of industries, but followed the literature in defining radical innovation as the 10% most cited patents within an industry (Akkermans et al., 2009). While we have cross-checked our results on the basis of a 5% threshold without detecting major deviations, here lies maybe the largest prospect for future research: the development of non-patent-based indicators of radical innovation, which better capture the social, institutional and organizational dimensions of radicality. Also, even with the employed transformation, the RCA index is not perfect, and the debate on specialization indices is ongoing (Deb and Hauk, 2015). In terms of modelling, due to the small number of obervations in each VoC-sector category the confidence intervals for the variables without a sectoral dimension will become wider, which is unavoidable.

A further point of concern may be that we use country indicators as proxies for their overall institutional constellations. This approach may be problematic when the individual institutions within a country are not entirely in line with the ideal-typical CMEs and LME constellations. Given that we here aimed at testing the VoC arguments on comparative institutional advantages, we strictly followed the approach of the broader literature where entire countries are used as proxies for their institutional environment. Yet, in line with this literature, we distinguished between stable and liberalized CMEs in order to accommodate different institutional constellations emerging within CME economies. Future research may, however, want to disentangle individual institutions in order to study their impact on specialization patterns separately.

Third, to ensure that our results are comparable to those of previous studies, we adhered to the OECD "Isic rev. 3" industry classification, which comprises only manufacturing industries (OECD, 2011). Given that services – with some minor IT exceptions – cannot be patented, and given furthermore that services are typically not exported, it is inherently difficult to calculate Balassa indices for service sectors. Hence, our findings apply to specialization patterns in manufacturing but not in service industries. Importantly, though, the VoC literature overall faces the same limitations: While some VoC scholars claim that their institutional arguments also apply to service industries, the data used to illustrate institutional impacts mostly stem from production sectors. Hence, further research into how institutions shape the development of service sectors would be particularly desirable.

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Appendix A1. : Concordance table relating the OECD high-tech sectors to IPC patent codes

Sector	Isic rev 3	Corresponding IPC codes (four digit)							
Aircraft and spacecraft	353	B64B							
		B64C							
		B64D							
		B64F							
		B64G							
Pharmaceuticals	2423	A61K	C07K						
		A61P	C12N						
		C07D	C12P						
		C07H	C12Q						
		C07J							
Office, accounting and computing machinery	30	B41J	G05F	G06G	G06T	G07G	H03K		
		B41K	G06C	G06J	G07B	G09D	H03L		
		B43M	G06D	G06K	G07C	G09G			
		G02F	G06E	G06M	G07D	G10L			
		G03G	G06F	G06N	G07F	G11B			
Radio, TV and communications equipment	32	B81B	G11C	H01L	H03B	H03H	H04J	H04Q	
		B81C	H01C	H01P	H03C	H03J	H04K	H04R	
		G03H	H01F	H01Q	H03D	H03M	H04L	H04S	
		G09B	H01G	H01S	H03F	H04B	H04M	H05K	
		G09C	H01J	H02J	H03G	H04H	H04N		
Medical, precision and optical instruments	33	A61B	A61J	B04B	G01F	G01N	G02C	G04D	G12B
		A61C	A61L	C12M	G01H	G01R	G03B	G04F	G21G
		A61D	A61M	F15C	G01J	G01S	G03D	G04G	G21K
		A61F	A61N	G01B	G01K	G01T	G03F	G05B	H05G
		A61G	A62B	G01C	G01L	G01W	G04B	G08C	
		A61H	B01L	G01D	G01M	G02B	G04C	G09F	

Appendix A2. : Concordance table relating the OECD medium-high-tech sectors to IPC patent codes

Sector	Isic rev 3	Corresponding IPC codes (four digit)								
Chemicals excluding pharmaceuticals	24 excl 2423	A01N	C01D	C06B	C08F	C09F	C10K	C25B	G03C	
		A62D	C01F	C06C	C08G	C09G	C10M	D01C	G21F	
		B01J	C01G	C06D	C08H	C09H	C11B	D01F		
		B09B	C02F	C07B	C08J	C09J	C11C	D06L		
		B09C	C05B	C07C	C08K	C09K	C11D	F17C		
		B27K	C05C	C07F	C08L	C10B	C12S	F17D		
		B29B	C05D	C07G	C09B	C10C	C14C	F25J		
		C01B	C05F	C08B	C09C	C10H	C23F	F42B		
		C01C	C05G	C08C	C09D	C10J	C23G	F42D		
Electrical machinery and apparatus, n.e.c.	31	B60M	F21M	G08B	H01H	H02B	H02P			
		B61L	F21P	G08G	H01K	H02H	H05C			
		F21H	F21Q	G10K	H01M	H02K				
		F21K	F21S	G21C	H01R	H02M				
		F21L	F21V	G21D	H01T	H02N				
Machinery and equipment, n.e.c.	29	A01B	B01D	B23D	B31F	B68F	D06B	F04B	F23N	F41J
		A01C	B01F	B23F	B41B	C10F	D06F	F04C	F23R	F42C
		A01D	B02B	B23G	B41C	C12L	D06G	F04D	F24B	G01G
		A01F	B02C	B23H	B41D	C13C	D06H	F04F	F24C	G21J
		A01G	B03B	B23K	B41F	C13D	D21B	F15B	F24D	H05B
		A01J	B03C	B23P	B41G	C13G	D21D	F16C	F24F	H05F
		A01K	B03D	B23Q	B41L	C13H	D21F	F16D	F24H	H05H
		A01M	B04C	B24B	B41N	C14B	D21G	F16F	F25B	
		A21B	B05B	B24C	B42B	C23C	E01C	F16G	F25C	
		A21C	B05C	B25D	B42C	D01B	E02D	F16H	F25D	
		A22B	B05D	B25J	B44B	D01D	E02F	F16K	F26B	
		A22C	B06B	B26D	B61B	D01G	E06C	F16M	F27B	
		A23N	B07B	B26F	B63G	D01H	E21B	F16N	F28B	
		A24C	B07C	B27B	B65B	D02G	E21C	F22D	F28C	
		A41H	B08B	B27C	B65C	D02H	E21D	F23B	F28D	
		A42C	B21B	B27F	B65G	D02J	E21F	F23C	F28F	
		A43D	B21D	B27J	B65H	D03C	F01B	F23D	F28G	
		A45D	B21F	B27L	B66B	D03D	F01C	F23G	F41A	
		A47G	B21H	B28D	B66C	D03J	F01D	F23H	F41B	
		A47J	B21J	B30B	B66D	D04B	F03B	F23J	F41C	
		A47L	B22C	B31B	B66F	D04C	F03C	F23K	F41F	
		A62C	B23B	B31C	B67B	D05B	F03D	F23L	F41G	
		B01B	B23C	B31D	B67C	D05C	F03G	F23M	F41H	
Motor Vehicles, trailers and Semi trailers	34	B60B	B60K	B60R	F01L	F02D	F02P			
		B60D	B60L	B60S	F01M	F02F	F16J			
		B60G	B60N	B60T	F01N	F02G	G01P			
		B60H	B60P	B62D	F01P	F02M	G05D			
		B60J	B60Q	E01H	F02B	F02N	G05G			
Rail and transport equipment n.e.c.	352 + 359	B61B	B61H	B62H						
		B61C	B61J	B62J						
		B61D	B61K	B62K						
		B61F	B61L	B62M						
		B61G	B62B	B65G						

References

Ahrweiler, P., Gilbert, N., Pyka, A., 2006. Institutions matter but... organisational alignment in knowledge-based industries. Sci. Technol. Innov. Stud. 2 (1), 3–18.

Akkermans, D., Castaldi, C., Los, B., 2009. Do 'liberal market economies' really innovate more radically than 'coordinated market economies'?: Hall and soskice reconsidered. Res. Policy 38 (1), 181–191.

Albert, M.B., Avery, D., Narin, F., McAllister, P., 1991. Direct validation of citation counts as indicators of industrially important patents. Res. Policy 20 (3), 251–259.

Allen, M., Funk, L., Tüselmann, H., 2006. Can variation in public policies account for differences in comparative advantage? J. Public Policy 26 (1), 1–19.

Amable, B., 2003. The Diversity of Modern Capitalism. Oxford University Press, Oxford.

Archibugi, D., Pianta, M., 1992. Specialization and size of technological activities in industrial countries: the analysis of patent data. Res. Policy 21 (1), 79–93.

Armingeon, K., Bertozzi, F., Bonoli, G., 2004. Swiss worlds of welfare. West Eur. Politics 27 (1), 20–44.

Balassa, B., 1965. Trade liberalization and revealed comparative advantage. Manchester Sch. Econ. Social Stud. 33, 99–123.

Bassanini, A., Ernst, E., 2002. Labour market regulation, industrial relations and technological regimes: a tale of comparative advantage. Ind. Corporate Change 11 (3), 391–426.

Blaas, W., 1992. The swiss model: corporatism or liberal capitalism? In: Pekkarinen, J., Pohjola, M., Rowthorn, B. (Eds.), Social Corporatism: A Superior Economic System? Clarendon Press, Oxford, pp. 363–376.

Boschma, R., (1996). The window of locational opportunity-concept. 10.6092/unibo/amsacta/776.

Carlsson, B., 2006. Internationalization of innovation systems: a survey of the literature. Res. Policy 35 (1), 56–67.

Casper, S., Lehrer, M., Soskice, D., 1999. Can high-technology industries prosper in germany? institutional frameworks and the evolution of the german software and biotechnology industries. Ind. Innov 6 (1), 5–24.

Casper, S., 2000. Institutional adaptiveness, technology policy, and the diffusion of new business models: the case of german biotechnology. Organ. Stud. 21 (5), 887–914.

Castaldi, C., Los, B., 2008. The identification of important innovations using tail estimators. ISU working paper, 08-07. In: Innovation Studies. Utrecht University, www.geo.uu.nl/isu/us.html.

Dahlin, K.B., Behrens, D.M., 2005. When is an invention really radical?: Defining and measuring technological radicalness. Res. Policy 34 (5), 717–737.

Dalum, B., Laursen, K., Villumsen, G., 1998. Structural change in OECD export specialisation patterns: de-specialisation and 'stickiness'. Int. Rev. Appl. Econ. 12 (3), 423–443.

Dalum, B., 1992. Export specialization, structural competitiveness and national systems of innovation. In: Lundvall, B.A. (Ed.), National Systems of Innovation – Towards a Theory of Innovation and Interactive Learning. Pinter Publishers, London.

De Rassenfosse, G., Dernis, H., Guellec, D., Picci, L., Van Pottelsberghe de la Potterie, B., 2013. The worldwide count of priority patents: a new indicator of inventive activity. Res. Policy 42 (3), 720–737.

Deb, K., Hauk Jr, W.R., 2015. RCA indices, multinational production and the Ricardian trade model. Int. Econ. Econ. Policy, 1–25.

Dreher, A., 2006. Does globalization affect growth? evidence from a new index of globalization. Appl. Econ. 38 (10), 1091–1110.

EPO, (2014). European patice office. European patent filings. http://www.epo.org/about-us/annual-reports-statistics/statistics/filings.html.
Faber, J., Hesen, A.B., 2004. Innovation capabilities of european nations: cross-national analyses of patents and sales of product innovations. Res. Policy 33 (2), 193–207.
Freeman, C., Perez, C., 1988. Structural crises of adjustment, business cycles and investment behaviour. In: Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., Soete, L. (Eds.), Technical Change and Economic Theory. London: Pinter.
Hall, P.A., Gingerich, D.W., 2009. Varieties of capitalism and institutional complementarities in the political economy: an empirical analysis. Br. J. Polit. Sci. 39 (3), 449–482.
Hall, P.A., Soskice, D., 2001. Varieties of Capitalism: The Institutional Foundations of Comparative Advantage. Wiley Online Library.
Hancké, B., Rhodes, M., Thatcher, M., 2007. Beyond Varieties of Capitalism: Contradictions, Complementarities and Change. Oxford University Press, Oxford.
Harcourt, M., Wood, G., 2007. The importance of employment protection for skill development in coordinated market economies. Eur. J. Ind. Relations 13 (2), 141–159.
Harhoff, D., Narin, F., Scherer, F.M., Vopel, K., 1999. Citation frequency and the value of patented inventions. Rev. Econ. Stat. 81 (3), 511–515.
Heckscher, E.F., 1919. The effect of foreign trade on the distribution of income. In: Flam, H., Flanders, J.M. (Eds.), Reprinted In: Heckscher-olin Trade Theory. The MIT press, Cambridge, MA.
Herrmann, A.M., Peine, A., 2011. When 'national innovation system'meet 'varieties of capitalism'arguments on labour qualifications: on the skill types and scientific knowledge needed for radical and incremental product innovations. Res. Policy 40 (5), 687–701.
Herrmann, A.M., 2008a. One Political Economy, One Competitive Strategy?: Comparing Pharmaceutical Firms in Germany, Italy, and the UK. Oxford University Press, USA.
Herrmann, A.M., 2008b. Rethinking the link between labour market flexibility and corporate competitiveness: a critique of the institutionalist literature. Socio-Econ. Rev. 6 (4), 637–669.
Hicks, A., Kenworthy, L., 1998. Cooperation and political economic performance in affluent democratic capitalism 1. Am. J. Sociol. 103 (6), 1631–1672.
Jackson, G., Deeg, R., 2006. How Many Varieties of Capitalism? Comparing the Comparative Institutional Analyses of Capitalist Diversity.
Jackson, G., Moerke, A., 2005. Continuity and change in corporate governance: comparing Germany and Japan. Corporate Gov. Int. Rev. 13 (3), 351–361.
Jaffe, A.B., Trajtenberg, M., Henderson, R., 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. Q. J. Econ. 108 (3), 577–598.
Jong, S., 2006. The development of Munich and Cambridge therapeutic biotech firms: A case study of institutional adaptation. In: EUI Working Paper, SPS no. 2006/10.
Johnston, J., DiNardo, J., 1997. Econometric methods. In: Jong, S. (Ed.), The Development of Munich and Cambridge Therapeutic Biotech Firms: A Case Study of Institutional Adaptation. EUI Working Paper, SPS No. 2006/10. , 4th ed. McGraw-Hill, New York.
Kirner, E., Kinkel, S., Jaeger, A., 2009. Innovation paths and the innovation performance of low-technology firms—an empirical analysis of German industry. Res. Policy 38 (3), 447–458.
Lange, K., 2009. Institutional embeddedness and the strategic leeway of actors: the case of the german therapeutical biotech industry. Socio-Econ. Rev. 7 (2), 181–207.
Laursen, K., 2000. Do export and technological specialisation patterns co-evolve in terms of convergence or divergence? Evidence from 19 OECD countries, 1971–1991. J. Evol. Econ. 10 (4), 415–436.
Leiponen, A., Drejer, I., 2007. What exactly are technological regimes?: intra-industry heterogeneity in the organization of innovation activities. Res. Policy 36 (8), 1221–1238.
Lundvall, B.A., 1992. User-producer relationships, national systems of innovation and internationalisation. In: National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning., pp. 45–67.
Lybbert, T.J., Zolas, N.J., 2014. Getting patents and economic data to speak to each other: an 'algorithmic links with probabilities' approach for joint analyses of patenting and economic activity. Res. Policy 43 (3), 530–542.
Mahmood, I.P., Singh, J., 2003. Technological dynamism in asia. Res. Policy 32 (6), 1031–1054.
Malerba, F., 2005. Sectoral systems. In: The Oxford Handbook of Innovation., pp. 380–406.
Mangematin, V., Lemarié, S., Boissin, J., Catherine, D., Corolleur, F., Coronini, R., et al., 2003. Development of SMEs and heterogeneity of trajectories: the case of biotechnology in france. Res. Policy 32 (4), 621–638.
Mokyr, J., 1990. The Lever of Riches: Technological Creativity and Economic Progress. Oxford University Press, Oxford.
Monti, M., 2010. A new strategy for the single market. In: Report to the President of the European Commission José Manuel Barroso, May, 10.
Nollert, M., 1998. Interlocking directorates in Switzerland: a network analysis. Schweizerische Zeitschrift Für Soziologie 24 (1), 31–58.
OECD, 2009. OECD Patent Statistics Manual. OECD Publishing, Paris.
OECD, 2011. ISIC REV. 3 Technology Intensity Definition Classification of Manufacturing Industries into Categories Based on R&D Intensities. OECD, Paris.
OECD, (2012a). Bilateral trade in goods by industry and end-use category. Retrieved March, 11, 2013, from www.oecd.org/sti/btd.
OECD, (2012b). Patents by technology. Retrieved March, 11, 2013, from http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC.
OECD, (2013a). OECD Citations database, version January 2013. Paris : OECD Directorate for Science, Technology and Industry.
OECD, (2013b). OECD REGPAT database, versions january 2013. Paris : OECD Directorate for Science, Technology and Industry.
OECD, (2015), Measuring Trade in Value Added: An OECD-WTO joint initiative http://www.oecd.org/sti/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.
Oesch, D., Menés, J.R., 2011. Upgrading or polarization? occupational change in britain, germany, spain and switzerland, 1990–2008. Socio-Econ. Rev. 9 (3), 503–531.
Ohlin, B., 1933. Interregional and International Trade. Cambrige. Harvard University Press, MA.
Porter, M.E., 1990. The Competitive Advantage of Nations. MacMillan Press, London.
Ricardo, D., 1821. On the Principles of Political Economy and Taxation. John Murray, London.
Rueda, D., Pontusson, J., 2000. Wage inequality and varieties of capitalism. World Politics 52 (3), 350–383.
Schmoch, U., Laville, F., Patel, P., Frietsch, R., 2003. Linking technology areas to industrial sectors. In: Final Report to the European Commission, DG, Research.
Schneider, M.R., Paunescu, M., 2012. Changing varieties of capitalism and revealed comparative advantages from 1990 to 2005: a test of the hall and soskice claims. Socio-Economic Review 10 (4), 731–753.
Schneider, M.R., Schulze-Bentrop, C., Paunescu, M., 2009. Mapping the institutional capital of high-tech firms: a fuzzy-set analysis of capitalist variety and export performance. J. Int. Bus. Stud. 41 (2), 246–266.
Schoenmakers, W., Duysters, G., 2010. The technological origins of radical inventions. Res. Policy 39 (8), 1051–1059.
Singh, J., Fleming, L., 2010. Lone inventors as sources of breakthroughs: myth or reality? Manage. Sci. 56 (1), 41–56.
Soete, L., 1987. The impact of technological innovation on international trade patterns: the evidence reconsidered. Res. Policy 16 (2–4), 101–130.
Soskice, D., 1990. Wage determination: the changing role of institutions in Advanced Industrialized societies. Oxf. Rev. Econ. Policy 6 (4), 36–61.
Streeck, W., Yamamura, K., 2001. The Origins of Nonliberal Capitalism: Germany and Japan in Comparison. Cornell University Press.
Streeck, W., 2010. E pluribus unum? Varieties and commonalities of capitalism. In: Max Planck Institute for the Study of Societies. MPIfG Discussion Paper No. 10/12.
Sturgeon, T., Van Biesebroeck, J., Gereffi, G., 2008. Value chains, networks and clusters: reframing the global automotive industry. J. Econ. Geogr. 8 (3), 297–321.
Sturgeon, T., 1997. Does manufacturing still matter? the organizational delinking of production from innovation. In: Berkeley Roundtable on the International Economy, Working Paper., pp. 92B.
Taylor, M.Z., 2004. Empirical evidence against varieties of capitalism's theory of technological innovation. Int. Organ. 58 (3), 601–631.
Thelen, K., 2012. Varieties of capitalism: trajectories of liberalization and the new politics of social solidarity. Annu. Rev. Polit. Sci. 15, 137–159.
Trajtenberg, M., 1990. A penny for your quotes: patent citations and the value of innovations. Rand J. Econ., 172–187.
Trampusch, C., Mach, A., 2011. Switzerland in Europe: Continuity and Change in the Swiss Political Economy. Taylor & Francis.
Trouille, J.M., 2011. Is the european project faltering? clash of capitalisms, economic nationalism and single market integration. In: Paper Presented at the EUSA Twelfth Biennial International Conference, Boston, March 3–5 2011, http://www.euce.org/eusa/2011/papers/2e_trouille.pdf.
USPTO, (2014) Calendar year patent statistics 2014 http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports_stco.htm.
Vanek, J., 1968. The factor proportions theory: the N-factor case. Kyklos 21, 749–756.
Yoshimori, M., 2005. Does corporate governance matter? Why the corporate performance of Toyota and Canon is superior to GM and Xerox. Corporate Gov. Int. Rev. 13 (3), 447–457.