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The Interdependence of Intellectual Property and Sales in the Manufacturing Industry: Evidence from the Triangle of Patents, Trademarks, and Sales

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The interdependence of intellectual property and sales in the manufacturing industry:

Evidence from the triangle of patents, trademarks, and sales

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Abstract

Firms often struggle with the successful commercialization of innovations, and there is a need for reliable predictors. Prior research suggests that intellectual property (IP) rights play a key role in the commercialization of innovations. However, to what extent can IP rights be used to predict successful commercialization of innovations in the manufacturing industry? Our paper studies the role of patents and trademarks and their complementary and substitutive relationships to predict commercialization success as measured by sales. We also analyze potential reciprocal relationships between commercial success and IP rights. The relationships are explored in a panel dataset of 2,617 German Mittelstand firms over a 10-year period. The results of a panel vector autoregressive model show a short-lived positive effect of patents on sales growth and vice versa. However, no significant effects are found between trademarks and sales growth. Finally, a positive and complementary relationship between patents and trademarks is documented.

Keywords: Innovation, Commercialization, Patents, Trademarks, Panel Vector Autoregression

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Jörn Block: Conceptualization, Writing - original draft, Supervision

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1. Introduction

In the realm of business and innovation, the successful commercialization of novel ideas remains a challenge for many firms as they struggle to protect their innovations and appropriate the benefits. The commercialization of innovations is a critical step for firms to generate profits by transforming innovations into tangible products that meet the needs and demands of consumers (Kirchberger & Pohl, 2016). Therefore, it is critical for firms to choose the right IP strategy to make the most of their innovations. Patents (e.g., Cohen, 2004; Mazzoleni & Nelson, 1998; Owen-Smith & Powell, 2001) and trademarks (e.g., Block et al., 2015; Castaldi, 2018; Flikkema et al., 2014) are a common method to protect innovations. In this regard, Colyvas et al. (2002) find that ownership of the technology facilitates successful commercialization, which highlights IP rights prediction power. Further, Shane and Stuart (2002) reported an increase in licensing of technologies when they are protected by a patent, showing the potential to appropriate innovation benefits using this strategy. Finally, Li et al. (2008) find evidence that successful commercialization is facilitated by CEOs ownership of the technology, for example, by holding a patent. Further positive effects of patents are also seen for employment (Buerger et al., 2012), firm growth (Coad & Rao, 2008), and macroeconomic growth (Frietsch et al., 2014). For trademarks, Malmberg (2005) and Mendonça et al. (2004) provide evidence that trademarks foster the successful commercialization of (high-tech) inventions in the manufacturing industry. Positive effects of trademarks are also seen for profitability (Ailawadi et al., 2003) and market valuation (Sandner & Block, 2011).

Although studies highlight the usefulness of patents and trademarks to appropriate innovation benefits, they have done it in a non-integrated manner. Research lacks evidence about a potential complementary versus substitutive relationship of patents and trademarks and their effect on sales over time. In case of a successful commercialization, the question arises which role the gained profit has when it comes to IP rights. One commonly held belief, reflected in the ‘success breeds success’ hypothesis, is that companies with higher levels of performance can allocate larger budgets and broaden their technological opportunities (Mansfield, 1968; Stoneman, 1983). The resulting anticipated temporal reciprocal effects of firm success on a firm’s patent and trademark portfolio is underexplored.

In this paper, we examine three research questions regarding the temporal relationships between patents, trademarks, and sales. First, we investigate to what extent patents and trademarks predict sales. Second, we examine the temporal relationship between patents and trademarks (i.e., does the relationship indicate a complementary or substitutive role in the commercialization process over time). Third, we investigate the reciprocal effect of commercial success on IP rights over time.

The present study uses quantitative data on patents, trademarks, and sales gathered from three distinct sources and applies a panel vector autoregressive (VAR) model to analyze the temporal interplay of the number of a firm’s patent applications, trademarks, and sales. We use a sample of 2,617 German Mittelstand firms from the manufacturing industry providing data on the yearly number of patent applications, trademarks, and sales spanning a 10-year period.

The results of our model show that patents predict successful commercialization better than trademarks. Filing for a patent is positively associated with sales growth in the following years. We also document that the relationship between IP rights is complementary rather than substitutive. Firms seem to not shy away from using both means of protection in their IP strategy instead of solely focusing on one. If a firm files for either, a patent or trademark, this is associated positively with filing for the other IP right. Our study also shows a positive reciprocal relationship between sales growth and patents over time. This implies that successful firms are able to bolster their IP portfolio.

Overall, our findings contribute to the literature on commercialization of innovations (e.g., Cohen, 2004; Kirchberger & Pohl, 2016; Owen-Smith & Powell, 2001). In particular, we advance the literature by combining patents, trademarks and sales in a VAR model. Previous studies, for example, explored patents and employment (Buerger et al., 2012) or R&D and sales (Coad & Grassano, 2019). We further advance this literature by including both patents and trademarks and establish more concrete predictions for the success of firms using the two most prominent types of IP rights at the firm level. Doing this we also contribute to the growing literature concerning the interplay between patents and trademarks (e.g., Grazzi et al., 2020; Llerena & Millot, 2020, Thoma, 2020). As we establish a VAR model, we can see the associations between the two IP rights not only immediately but evolving over time. This allows us to better understand the strategies and timing decisions behind IP rights. Advancing the discussion on the 'success breeds success' hypothesis (e.g., Buerger et al., 2012; Bartoloni & Baussola, 2018; Tavassoli & Karlsson, 2015), we broaden the spectrum of analysis by incorporating trademark data and linking success to patents and trademarks in a longitudinal analysis. Previous studies have often focused on time persistent effects in success and innovation variables like patents and R&D (e.g., Coad & Daunfeldt, 2018; Geroski et al. 1997; Manez et al., 2015). To the best of the authors' knowledge, trademarks are entirely missing in the discussion. By incorporating trademarks and analyzing reciprocal effects between patents, trademarks, and sales growth, we get a more complete picture of the 'success breeds success' cycles. We gain deeper knowledge of how this mechanism works as sales growth and IP rights portfolios influence one another persistently and reciprocally over time.

2. Background on patents and trademarks in commercialization

A crucial factor to appropriate the benefits of innovations are IP rights. Most common is the use of patents or trademarks (WIPO, 2022). The innovation process is often characterized by substantial investments, which are accompanied by considerable risks. To profit from the taken risk, firms must have suitable appropriation strategies in place. The diverse characteristics of innovations, especially patentability, make a one-size-fits-all approach for the appropriation of innovation returns impossible (Neuhäusler, 2012). Firms may focus on either product, process, service, or business model innovation or multiple of those according to their respective industry or business model. Accordingly, firms may use only one or a combination of means in their appropriation strategy (Llerena & Millot, 2020). The appropriation strategies are either to profit from innovations by using them in the own product or service, using a third party through for example licensing agreements, or indirectly by the production of complementary goods.

If the firm decides to use the innovation in their own product or service, or license it to a third party, then the firm usually applies for a patent if applicable. A patent grants the owner a time-limited exclusive right for the use of a certain invention in exchange for public disclosure of the invention in a specific country or region. Patents exclude competitors from the use of the innovation, thereby increasing their costs and strategically blocking them from the use of certain technological fields. Thereby innovative firms gain a competitive advantage through patenting of innovations. The competitive advantage offsets the substantial R&D investments and taken risks and thereby rewards the firm with growth and profitability. This rationale leads to a close link between technological innovations and patents, which is accompanied by a vast literature (e.g. Archibugi, 1992; Burhan et al., 2017; Mazzoleni & Nelson, 1998).

Beside patents, the use of trademarks is a common method for firms to appropriate the benefits of their innovations. Trademarks include word creations, pictures, visual elements, and sounds and thereby protect the brand as an image for firms, products, or services. The filing of a trademark brands a specific innovation. It protects the image of the brand and enables the buildup of the brand as a marketing asset. Trademarks have different characteristics than a patent. A trademark in contrast to a patent protects an image instead of a specific invention itself, therefore it is used differently (Neuhäusler, 2012). Hence, trademarks are more commonly used for service-, organizational-, and marketing innovations where patents are rarely applicable. These are often innovations with either a low or non-existent technological background (Millot, 2009). Apart from the use of trademarks for non-patentable innovations, trademarks are also used for patentable innovations. As trademarks protect marketing assets, they are also applied for innovations that are already protected via a patent. If these patented innovations are then branded in preparation for the commercialization phase, firms also often file a trademark (Flikkema et al., 2019; Llerena & Millot, 2020). Trademarks appropriate the innovation benefits through the protection and utilization of the brand image. The brand image is a competitive advantage for the firm, as the strong and positive image in the mind of the consumer leads to repeated purchase through perceived lower risk or higher value (Rao & Monroe, 1988; Romaniuk & Sharp, 2003). The described mechanisms link service-, organizational-, and marketing innovations, as well as technological innovations to the filing of trademarks. In comparison to the patent literature, the number of trademark studies is still less prominent but growing (e.g., Flikkema et al., 2014; Gotsch & Hipp, 2012; Mendonça et al., 2004). Castaldi (2020) highlights the association with reputational assets, market variables, firm capabilities, and industries. The relation between trademarks and firm growth, profitability and success in general is less researched than in the patent literature.

3. Hypotheses on the triangle of patents, trademarks, and sales

Patents, trademarks, and sales are connected through reciprocal relationships in a triangular. If either of them grows, it has a positive effect on the others and then in turn is positively influenced by their development.

3.1. Complementarity and substitutability of patents and trademarks

The appropriation strategy for innovation benefits is determined by factors, like the type of innovation, the industry, and the business strategy. Because of this variety, there is no clear link between patents and trademarks (Flikkema et al., 2015; Seip et al., 2018). As both concepts are most commonly used to appropriate innovation benefits, the question about their relationship rises. The appropriation strategy can be that patents and trademarks complement each other or that they have a substitutive relationship where either a patent or a trademark is used to protect the innovation.

Being different in their nature, both can complement each other to yield the most innovation benefits, which speaks for a complementary relationship. The combination of both would be the all-around protection strategy. On the product level, the combined use yields both the benefits of protecting the core of the invention via patent and the benefits of protecting the marketing assets via trademark (Llerena & Millot, 2020). On the firm level, the complementarity reflects the investments in technological innovations and marketing assets (Flikkema et al., 2019). Thoma (2020) shows the benefits of the combination of both IP rights as the patent value almost doubles by pairing patenting and trademarking activities. Reflecting on the commercialization processes in the manufacturing industry, a complementary relationship is suggested. In the manufacturing industry, innovations are often technological in nature, which makes patents applicable, while branding efforts can be supported by trademarks. Accordingly, our first hypothesis is as follows:

Hypothesis 1: There is a positive reciprocal relationship between patent growth and trademark growth over time.

3.2. The effects of patents and trademarks on sales

As previously described, a firm's IP rights portfolio and the firm performance have a close relationship. The IP rights portfolio is considered in terms of patents and trademarks and firm performance in terms of sales figures. Patents and sales as well as trademarks and sales are in a reciprocal relationship.

Following the steps of the classic innovation process, the R&D department develops an innovation that is then protected by filing for IP rights. Patents and trademarks help the firm in the appropriation of the innovation benefits in the commercialization process by protecting the core of the invention and all marketing assets related to branding the innovation. Therefore, patents and trademarks have a positive effect on sales of the firm. Looking at different objects of innovation, we can disentangle the effect of patents on sales and trademarks on sales. For service or marketing innovations with small relation to technology, trademarks are filed because patents are seldom applicable. The trademarks than have a positive influence on sales, as the innovation benefits are appropriated. Ailawadi et al. (2003) found positive effects on profitability for trademarking firms. In addition, Sandner and Block (2011) examined the positive effects of trademarks on market valuations of firms. Hence, we conjecture:

Hypothesis 2 (a): The growth of sales is positively related to previous growth of trademarks.

In case of product and process innovations, where technological innovations are often the core, patents are applied which have a positive impact on sales. The link between patents and firm measures is well documented. Coad and Rao (2008), for example, explore the effect of patents on firm growth and conclude that patents are of crucial importance for a handful of 'superstar' fast-growth firms. At a regional-level, Buerger et al. (2012) show the close positive interrelationships between patents, growth of employment, and R&D budgets in certain industries. In addition, at a macroeconomic-level Frietsch et al. (2014) examine close correlations between patents and their individual characteristics and the export performance of countries. Similar to hypothesis 2 (a), we conjecture:

Hypothesis 2 (b): The growth of sales is positively related to previous growth of patents.

3.3. The reverse effect of sales on patents and trademarks

Growing sales figures of firms also have reverse effects on their patent and trademark portfolio. These reverse effects are grounded in theory. The groundwork was laid by Phillips (1971) who argues that the success of a firm would set growing barriers for entry. Eventually a situation would arise where industries are primarily dominated by a few successful firms. These thoughts are reflected by Mansfield (1968) and Stoneman (1983) who argue the case for successful innovating firms. They describe that these firms can broaden their technological opportunities based on their previous success. This in turn bolsters their patent and trademark portfolio, which makes the following commercialization success more likely. Hence, a cycle of success arises. Mansfield's (1968) 'success breeds success' hypothesis describes firms being persistently successful, in this case through persistent innovation activity. Previous studies have focused on time persistent effects in sales growth (Coad & Daunfeldt, 2018) and innovation variables like patents and R&D (e.g., Geroski et al. 1997; Manez et al., 2015). Looking deeper into the mechanisms behind the 'success breeds success' hypothesis, innovations are patented and trademarked, which drive the firm performance and the growth of firm budgets. This leads to a larger IP budget and increased internal funding for patents and trademarks. The positive cycle is then closed, as the patents and trademarks facilitate more commercialization success. Therefore, 'success breeds success' hypothesis, when examined closely, reflects on the interrelationships of patents, trademarks, and sales, their dynamics, and the positive or negative cycles of firm performance that can arise.

What becomes clear is that there are no one-way relationships or paths. The dynamics between patents, trademarks and sales lead to a positive cycle of growth where an ever-growing sales performance leads to more patents and trademarks. A successful firm could thereby always stay competitive. However, caution must be taken, as external effects could have long lasting effects on the dynamics in the triangle. As for example sales performance is decreased by some external factor, the manager can be forced to cut budgets. The reduction leads to less patents and trademarks. This would harm the competitiveness of the firm and have a negative effect on the sales performance. This describes how the dynamics in the triangle can manifest in a positive or negative cycle. Accordingly, our final set of hypotheses is as follows:

Hypothesis 3 (a): The growth of trademarks is positively related to previous growth of sales.

Hypothesis 3 (b): The growth of patents is positively related to previous growth of sales.

4. Data and econometric methodology

4.1. Data

We gathered quantitative data from three distinct sources and combined these at the firm level. First, we use the Orbis database (Bureau van Dijk) to generate a sample of firms. The initial sample obtained from Orbis includes 10,765 firms that match the following search criteria: (1) active as of September 2020; (2) located in Germany; (3) primary NACE code between 20 and 30 (manufacturing industry); (4) number of employees between 50 and 2,999; (5) at least ten years old; (6) not a subsidiary, foreign firm, non-profit firm, or public organization. The sample refers to a wide range of different manufacturing industries that are mostly research-intensive. Limiting firm age and the number of employees prevents us from including startups, which reflects our focus on established, mid-sized firms (e.g., European Commission, 2003; Institut für Mittelstandsforschung (IfM) Bonn, 2016; Röhl, 2018). Next, we obtain the sales figures of each firm over ten years from 2010 to 2019. As the sales figures provided by Orbis are not complete, we use only firms with a minimum of six waves between 2010 and 2019. For the remaining firms, we use linear time series models to interpolate singular missing data points. This results in a balanced panel for 2,617 firms.

To gather patent information for each firm in each year, we rely on the patent database PATSTAT, which is provided by the European Patent Office (EPO). Patents are identified by comparing firm names provided by Orbis with the harmonized and original names of patent applicants provided by PATSTAT. We further gather data on trademarks from the DPMA (German patent and trademark office) for each firm in each year. Only trademarks with protective rights in Germany are covered. Trademarks are identified by using firm names provided by Orbis and the online trademark search function provided by the DPMA.

As result of the identification processes, we generated two datasets with trademarks and patent applications whose applicants could potentially match the firms of our initial sample. Sales, patent, and trademark information is matched at a firm-level basis using approximate address and name comparisons following the approach by Willeke et al (2023). The final sample consists of annual sales, patent, and trademark information of 2,617 firms over the period 2010–2019. The panel dataset is arranged in the long format and strongly balanced.

4.2. Econometric methodology

Since the existing literature and our framework are inconclusive about one-way (causal) directions from, say, patents to sales, we employ a panel vector autoregressive approach with three endogenous variables. Our general specification is based on Holtz-Eakin et al. (1998) and can be represented as follows:

$$\boldsymbol{y}_{i,t} = \boldsymbol{\alpha}_i + \sum_{l=1}^{p} \boldsymbol{A}_l \boldsymbol{y}_{i,t-l} + \varepsilon_{i,t} \quad (1)$$

$\boldsymbol{y}_{i,t}$ is a $3 \; x \; 1$ vector of endogenous variables for the cross-sectional unit i at time t and $\boldsymbol{\alpha}_i$ are firm-specific effects capturing time-invariant unobserved heterogeneity. $\boldsymbol{A}_l$ are $3 \; x \; 3$ parameter matrices and $\varepsilon_{i,t}$ is the $3 \; x \; 1$ vector of i.i.d. errors with $E[\varepsilon_{i,t}] = 0$ and $Var[\varepsilon_{i,t}] = \boldsymbol{\Sigma}_\varepsilon$ with $\boldsymbol{\Sigma}_\varepsilon$ being a positive semi-definite matrix. We remove the fixed effects $\boldsymbol{\alpha}_i$ with the help of a forward orthogonal transformation (Arellano & Bover, 1995), where the mean of all future observations in the sample is subtracted from $\boldsymbol{y}_{i,t}$ for each firm and each point in time.[1]

We estimate three different specifications. In the baseline specification, we employ the natural logarithm of trademarks, the natural logarithm of patents, and the log differences of sales as endogenous variables.[2] We apply this specification on the full (imputed) dataset as well as the original (non-imputed) dataset. As first extension, we estimate an 'extensive margin'-type model for trademarks and patents. That is, we estimate a linear probability model with two dummy variables for trademarks and patents; these take the value 1 if a firm registers at least one trademark (one patent) in a given year, and zero otherwise. Sales enter this second specification again in log differences. As second extension, we replicate the baseline model but restrict the sample to those firms that have registered at least one trademark or patent during our period of study. This can be interpreted as 'intensive margin'-type model.

We set $l = 2$ and, hence, employ two lags. This marks a good compromise between capturing the dynamics of the three endogenous variables, while at the same time being as parsimonious as possible given the short time series dimension of our dataset. To avoid potential issues with too many instruments (Roodman, 2009), we restrict the number of lags

[1] Note that applying first differences is equivalent to the forward orthogonal transformation in the case of a balanced panel. However, in one of our robustness tests we rely on the original dataset with a lot of missing values. In such an unbalanced panel, the forward orthogonal transformation minimizes the loss in data as compared to forming first differences.

[2] In the case of trademarks and patents, we employ a "log plus one" transformation to avoid data losses. Non-differencing log sales leads to a violation of the stability condition of the panel VAR and non-stationary impulse response functions.

for instrumenting to 2. Following the idea of Blundell and Bond (1998), we estimate the stationary panel VAR using the system GMM estimator where the model is additionally estimated in levels. Lastly, we apply the Windmeijer (2005) two-step estimator as a small sample correction. All resulting panel VAR models are found to be stable.

One problem with the estimation of Eq. (1) is the potential correlation of the error terms across equations. Without a proper identification of the reduced-form panel VAR, we are not able to calculate the contemporaneous effects of, for example, patents on sales, as potentially the other variable (i.e., trademarks) co-moves with the changes in patents. One solution to this issue is the calculation of so-called generalized impulse responses (Pesaran & Shin, 1998):

$$GIRF(k, r, \boldsymbol{\Sigma}_\varepsilon) = E\left[\boldsymbol{y}_{i,t+k} \middle| \varepsilon_{i,t,r} = \delta_r, \boldsymbol{\Sigma}_\varepsilon\right] - E\left[\boldsymbol{y}_{i,t+k} \middle| \boldsymbol{\Sigma}_\varepsilon\right] \quad (2)$$

k is the number of periods after the shock to the rth component of $\varepsilon_{i,t}$ and $\boldsymbol{\Sigma}_\varepsilon$ is the variance covariance matrix of $\varepsilon_{i,t}$. The generalized mean impulse response is then the difference between the expected value of $\boldsymbol{y}_{i,t+k}$ with a shock $\delta_r = \sqrt{\boldsymbol{\Sigma}_{\varepsilon,r,r}}$ in place and the historically observed distribution of the errors.[3] The bootstrapping procedure for the confidence bands of the generalized impulse responses follows Kapetanios (2008).

5. Results

The following discussion focuses on the impulse response functions since the individual coefficients of a VAR model are difficult to interpret due to the potentially offsetting effects of the different lags. In addition, the coefficients only show lagged effects of, say, patents on sales. Nevertheless, Tables A1 - A4 in the Appendix display all coefficients, their standard errors and significance, and the test for overidentifying restrictions.

[3] An alternative would be a recursive identification using a Cholesky decomposition. However, this requires zero restrictions on three of the nine contemporaneous impulse response functions. For example, we could allow for a contemporaneous effect of trademarks on patents, but then we would have to rule out the opposite instantaneous reaction.

5.1. Baseline specification

Fig. 1 shows the generalized impulse responses for the baseline specification and the imputed dataset. Black lines show the mean IRFs to a 100% (one unit) shock in trademarks (upper panel), a 100% (one unit) shock in patents (middle panel), and a 10% (0.1 units) shock in sales (lower panel). Gray-shaded areas indicate 95% confidence bands. The x-axis represents the number of years since the shock.

The IRFs on the main diagonal represent the response of the variable to itself, that is, the degree of persistence of the shocks. Shocks to trademarks vanish quicker than shocks to patents, but both IRFs eventually die out. One year after a shock in sales, this variable turns negative, indicating a much lower degree of persistence in this variable. However, this is due to the specification of sales as log difference variable, as a model with this variable in log levels would yield a non-stable VAR with non-stationary IRFs.

Trademarks and patents are reinforcing each other. A 100% increase in trademarks leads to a 14.1% increase in patents that dies out slowly over time. The corresponding increase in patents leads to a 9.4% rise in trademarks that becomes insignificant after two years. Sales and trademarks exert no significant effect on each other. A shock to patents exerts a short-lived positive effect on sales, albeit a very small one with 1.4% after a 100% shock. Lastly, a 10% shock to sales also exerts a short-lived and small positive influence on patents by 0.5%.

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Figure 1 about here

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Fig. A1 in the Appendix shows the corresponding IRFs for the non-imputed dataset. These are qualitatively very similar to the results in Fig. 1. However, the range of the confidence bands is substantially larger (except for the responses of the variables to themselves), highlighting one benefit of imputing the missing observations in sales, that is, an increase in estimation efficiency. The relationship between patents and trademarks is also quantitatively similar to that in Fig. 1. The only noticeable difference to the model using the imputed dataset is for the sales-patents pair. The effect of sales on patents is almost three times larger in Fig. A1 (1.4% after 10% shock in sales) and dies out very slowly. A 100% shock in patents leads to an increase in sales by 4.4%, which however is quickly reversed one year after the shock.

5.2. Extensions

Fig. 2 shows the results for the 'extensive margin' model. Here, the IRFs are for a 100pp (one unit) shock in the probability to register a trademark (upper panel), a 100pp (one unit) shock in the probability to register a patent (middle panel), and a 10% (0.1 units) shock in sales (lower panel). The following discussion focuses on the results outside the main diagonal.

Trademarks and patents are reinforcing each other in this specification, too. A 100pp increase in the probability to register a trademark leads to a 15.1pp increase in the probability to register a patent. The corresponding increase in patents leads to an 11.5pp rise in the probability to register a trademark. Both responses die out quickly. Sales and trademarks once more exert no significant effect on each other. Lastly, the qualitative relationship between sales and trademarks from Fig. 1 is also replicated in this extension. A shock to the probability to register a patent exerts a short-lived positive effect on sales (0.4% after a 100pp shock). Lastly, a 10% shock to sales also exerts a short-lived and small positive influence on the probability to file a patent by 1.9pp.

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Figure 2 about here

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Fig. 3 shows the results for the 'intensive margin' model. Similar to Fig. 1, black lines show the mean IRFs to a 100% (one unit) shock in trademarks (upper panel), a 100% (one unit) shock in patents (middle panel), and a 10% (0.1 units) shock in sales (lower panel). However, the sample is now restricted to firms that have registered at least one trademark or patent during the period of our study. The following discussion again focuses on the results outside the main diagonal.

Trademarks and patents are reinforcing each other once more, but the effects are smaller as compared to the sample of all firms (Fig. 1). A 100% increase in trademarks leads to a 6.8% increase in patents that dies out slowly over time. The corresponding increase in patents leads to a 4.8% rise in trademarks that quickly becomes insignificant. Shocks in sales and trademarks exert no significant effect on each other. A shock to patents exerts a small and short-lived positive effect on sales (0.5% after a 100% shock). Lastly, a 10% shock to sales also exerts a short-lived and small positive influence on patents by 0.7%.

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Figure 3 about here

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6. Discussion

There are some key results of the VAR models with respect to the proposed framework of the triangle of patents, trademarks, and sales, which are depicted in Fig. 4. First, the observed positive effect of patents on trademarks and vice versa, which supports hypothesis 1. Second, the short-lived positive effect of patents on sales growth and vice versa, which supports hypotheses 2b and 3b. Third, the absence of an effect of trademarks on sales growth and vice versa, which means that hypotheses 2a and 3a are not supported.

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Figure 4 about here

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As expected on the grounds of previous research and theoretical mechanisms, patents have a positive effect on trademarks and vice versa (H1). The results underline the positive dynamics in the use of patents and trademarks by firms. Rather than being of a substitutive nature, where innovations are protected by a patent or a trademark, the results highlight the complementary relationship of both. Here both are used together in order to drive successful commercialization. The results indicate that patents and trademarks are mutually beneficial due to their unique features. Traditionally appropriation strategies for the commercialization of innovations would suggest protecting technological innovations through patents, while low or non-technological innovations, especially service-, organizational-, and marketing innovations, are protected via trademark (Castaldi, 2020; Millot, 2009). Our results suggest that patents and trademarks do not have a simple substitutive 'either or'-relationship, but a more complex reinforcing complementary relationship. This type of relationship was previously explored at the product- and firm-level. At the product-level, Llerena and Millot (2020) highlight the complementary relationship with the protection of the core of the invention via patent and the marketing assets for the product via trademark. In accordance with our study at the firm level, Flikkema et al. (2019) show the complementarity in the use of patents and trademarks as a reflection of a firm's investment in technological innovations and marketing assets in general. Our results add to the discussion that patents and trademarks are in a reciprocal relationship. In all VAR models and extensions, the application of a patent had a positive effect on the filing of a trademark in later periods and vice versa.

The traditional commercialization process reflects on one side of this reciprocity where an initial patent is followed by a trademark. Here, the patent is followed by the firm building marketing assets and protecting them via trademark (Llerena & Millot, 2020). However, the reciprocity in our findings also highlight the opposite path as the occurrence of trademarks positively influences patents. One possible underlying scenario could be that a possible preceding innovation is not yet patentable. The firm can already file for a trademark and start preparing their marketing activities to build a brand and commercialize the innovation later. Parallel to these activities, the R&D department can finish the innovation process and apply for a patent. As the commercialization begins, both means to appropriate the innovation benefits would be ready. This process would explain the positive effect of trademarks on patents. The innovation process seems to be more flexible in order to commercialize. To fit the situation the commercialization process can be adapted.

Following the proposed reasoning of commercialization and the 'success breeds success' hypothesis, patents and sales growth have a short-lived but positive effect on each other (H2b and H3b). The protective mechanism of a patent allows the firm to offset their substantial R&D expenditures and gain a competitive advantage. A firm can only profit from the commercialization of the innovation and its competitive advantage for a short amount of years as the value of the patent significantly decreases. One reason for this is that the firm must publicly disclose the information related to the innovation and competitors can access the information. Competitors are not able to use it; however, they can try to work around the patent without infringing the IP rights of the patent holder. In addition, they could build upon the innovation publicly disclosed in the patent and create an innovation of their own. These arguments could be possible explanations for the existing but short-lived positive effect of patents on sales growth. Similar findings are also found by Buerger et al. (2012) whose VAR model shows at a regional level that an increase in patents is associated with growth of employment in the medical and optical equipment industry as well as in the electrics and electronics industry. With respect to the latter, the growth of patents is also associated with subsequent growth of R&D.

The reciprocity in the results also reflects on the effect of sales growth on patents and the 'success breeds success' hypothesis. Firms with a higher sales growth apply more patents, but in contrast to the reciprocal effect of patents and trademarks, the effect is rather short-lived (H3b). One explanation could be that budgets are allocated differently after some time. The focus of managers could change from investing into the IP department to investments in other parts of the business. In addition, the successful firm could decide, to reward its investors by paying higher dividends. Another explanation could be that if the business is currently well running, the management could not see any reason to invest more. Rather than building upon the achieved success and invest in IP, the management could be in a position where they do not want to lose their comfortable position and what they have achieved. They avoid the risk and do not invest more and focus on skimming the market with the previously achieved competitive advantage.

All these mechanisms, strategies and reasons point to a dangerous development for firms, where they no longer benefit from a 'success breeds success' situation. If a firm neglects important investments during successful periods, it lacks behind in the future. The firm could lose its competitive advantage and position in the market and be overtaken by competitors. Interestingly Coad and Rao (2010) find as a result of their panel VAR model that firms increase their R&D expenditures following a growth in sales over up to three years. This stands in contrast to the more short-lived effect of sales growth on R&D in our analysis.

The effect of sales growth on trademarks and vice versa is smaller than with patents (H2a and H3a). This underlines that patents and trademarks have different characteristics and serve different purposes in the commercialization process. One explanation could be the special dynamics of German Mittelstand firms from the manufacturing industry in the commercialization of their innovations. Many of these firms operate as a B2B business, which perceive social media marketing and branding less effective (Iankova et al., 2019), and therefore invest less. The customers in this industry are well informed. They either already have their opinions or are in a rational decision-making mode and are not accessible for marketing efforts. Consequently, firms from the manufacturing sector could decide to invest less in their marketing compared to other industries. This highlights the minor importance of trademarks in the commercialization process of innovations in the manufacturing industry. In addition, the manufacturing industry delivers more technological innovations (protected via patent) as compared to service-, organizational-, and marketing innovations (protected via trademarks) (Millot, 2009). Therefore, the missing reciprocal effect of sales growth on trademarks partly contradicts the ‘success breeds success’ hypothesis derived from Mansfield (1968) and Nelson and Winter (1977).

7. Conclusions

In this paper, we addressed three research questions. Our first research question asked to what extent patents and trademarks predict the commercialization success in terms of sales growth. While the second research question asked if the relationship between patents and trademarks is of a complementary or substitutive nature, the third investigated the reciprocal effect of commercialization success on IP rights. The results show clear positive associations between patents and trademarks, which persistent for several periods after a shock. Patents and sales growth also show a positive connection. Already in the first period after a shock in patents, sales growth is positively affected. Reciprocally, a positive shock in sales growth also has positive effect on patents. In contrast to the relationship between patents and trademarks, the positive reciprocal effects between patents and sales growth expires after a few periods. Trademarks and sales feature shared no associations.

The results of the analysis entail theoretical and empirical implications. Patents predict sales growth better than trademarks. This evidence for successful commercialization of innovations by patents is also reflected in the literature (e.g., Li et al., 2008; Shane & Stuart, 2002). However, the effect of patents on sales growth is only short-lived and runs out after a few periods. These results imply a short, but immediate and strong boost in sales growth from patents, in comparison to trademarks, which fall short in this scenario. Our findings on trademarks imply that patents are better suited as a predictor for sales growth than trademarks. This shows that no direct association between trademarks and commercialization success can be drawn, and the positive effect of trademarks is only found in combination with patents. Patents and trademarks are closely related. Their relationship is reciprocal and complementary, rather than substitutive. A positive (or negative) shock in patents leads to an immediate long-lasting positive (or negative) development in trademarks and vice versa. This shows that the commercialization process of innovations must be understood as a flexible structure as both directions are possible. A shock in sales growth does partially lead to growth in IP rights; while it has no effect on trademarks, it is closely associated with patents. This implies that commercialization success leads to bolstered budgets for IP departments, particularly for the application of patents. This reciprocal relationship is positive for the persistent success of the firm. The 'success breeds success' hypothesis (Mansfield, 1968) is therefore partially supported by the results.

Some managerial implications can be drawn from the results. Managers should focus on patents as the primary way to commercialize their innovations. Trademarks should be used if the firm is willing to put a genuine effort in the marketing strategy to leverage the trademark. Marketing representatives must find better strategies and invest more to leverage the potential of trademarks. This way trademarks can be built to be a marketing asset for the firm. Managers should also be aware that commercialization of innovations through IP rights and financial success are closely linked through patents and sales growth in a reciprocal relationship. This relationship can be used by managers to steer their business into a positive cycle of growth. On the other hand, external shocks should be monitored because they could break the positive cycle or even turn it negative through budget cuts.

The paper has several limitations that provide guidance for further research. First, the analysis was conducted at the firm level. A further analysis on the reciprocal relationship of patents and trademarks on product level could prove fruitful as a clearer connection could be drawn between the IP rights. Second, the period was restricted to the years 2010 to 2019. This can be considered a short time frame considering the development of innovations and growth of firms. A longer observation period would provide the possibility to explore the relationships and dynamics in the triangle more deeply. It would also serve to study the 'success breeds success' hypothesis more in depth. Third, only sales growth was considered as a measure of firm performance. To generalize the results, different measures of firm performance like ROE, ROA, ROS or market capitalization could be tested. Fourth, the sample consists of manufacturing firms. A fruitful avenue for further research could be the implementation of firms from other industries. This could affect the relationships and dynamics in the triangle, in particular for trademarks. Fifth, the theoretical model of the triangle includes patents, trademarks, and sales growth. To better grasp the dynamics of the commercialization processes of innovations, as well as their funding, the model could be extended. A possible extension could be a square model in which the R&D budget is included as a fourth construct, connecting to patents, trademarks, and sales growth.

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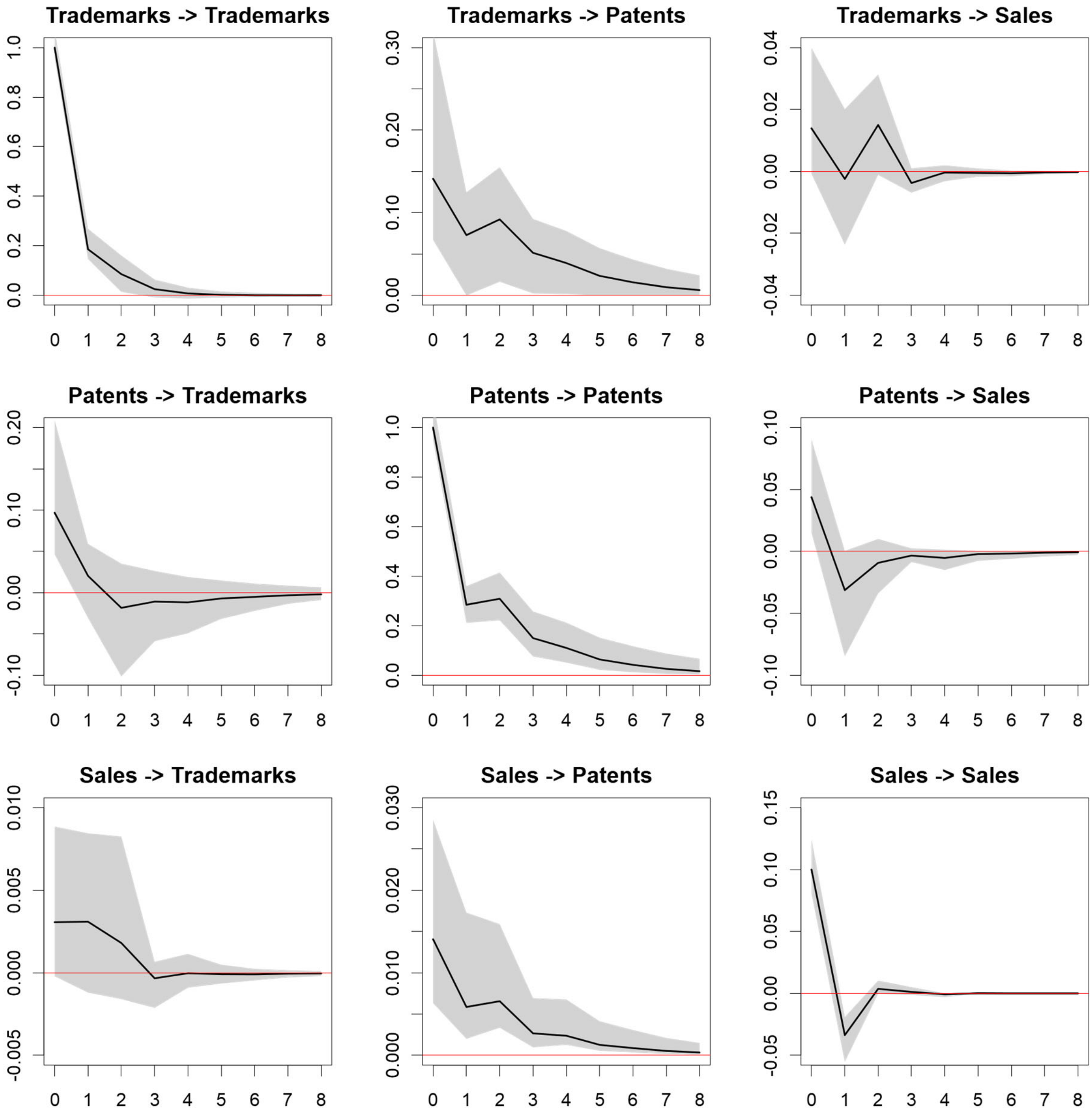
Appendix

Fig. A1 Impulse Responses for Robustness Test with Baseline Specification (Original Dataset)



Notes: Black lines show mean generalized impulse responses to a 100% (one unit) shock in trademarks (upper panel), a 100% (one unit) shock in patents (middle panel), and a 10% (0.1 units) shock in sales (lower panel). Gray-shaded areas indicate 95% confidence bands. The x-axis represents the number of years since the shock.

Table A1 Coefficients for Baseline Specification (Imputed Dataset)

	Log(TM)	Log(Pat.)	ΔLog(Sales)
$Log(Trademarks)_{t-1}$	0.1471**	0.0415	-0.0016
	(0.0274)	(0.0225)	(0.0066)
$Log(Patents)_{t-1}$	0.0107	0.2759**	0.006
	(0.0192)	(0.0334)	(0.0070)
$\Delta Log(Sales)_{t-1}$	0.0011	0.0043	-0.2457**
	(0.0161)	(0.0190)	(0.0482)
$Log(Trademarks)_{t-2}$	0.0467*	0.0232	0.0059
	(0.0231)	(0.0188)	(0.0057)
$Log(Patents)_{t-2}$	-0.0013	0.2032**	-0.0009
	(0.0162)	(0.0245)	(0.0070)
$\Delta Log(Sales)_{t-2}$	0.0085	-0.0038	-0.0953**
	(0.0141)	(0.0222)	(0.0261)
Constant	0.1043**	0.1717**	0.0462**
	(0.0143)	(0.0202)	(0.0052)

Notes: **/* indicates significance at 1%/5% level. Hansen test for over-identifying restrictions: $Chi^2(9) = 14.46$ [0.107]. Observations: 13355. Groups: 2671.

Table A2 Coefficients for Robustness Test with Baseline Specification (Original Dataset)

	Log(TM)	Log(Pat.)	ΔLog(Sales)
$Log(Trademarks)_{t-1}$	0.1848**	0.0329	0.0046
	(0.0412)	(0.0321)	(0.0097)
$Log(Patents)_{t-1}$	0.0014	0.2806**	-0.017
	(0.0312)	(0.0506)	(0.0136)
$\Delta Log(Sales)_{t-1}$	0.025	0.018	-0.3354**
	(0.0196)	(0.0348)	(0.0600)
$Log(Trademarks)_{t-2}$	0.0543	0.0334	0.0175
	(0.0357)	(0.0287)	(0.0091)
$Log(Patents)_{t-2}$	-0.028	0.2246**	-0.0134
	(0.0272)	(0.0404)	(0.0110)
$\Delta Log(Sales)_{t-2}$	0.023	0.0216	-0.0746
	(0.0204)	(0.0302)	(0.0402)
Constant	0.1141**	0.1664**	0.0567**
	(0.0236)	(0.0325)	(0.0097)

Notes: **/* indicates significance at 1%/5% level. Hansen test for over-identifying restrictions: $Chi^2(9) = 4.81$ [0.850]. Observations: 5801. Groups: 2671.

Table A3 Coefficients for Extensive Margin (Trademarks/Patents Yes/No)

	TM(Yes/No)	Pat.(Yes/No)	ΔLog(Sales)
Trademark(Yes/No)$_{t-1}$	0.1100**	0.0074	-0.0006
	(0.0194)	(0.0167)	(0.0075)
Patent(Yes/No)$_{t-1}$	0.0138	0.1158**	0.0018
	(0.0175)	(0.0223)	(0.0102)
ΔLog(Sales)$_{t-1}$	0.0028	-0.0091	-0.2402**
	(0.0151)	(0.0152)	(0.0483)
Trademark(Yes/No)$_{t-2}$	0.0215	-0.0018	0.0087
	(0.0172)	(0.0144)	(0.0058)
Patent(Yes/No)$_{t-2}$	0.0015	0.1070**	-0.0028
	(0.0157)	(0.0211)	(0.0094)
ΔLog(Sales)$_{t-2}$	0.0075	0.0047	-0.0928**
	(0.0125)	(0.0135)	(0.0253)
Constant	0.0983**	0.1854**	0.0479**
	(0.0094)	(0.0118)	(0.0053)

Notes: **/* indicates significance at 1%/5% level. Hansen test for over-identifying restrictions: $Chi^2(9) = 12.56$ [0.184]. Observations: 13355. Groups: 2671.

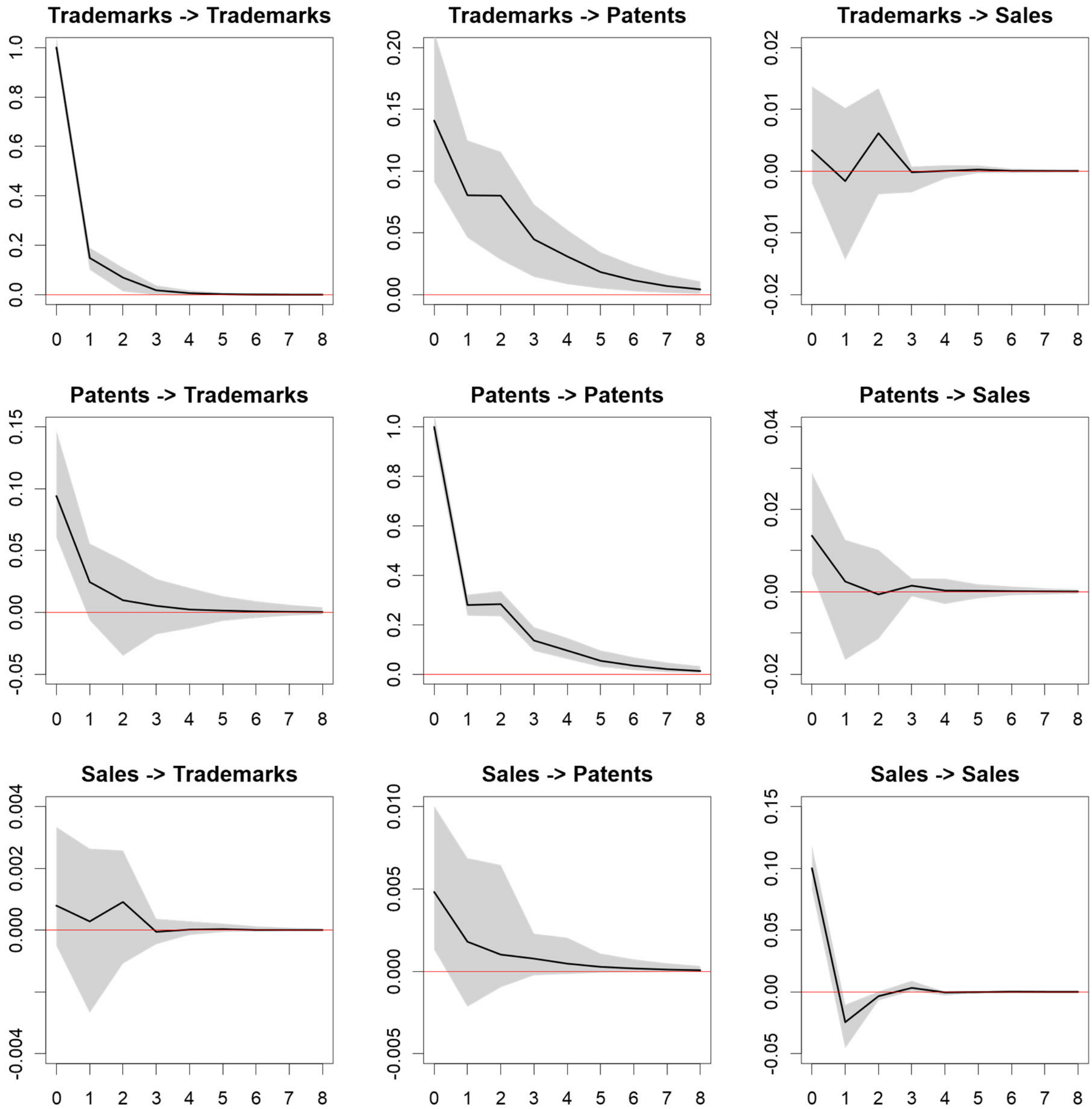
Table A4 Coefficients for Extensive Margin (Firms with Patents/Trademarks only)

	Log(TM)	Log(Pat.)	ΔLog(Sales)
Log(Trademarks)$_{t-1}$	0.1491**	0.0450*	-0.0014
	(0.0268)	(0.0218)	(0.0066)
Log(Patents)$_{t-1}$	0.0229	0.2930**	0.0054
	(0.0178)	(0.0303)	(0.0066)
ΔLog(Sales)$_{t-1}$	-0.0045	0.0055	-0.2732**
	(0.0250)	(0.0295)	(0.0634)
Log(Trademarks)$_{t-2}$	0.0473*	0.0247	0.0059
	(0.0229)	(0.0187)	(0.0057)
Log(Patents)$_{t-2}$	0.0052	0.2135**	-0.0009
	(0.0155)	(0.0231)	(0.0068)
ΔLog(Sales)$_{t-2}$	0.0071	-0.0067	-0.0828*
	(0.0217)	(0.0319)	(0.0338)
Constant	0.1739**	0.2868**	0.0485**
	(0.0234)	(0.0323)	(0.0080)

Notes: **/* indicates significance at 1%/5% level. Hansen test for over-identifying restrictions: $Chi^2(9) = 14.17$ [0.116]. Observations: 7520. Groups: 1504.

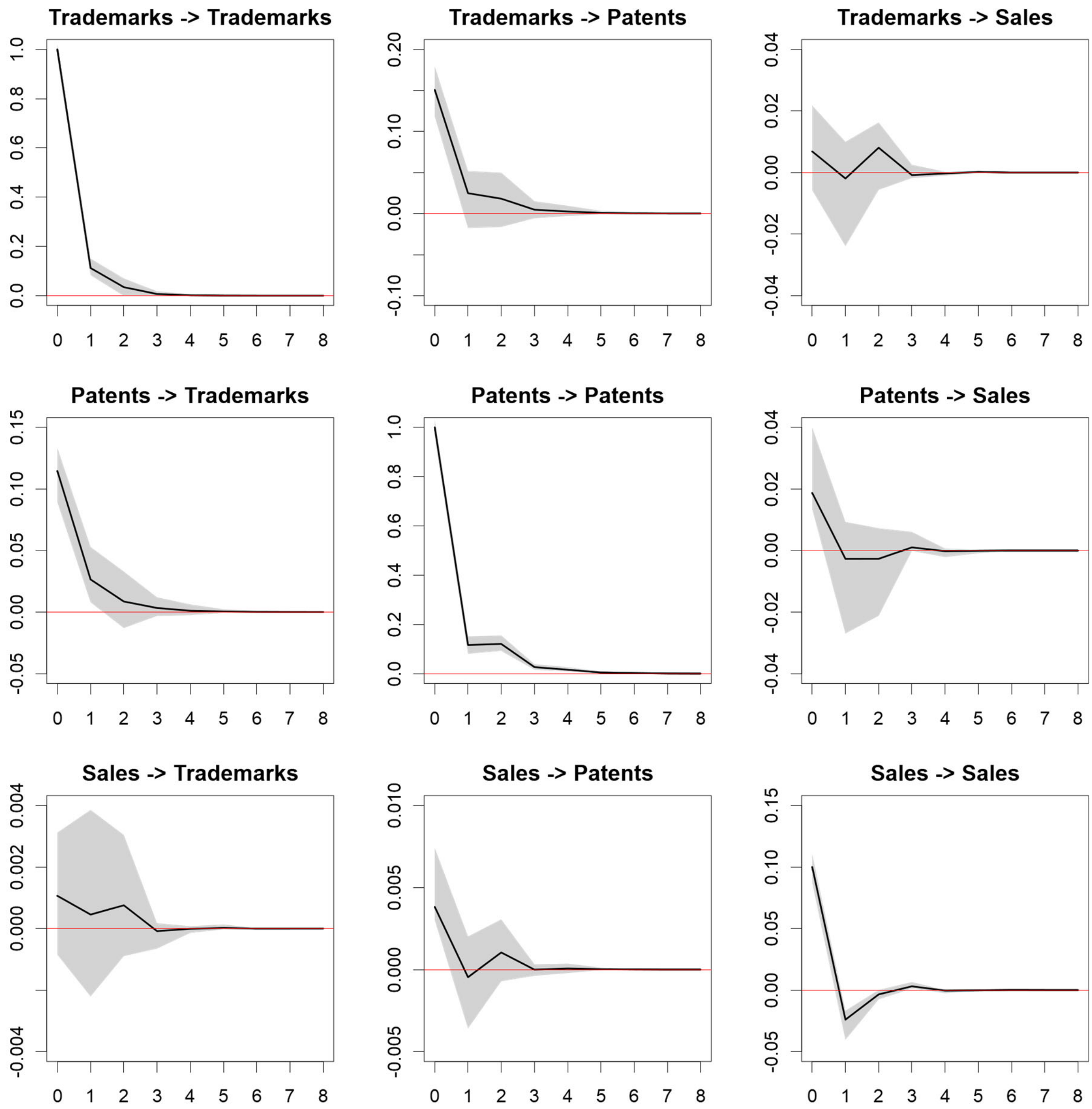
Figures

Fig. 1 Impulse Responses for Baseline Specification (Imputed Dataset)



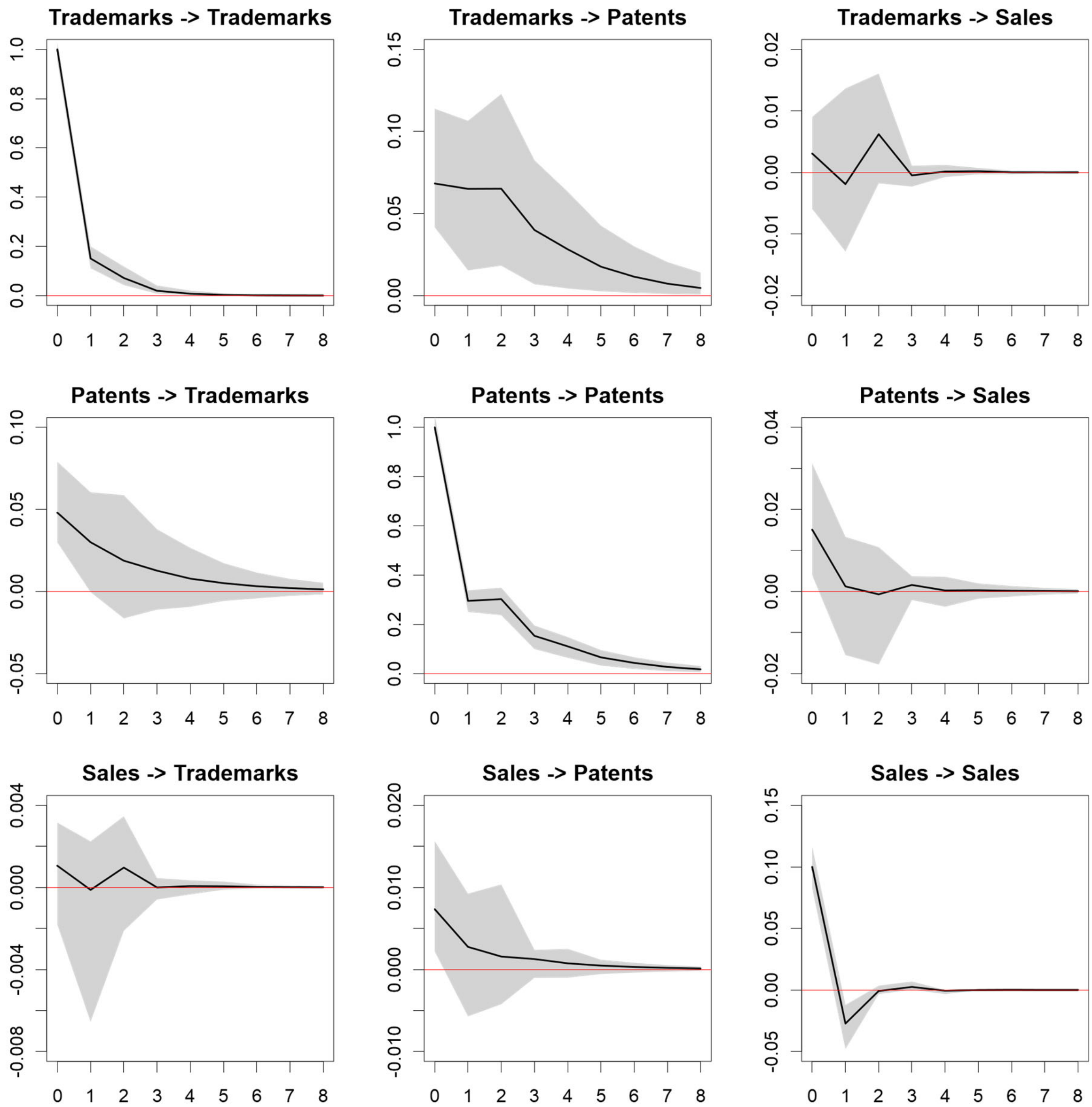
Notes: Black lines show mean generalized impulse responses to a 100% (one unit) shock in trademarks (upper panel), a 100% (one unit) shock in patents (middle panel), and a 10% (0.1 units) shock in sales (lower panel). Gray-shaded areas indicate 95% confidence bands. The x-axis represents the number of years since the shock.

Fig. 2 Impulse Responses for Extensive Margin (Trademarks/Patents Yes/No)



Notes: Black lines show mean generalized impulse responses to a 100pp (one unit) shock in the probability to register a trademark (upper panel), a 100pp (one unit) shock in the probability to register a patent (middle panel), and a 10% (0.1 units) shock in sales (lower panel). Gray-shaded areas indicate 95% confidence bands. The x-axis represents the number of years since the shock.

Fig. 3 Impulse Responses for Intensive Margin (Firms with Patents/Trademarks only)



Notes: Black lines show mean generalized impulse responses to a 100% (one unit) shock in trademarks (upper panel), a 100% (one unit) shock in patents (middle panel), and a 10% (0.1 units) shock in sales (lower panel). Gray-shaded areas indicate 95% confidence bands. The x-axis represents the number of years since the shock.

Fig. 4 Results for the triangle of patents, trademarks, and sales