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The Impact of M&As on Drug Development

Hendrik Meder
KU Leuven & Boston University
MSI (KU Leuven), Strategy & Innovation (BU)
hendrik.meder@gmail.com

Abstract

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Hendrik Meder, KU Leuven, Belgium & Boston University, United States
4th year PhD Student, expected graduation December 2015
hendrik.meder@kuleuven.be, hmeder@bu.edu, hendrik.meder@gmail.com
For competition policy and managerial economics it is of substantial interest to examine and to understand the impact of mergers and acquisitions (M&As) on innovation and product variety. Most empirical studies, examining the effects of M&As on innovation, focus on R&D expenditures and patent counts on ï¬•rm-level and use non-merging ï¬•rms as a control group and show ambiguous results. In contrast, our study is concerned about rivalsâ?? strategic reactions in terms of innovation to a merger in a market because rivalsâ?? reactions have received little attention in competition policy and research on the effects of M&As so far. We aim to analyse outsidersâ?? responses to M&As in terms of drug development efforts in the pharmaceutical sector on a narrowly defined market-level. We focus on two aspects: First, although strategic interactions between merging and non-merging ï¬•rms are well established in standard models of oligopoly for price and quantity competition, only little attention has been paid on possible strategic responses of rivals in terms of innovative eï¬?ort. Second, methodologically, competition authorities require a narrow deï¬•nition of relevant and aï¬?ected product markets for analysing the impact of M&As. Most previous studies use aggregated measurements on ï¬•rm-level, which potentially cause the altering and ambiguous results. We exploit rivalsâ?? reactions in terms of market-level drug development projects to M&As with a focus on dïï¬?erent eï¬?ects across markets. We use a dataset in which drug development projects are linked to the research conducting ï¬•rm, containing information on the state of development, start and discontinuation/registration events for pharmaceutical development projects worldwide for the period 1992-2005. All projects are classiï¬•ed using the Anatomical-Therapeutic-Classiï¬•cation System (ATC), developed by the WHO. This data and classiï¬•cation scheme provides a unique link between measurements of innovation - drug development in this case - and distinct product markets. We apply an adapted Differences-in-Differences estimation method with a research design which determines treatment and control groups through indicators describing a marketâ??s level of exposure to a merger. We distinguish between two possible treatments: markets with both merging ï¬•rms active and markets with only one merging ï¬•rm active. Controlling for time-eï¬?ects and market-ï¬•xed eï¬?ects for unobserved heterogeneity across markets, the indicators identify the potential eï¬?ects of M&As relatively to non-aï¬?ected markets. We use a dummy-variable approach for treatment

eï¬?ect estimation using Tobit and count data regression models. The level of observation is a unique market-quarter combination with 176 markets over 56 quarters. The discontinuation and entry rates of pharmaceutical development projects are our main dependent variables. Regarding the results, we can summarize the following: The discontinuation rate of projects is about 5 % lower in markets with both merging ï¬•rms active relatively to markets with only one merging ï¬•rm active and non-aï¬?ected markets in post-merger periods. Additionally, we can observe that signiï¬•cantly more projects are started in markets with both and only one merging ï¬•rm active. In sum, we ï¬•nd some evidence that mergers have a positive eï¬?ect on the number of drug development projects in terms of the number of ongoing projects and the number of newly started projects. Additionally, we test for treatment effect heterogeneity and find some evidence that the importance of M&As, measured in merging firmsâ?? share of development activities, influence the magnitude of the treatment effects.

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Hendrik Meder*

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Abstract

Mergers and acquisitions (M&As) are a common strategic tool of firms to get access to markets and to obtain market power. M&As have several effects and can affect rivals' innovation strategies. We estimate the effect of M&As on rivals' product development efforts using data on the pharmaceutical industry. We link development projects to narrowly defined pharmaceutical submarkets and estimate the effects of M&As on drug development aggregated on market level. We distinguish between effects on markets in which both merging firms are active and markets in which only one of the merging firms is active. The results indicate that rivals react strategically to M&As in a positive manner. Non-merging rivals discontinue 2.3% less and start 3% more development projects in markets when both merging firms are active. In markets with only one merging firm active, we estimate that rivals discontinue 1.7% less projects. We only find weak evidence that the effects increase in the importance of the merger for a given submarket.

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1 Introduction

Mergers and acquisitions (M&As) are a common strategic tool of firms in order to get access to markets, technologies and to obtain market power. M&As have several different effects on various factors, inter alia on innovation. Innovation as such, as well as product variety, is a key factor of economic growth, welfare and firm performance. Therefore, it is of substantial interest and importance for competition policy and managerial economics to examine and to understand the impact of M&As and changes in market structure on innovation and product variety. The literature concerning the effects of M&As on innovation is broad, growing and results are ambiguous. Most studies focus on R&D expenditures and patent counts on firm-level and use non-merging firms as a control group [e.g. Hall (1990, 1999), Hitt et al. (1991, 1996), Ornaghi (2009) and Valentini (2012)]. The research question we address is whether and how non-merging rivals strategically react to a merger with the aim to analyze outsiders' responses in terms of innovation and future product portfolios using data on the pharmaceutical industry. It can be argued that rivals adapt their R&D in response to a merger leading to a new market equilibrium, as it can be observed for pricing and quantity decisions. Contributions in the field of industrial organization show that firms reposition their product portfolio in post-merger periods and that a merger has an impact on product variety [Berry and Waldfogel (2001), Gandhi et al. (2008) and Draganska et al. (2009)].

While the expected effects on merging firms' innovative activities, relatively to non-merging rivals, have been empirically addressed on firm-level in sectoral and cross-sectoral studies[1], only limited research has been conducted on two related issues. First, although strategic interactions between merging and non-merging firms are well established in standard models of oligopoly for price and quantity competition, only little attention has been paid to potential strategic responses of rivals in terms of innovative effort. Hence, our focus is on whether and how rivals' product development activities are affected by M&As. Second, it is common practice in analyzing the effect of M&As on prices and quantities to narrowly

[1]Please see Schulz (2008) for a detailed survey.

define relevant and affected product markets [European Commission (2004)]. Most previous studies examining the relationship between M&As and innovation use aggregated measurements of innovation on firm-level, and do not consider definitions of separate submarkts as required by competition authorities. We thus follow methodological approaches in retrospective M&A analyzes on prices and quantities,[2] and we analyze the impact of M&As on market-level using well-defined product markets as it is standard in merger and antitrust proceedings.

In sum, we attempt to shed some light on market-specific outsiders' responses by exploiting rivals' reactions in terms of drug development projects which target a specific submarket. In the analysis we focus on different effects across markets, depending on the merging firms' activities. We distinguish between markets with both merging firms active and markets with only one merging firm active because we expect that effects are different between these possibilities.

We chose to examine the pharmaceutical industry for mainly three reasons: First, the pharmaceutical sector is characterized as an R&D intensive sector, where innovation is one of the main strategic dimensions of the market participants. Additionally, new developments in pharmaceutical research provide a dynamic environment in which the firms need to adopt their product and R&D portfolio constantly in order to be successful [Danzon et al. (2007)]. Second, the pharmaceutical sector experienced major consolidations within the past decades. The numerous and in size significant M&As reshaped the industry and in particular complete therapeutic fields in terms of market concentration. Third, the most important and pharmaceutical-specific argument is the possibility of the clear definition of separated submarkets. The pharmaceutical industry is complex and divided in numerous therapeutic fields and pharmacological subgroups which are non-substitutable. Within a submarket all products are substitute goods but cannot be replaced by preparations from different submarkets. Most firms are active in multiple submarkets such that each firm must choose not only its level of R&D effort, but also the manner in which its R&D efforts should

[2]See for example Hosken and Weinberg (2013).

be divided among the various submarkets [Sutton (1998)]. This means that for the pharmaceutical industry we should analyze competition, market structure and innovation at the level of the submarket instead of firm-level in order to get a detailed picture. Within a given submarket products can be weak or close substitutes such that the pharmaceutical sector can be characterized by a Bertrand competition model with differentiated products.

We use a database on worldwide drug development projects for the period 1992-2005. Each project can be linked are linked to the sponsoring or research conducting firm. The database contains information on the state of development and start and ending (discontinuation or registration) events. All projects are classified using the Anatomical-Therapeutic Classification System (ATC), developed by the World Health Organization, which is used by competition authorities and the pharmaceutical industry for defining relevant product markets in merger and antitrust proceedings with pharmaceutical firms involved. This data and classification scheme provides a unique link between measurements of innovation - drug development in this case - and distinct product markets.

In general, there is a distinction between *research* and *development* in the pharmaceutical sector. Research can be seen as the innovative activity of basic exploration which identifies promising and potential compounds or preparations to treat a disease. Development in the pharmaceutical industry refers to the specific process aiming to advance and test preparations in order to launch them to a pre-defined market. Hence, development projects are a clear and precise measure for the intention of a firm to enter a market with a new or at least own product.

Previous studies mostly used patent data without a clear link to product markets because it is often difficult to link a patent to product markets since patent classes do not correspond to market definitions. The link and identification of relevant product markets is essential for predicting post-merger outcomes because a merger, especially in industries with multi-product firms which are active in different submarkets. The detailed project-level data give us the opportunity to explore, retrospectively, the impact of M&As on market-level drug

development, by estimating their effect on the number of discontinued and newly started projects, which is, to the best of our knowledge, a novel approach in analyzing the impact of M&As on innovation.

It is accepted that mergers affect innovation, especially in knowledge-driven sectors. Nevertheless, the effects of M&As on innovative activities and outcomes are difficult to predict and ambiguous, even for the merging firms. For merging firms effects can be of both positive and negative nature and therefore partly counterbalancing [Cassiman et al. (2005)]. Although merger-induced effects on rivals' pricing and quantity decisions are broadly accepted and applied in competition policy, the effect on rivals' R&D and product portfolio are barely discussed in academic literature and only partly addressed by competition authorities [Veugelers (2012)]. In our study we present economic rationales for potential effects of M&As on rivals' innovative activities, leaning on theoretical models from the field of industrial organization, and test empirically our predictions.

The remainder of the article is organized as follows: section 2 describes the pharmaceutical innovation process section 3 discusses some theoretical considerations on the expected effect of M&As on innovation, section 4 is concerned with the creation of the dataset, and section 5 discusses the empirical strategy. Results are presented in section 6 and section 7 concludes.

2 The Pharmaceutical Innovation Process

Pharmaceutical research is a very costly and lengthy process involving multiple stages from identifying promising compounds and formulations, over pre-clinical trials, clinical studies for the verification of safety and efficacy finalized by a registration and validity process by national authorities. Until the market launch of a new chemical entity a pharmaceutical company has spent 800 million US$ and on average 12 years pass by [DiMasi et al. (2003) and Pommoli et al. (2011)].

R&D projects are always costly and, in the case of pharmaceutical R&D, become even

more costly with the advancement of the study [DiMasi et al (2003)]. Each pharmaceutical development project can be essentially divided into two parts, a research and a development phase. A project starts with the research phase in which numerous chemical compounds and their combinations with other compounds, targeting a certain disease, are identified. In laboratory tests the number of compounds is reduced to a small number of candidate compounds which seem to have the highest potential efficacy. Subsequently to this early stage, the project follows a strict regulatory framework required for market launch [Pomolli et al. (2011)]. Within this regulatory framework the drug is developed towards a product. In most cases the regulatory framework requires 4 consecutive trial phases, namely pre-clinical, Phase I, Phase II and Phase III clinical trials. Pre-clinical testing is used to ensure safety and non-toxicity for organisms (in-vitro and in-vivo testing) in which the so-called lead compound with the best expected trade-off between tolerance, safety and efficacy is identified. If the lead compound is identified and has shown sufficient non-toxicity and expected efficacy for the human organism, the development enters Phase I clinical trials. In Phase I the compound is tested in healthy volunteers for tolerability and non-toxicity for the human being. The research stage, preclinical and Phase I trials might add up to 8 years in total. After passing all requirements in the early development stages, the lead compound is further tested in more advanced stages, namely Phase II and Phase III clinical trials. Phase II and Phase III trials aim to test and to verify efficacy, tolerability with other drugs, optimal dosaging and adverse drug effects. Phase II trials test efficacy, tolerability and optimal dosaging in a sample of 70-100 patients with the disease prevalence. Phase III clinical trials test for efficacy, tolerability and adverse drug reactions in a large sample of 800-1000 patients with and without the prevalence of the disease, optimally in a double-blind randomized trial, in order to establish and fulfill all regulatory requirements for launching the product. The two last stages may take up to 5 years [Pomolli et al. (2011)]. The costs and success rate of each stage increase with the level of development. Early stage projects (pre-clinical and clinical Phase I) are less expensive, while late stages (Phase II and Phase III trials) consume a large

amount of research funding and resources. At any point in time of the development process a project can experience a technical failure and can be discontinued. While the early stages show a high failure rate, the likelihood of a successful finalization of the whole project is high if the project has reached the Phase II trial stage and even higher if it entered Phase III trials. Furthermore, the research conducting and sponsoring firm can decide to discontinue the drug development for strategic reasons.

3 Theoretical Considerations

Theoretical predictions of rivals' reactions to M&As in terms of innovation and entry or exit are scarce. For the theoretical development of the expected outcome of a merger on innovative development projects, we follow the economic rationale found in Davidson and Deneckere (1986) and Dixit (1989). Assume that pharmaceutical companies seek to maximize profits when they consider to invest in R&D. We postulate that firms form expectations about the profit they will eventually obtain if the project leads to a product that is successfully launched to the market. Consider that each firm in each period re-evaluates its R&D efforts. This evaluation is based upon own progress and intermediary results, as well as on the market and regulatory environment and circumstances. The market environment is, inter-alia, related to the level of competition a company may face. A merger might change the market environment for all incumbent firms and potential entrants. Suppose two firms in the same market merge and the number of competitors reduces after the merger. This will lead to higher market concentration and potentially to one (more) dominant firm. Davidson and Deneckere (1986) show that in a market, characterized by Bertrand competition with differentiated products, so-called unilateral effects cause that prices of both the merging firms and non-merging rivals increase depending on their substitutability. Given that prices increase on average, at least temporarily, the expected profits of being an incumbent firm raise. Dixit (1989) shows that an increase in prices induces more entry and less exit into the market, even if the increase is only temporarily. Following Dixit (1989) firms enter and exit

markets depending on the prices they can realize. In his model a lower and an upper bound are established which determine the entry-exit decisions of the firms. If the price falls under the lower bound, firms are more likely to exit since the expected profits do not outweigh the investments anymore. If the price increases above the upper bound, firms are more likely to enter since the expected profits are higher. Applying this result to M&As and taking into account that prices increase as in Davidson and Deneckere (1986), one might argue that in post-merger periods firms re-evaluate their strategic decisions relating to markets with expected price increases relatively to markets without. As a consequence, firms are more likely to enter and are less likely to exit markets where a merger occurs. Additionally, we also consider the possibility that markets in which only of the merging firms is active might be influenced. A player with greater financial capabilities and more research capabilities might create positive spillovers to its rivals. Furthermore, merging firms tend to reshape their boundaries [Phillips et al. (2011)]. They potentially tend to exit markets for which they do not expect large synergies. In other words, the merging parties decide to discontinue projects in markets in which only one of the merging firms is active. This exit has a similar positive effect on prices as a merger in a market in which both merging firms are active. Consequently, also for markets with only one merging firm rivals might be less likely to exit and might be more likely to enter due to the higher expected prices if the merging firm exits. Since the exit of a merging firm is only one option, we expect that the effect in markets with only one merging firm active is smaller than for markets with both firms active. In general, we expect the effects to increase in the significance or importance of a merger for the market because the price effects are more severe if merging firms control a significant part of the markets. In other words, mergers between two large players have a stronger impact than smaller M&As.

Applying the argumentation above we can summarize our expectations on the impact of M&As on rivals' development activities in different submarkets as follows: (i) Markets with both merging firms active experience lower discontinuation and higher entry rates relatively

to markets with only one merging firm active and non-affected markets; (ii) markets with only one merging firm active experience lower discontinuation and higher entry rates relatively to non-affected markets; (iii) the effects in markets with both merging firms are stronger than in markets with only one merging firm active; and (iv) the observed effects are increasing in the importance of a merger or acquisition for the market.

4 Data

In this section we describe the data sources and how the dataset for identifying effects of M&As on innovation in different markets, depending on the activities of the merging firms, is constructed. We combine the Pharmaceutical Industry Database (PhID), developed by the Institute for Markets and Technology at Lucca, Italy, and the SDC Platinum Database, developed and maintained by Thompson Financial Services.

4.1 Drug Development Data

The Pharmaceutical Industry Database (PhID) is used to identify firms and their research activities by submarket. PhID combines data on more than 20,000 pharmaceutical research projects and drug development activities and collaborations. For each development project the data tracks (at most) the complete development history from discovery, over clinical trial stages to their market launch and the firm(s) involved in the development.[3] PhID classifies each project according to the Anatomic-Therapeutic-Classification system (ATC) which links innovation and projects to distinct product markets. The ATC-system is segmented into five levels: the main anatomic group (ATC-1), the main therapeutic group (ATC-2), the

[3]We observed that around 20% of the projects in PhID only have an incomplete development history due to non-reporting issues. For those projects we imputed missing development steps using the following procedure: For each ATC-3 category a gamma distribution of the duration between the development steps was estimated using the observed durations. Based upon the parameters of the estimated distribution we imputed the missing information if necessary by assigning duration between stages randomly. We chose this procedure on ATC-3 level in order take into account that duration between development stages can depend on the therapeutic field and/or disease. For example the clinical trial testing for chronicle diseases takes generally takes longer than the tests for fast-acting analgesics. As a robustness check we also performed the analyses only with the projects with complete development history which holds qualitatively similar results.

pharmacological subgroup (ATC-3), the chemical subgroup (ATC-4) and the chemical substance level (ATC-5). The European Commission and pharmaceutical companies (mostly) define relevant product markets on ATC-3 level because a product in one ATC-3 class can usually be substituted by a product from the same ATC-3 class but not by a product form a different one even if they both have the same indication on therapeutic field level (ATC-2). To give an example, ATC-1 *A* includes all products which regulate the alimentary tract and metabolism, ATC-2 *A10* includes all drugs used in diabetes, ATC-3 *A10A* describes insulins and analogues, while *A10B* incorporates blood glucose lowering drugs, excluding insulins. The markets *A10A* and *A10B* are mutually exclusive since diabetes products on insulin basis and non-insulin basis cannot be interchanged due to possible patient characteristics as e.g. insulin intolerance. The market definition on ATC-3 level will also be key to our analysis. For the analysis we exclude (i) projects which are solely sponsored and/or conducted by governmental institutes, universities, hospitals, foundations or other international and non-profit organizations in all development stages, (ii) projects with missing development-related information, and (iii) projects involving compounds which can only be linked to unspecific ATC-3 categories. Additionally, projects can also be classified in more than one ATC-3 class due to plurality in usage of the compound or a project focuses on interactions of simultaneously administered drugs in two different ATC-3 classes. Projects with more than one ATC-3 classification are considered as multiple projects according to the number of reported ATC-3 categories. As a robustness check, we also excluded all projects with multiple ATC-3 classes. Using only projects with single ATC-3 classes does not change the results significantly. After imposing all necessary restrictions the innovation data reports 11,551 projects with 14,090 unique project-market combinations[4], distributed over 2,303 firms and 178 distinct markets for the period 1992-2005. Within the period we observe that 7,081 projects have been discontinued, 9,706 projects have been started and 995 projects have been successfully completed. Figure 1 shows the total number of development projects, the number of newly started projects and the number of discontinued projects of all non-merging rivals over

[4]9,543 projects report single ATC-3 codes, 2,008 report multiple ATC-3 classes

time. For the empirical analysis of the impact of M&As on market-level drug development by rivals, we aggregate the firm-project data on market level (ATC-3). The unit of observation for the empirical study is a market-quarter combination. The innovation data incorporates an initial estimation sample of 9,968 market-quarter observations over 178 markets and 56 quarters.

4.2 M&A Data

SDC Platinum reports M&A activities worldwide. Focusing on the pharmaceutical industry, we restrain the sample of potential M&As to all transactions where both firms are active in pharmaceutical related SIC codes, namely 2833 (Medicinal Chemicals and Botanical Products), 2834 (Pharmaceutical Preparations), 2835 (In Vitro and In Vivo Diagnostic Substances) and 2836 (Biological Products, Except Diagnostic Substances). During the period of interest, 1992-2005, SDC Platinum reports 4,331 announced deals. We generally categorize firms active in one of the four pharmaceutical related SIC codes as the following: (i) Pharmaceutical companies, active in manufacturing and R&D of compounds, i.e. Pfizer, Merck & Co., Sanofi-Aventis; (ii) generic drug companies, mainly active in manufacturing of licensed-in or off-patent pharmaceutical preparations and less active in pharmaceutical R&D, i.e. Mylan, Teva, Impax; (iii) pharmaceutical research firms, exclusively active in R&D of new chemical compounds and entities with the aim of engaging in licensing agreements either with pharmaceutical or generic drug companies; (iv) pharmaceutical manufacturing firms, usually sub-contractors of pharmaceutical companies or generic drug companies, exclusively active in the production of pharmaceutical preparations, non-active in R&D. Since we are interested in the relationship of innovation and rivalry in the product and technology market, we restrain the full universe of transactions in the pharmaceutical industry in two ways. Firstly, only M&As are considered in which both partners are capable to launch a product independently. Secondly, only M&As are considered in which both partners are capable to conduct pharmaceutical R&D. A firm's capability of launching a product is assumed to be

given if a firm has ever launched a product in the period 1985-2005 in any OECD country. A firm's capability of conducting R&D is assumed to be given if a firm has ever conducted or participated in a drug development project. Thus, given our classification of pharmaceutical firms, we generally consider all mergers between two pharmaceutical companies, two generic drug companies and a pharmaceutical company and a generic drug producer. We exclude mergers with pharmaceutical research companies and manufacturing contractors because those types of companies do not intend to compete with pharmaceutical or generic drug manufacturers by entry into a product markets and those mergers are therefore not in line with the focus of this study. Furthermore, SDC Platinum also reports M&As which are announced - but withdrawn - and which feature only single assets or acquisitions of minority stakes. Consequently, all announced but withdrawn deals are excluded, as well as all transactions in which the acquirer does not obtain corporate control over the target. This means, the acquirer does not own more than 50 percent of the target after a partial acquisition. Deals, featuring the transactions of single assets, are removed from the sample of considered M&As if it involved plants, single brands or non-pharmaceutical assets. Transactions of assets are considered if complete pharmaceutical divisions of conglomerates are traded. Transactions which involved assets were manually checked through press releases or financial service providers and were removed or remained in the sample according to this information. After restraining the universe of transactions to the above mentioned characteristics, the sample of considered transactions consists of 99 transactions in the period 1992-2005. Figure 2 displays the distribution of deals over time. Table 9 lists all transactions considered.

4.3 Generating Post-Merger Indicators

Essential for the empirical identification strategy is the definition of treatment and control observations and groups. Combining the drug development data from PhID and SDC Platinum frames treatment and control groups with a market-quarter identifier. We use the drug development data for identifying treatment groups and the M&A data for identifying

treatment periods.

We distinguish between two types of treatment given merging firms' development activities. We generate two treatment indicators depending on a market's level of exposure to a merger, namely *directly affected* and *indirectly affected* observations. A market's level of exposure to a merger is defined by the development activities of the merging parties in a given market. A *directly affected* market is a market in which both merging firms actively control at least one development project each in the quarter the merger is announced. In other words, a directly affected market is a market for which, everything else equal, a future increase in market power or concentration can be expected. Hence, for all observations in a given ATC-3 market, in which both merging firms are present, the indicator variable for direct effect is equal to 1, and 0 otherwise. The direct effect indicator captures effects due to the change in market structure and potential change in the occurrence of a larger firm. An *indirectly affected* market is a market in which only one of the merging firms actively sponsors a development project in the quarter of the merger announcement. In other words, an indirectly affected market is a market with no increase in market power due to the merger but a firm with greater capabilities might occur. The indirect effect indicator captures potential effects of a merger on a market due to a change in firm size and research capacities of the merged entity. The indirect effect indicator is constructed analogously to the direct effect indicator. The two treatment indicator variables are interacted with a set of post-merger indicators. We are rather interested in the short- and mid-term effects of M&As than only on the immediate impact that occurs. Especially, the timing of decision making in pharmaceutical firms are of concern since it is very likely that firms do not immediately respond to a change in market structure but within a year when board meetings or other decision mechanisms take place after learning about the potential consequences for their own development projects. Hence, the set of post-merger indicators consist of one indicator for the period of the merger and a set of indicator variables, one for each period up to 1 year, or 4 quarters respectively, after the transaction has been announced.[5]

[5]We experimented with various treatment-time-windows for post-merger periods but did not find any

Besides to the treatment indicator variables for directly and indirectly affected markets, we construct 10 additional variables in order to explore treatment effect heterogeneity. We use the merging firms' share in total development projects for classifying the importance of a merger for a market. The rationale behind is that mergers with a significant higher share in development projects may have a different impact than mergers between two firms which represent only a small part in a given therapeutic field. In order to construct the heterogeneous treatment variables, we interact the merging firms' share in development projects in the quarter of the announcement with the treatment indicators. Hence, likewise the treatment indicators, the variables informing on the importance of a merger are time-invariant for the 5 quarters of considered treatment. In the case of multiple mergers within one quarter, affecting the same market the same way (directly or indirectly) the shares of all transactions are summed up since the sum represents the total share of development projects which are subject to mergers in the given quarter and market.

In sum, we obtain two treatment groups, directly and indirectly affected markets, and one control group, the non-affected markets. Given our definition of treatment indicators, figure 3 displays the distribution of treatment and control observations. 4,555 observations are not affected by any merger or acquisition and serve as control group. 5,413 observation belong to the treatment groups, in which 3,636 observations are indirectly and 1,777 observations are directly affected by a merger or acquisition. Figure 4 shows the evolvement of the number of treatment and control observations over time, given a treatment-time-window of 4 quarters after a merger. Due to the potential occurrence of multiple mergers affecting a market within the treatment-time-window a market-quarter observation can be simultaneously directly and indirectly treated. The estimation sample for the empirical analysis is aggregated on market level with quarterly observations.

Our main dependent variables are the discontinuation rate and the entry rate in a given market in a given quarter. Discontinuation and entry rates are defined as the number of discontinued projects, or newly started projects respectively, in a given market in t divided

effect and more explanatory econometric specifications when we included more than 4 quarters.

by the number of ongoing projects in the same market in $t-1$. Due to the fact that, by definition, the calculation of discontinuation and entry rates is impossible, if the number of ongoing research projects in $t-1$ is equal to 0, we exclude these observations from our final sample. In the calculation of the discontinuation and entry rates we exclude all projects of merging firms for mainly two reasons. First, a challenge, all empirical studies on the effect of mergers on innovation face, is the potential endogeneity of mergers. Innovation can be one of the motives to merge or to acquire a rival [Grimpe and Hussinger (2006)]. In the case of innovation driven mergers, the indicator variables are not independent of unobserved transitory shocks. If the reverse causality is persistent, the results for the effect of mergers on innovation will be biased. In order to minimize the risk of endogeneity, we exclude all projects by merging firms from our sample. This means that projects, sponsored by a merging firm, do not influence our dependent variables, the discontinuation and entry rate. Second, the scope of this study is to examine potential reactions by non-merging rivals for both competition policy and managerial insights. Due to the fact, that we use aggregated data on market level, it is necessary to exclude the projects of merging firms in order to isolate the effect on the rivals. If merging firms' projects are incorporated, we could not identify the effect since a change in discontinuation and entry rate might be driven by a change in merging firms' behavior. The final sample is an unbalanced panel with gaps. 27 markets do not have a continuous time series. The resulting estimation sample contains in total 8,502 observations over 178 markets and 56 quarters.

5 Empirical Framework

Our empirical strategy is to examine non-merging rivals' drug development efforts at the market level (ATC-3) by exploiting variation in exposure to M&As over time and across markets. We are particularly interested in different effects of M&As on markets in which both merging firms are active and markets in which only one of the merging firms is active relatively to markets which do not experience any merger. The identification of control

groups in natural and quasi-experiments is always a challenge in treatment effect studies.[6] The research design clearly determines treatment and control groups through the indicators describing the level of exposure to a merger. The treatment groups consist of the observations for which one of the post-merger indicators is equal to 1. The control group consists of the observations which are not influenced by a merger by any order of exposure and all indicators, informing on treatment, are equal to 0. Controlling for other factors, as well as for market-fixed and time effects, the treatment indicators identifies the potential effects of M&As in markets which are affected relatively to markets which are not affected.

We adopt a dummy-variable approach for treatment effect analysis and estimate equations the following form:

$$y_{gt} = \alpha_g + \lambda_t + \beta' \mathbf{X}_{gt} + \sum_{j=0}^{\tau} \delta_{j+1} dDIRECT_{gt} * POST_{t-j} + \sum_{j=0}^{\tau} \gamma_{j+1} dINDIRECT_{gt} * POST_{t-j} + \varepsilon_{gt},$$

where y_{gt} refers to our main variable of interest, the discontinuation and entry rate in market g at time t. α_g is a market-specific unobservable fixed effect, possibly correlated with the treatment indicators and λ_t is a set of quarter-dummy variables for capturing time-effects. $\mathbf{X}_{gt}$ is a vector of market-specific characteristics, mainly incorporating the ln(# of Projects in $t-1$) in order to control for market size in terms of development projects. $dDIRECT_{gt} * POST_{t-j}$ and $dINDIRECT_{gt} * POST_{t-j}$ are the treatment-effect variables for the period of a merger and the 4 consecutive periods, as described above and ε_{gt} is the error term. The coefficients δ_{j+1} and γ_{j+1}, with $j = \{0, 1, 2, 3, 4\}$, reflect the change in the dependent variable of interest due to M&As which either directly or indirectly affect a market.

In general, we use the within and between group variation to identify the effect of M&As on efforts in market-level drug development. Markets can incorporate persistent differences in discontinuation and entry rates associated with the therapeutic field or pharmacological subgroup. Although the regulatory guidelines and requirements for testing for superiority or non-inferiority in clinical trials are equal across therapeutic or pharmacological subgroups,

[6] See Meyer (1995) and Bertrand et al. (2004) for a detailed discussion

there may exist differences in the average duration of development. For instance, drug development for chronicle, rare and long-lasting diseases may require more time than fast-acting emergency analgesics or pain relievers either due to bodily absorption time, action time or other pharmcokinetics or simply due to the rare availability of potential trial subjects. Additionally, some ATC-3 classes incorporate a higher risk of technical failure than other classes, e.g. biotechnology compounds for the treatment of cancer can be more complex than single-acting dermatological preparations. Due to the fact that differences in duration and general risk of technical failure are permanent and time-invariant because the disease does not change over time, the incorporation of therapeutic-field-specific or market-specific fixed effects should capture the differences. The within transformation captures all unobservable differences between markets and returns consistent estimates if the assumption of strict exogeneity is fulfilled. We argue that our data only exhibits a limited risk of contemporaneous correlation between the residuals and the treatment indicators because the decision of two firms to merge can be assumed to be determined before at least the quarter the merger is announced or even earlier because M&As require preparation and negotiation time and are usually kept secret. Additionally, the dependent variables exclude merging firms' projects and, even if merging firms would prepare or adjust their drug development portfolio before a merger is announced, it is most unlikely that the non-merging rivals have any information about the planned transaction or can anticipate the change in market structure in periods before announcement with certainty. We are aware of the fact that hostile takeovers are public before the finalization of the transaction but those kind of acquisitions are rare. One more concern are rumors about forthcoming M&As in the industry. We argue that this risk is rather minor because the rumors incorporate a large portion of uncertainty and therefore have only a small influence of non-merging rivals' pipeline portfolio.

An important assumption for treatment effect estimation is the so-called common trend assumption. The common trend assumption assures that treatment and control groups are sufficiently comparable. Figures 5 and 6 show the average discontinuation and entry rate

over time for non-affected, indirectly and directly affected markets. The figures suggest that there is no significant difference in trends between the treatment and control groups over time. Additionally, the conditional summary statistics, displayed in tables 1-3, and two-sided t-tests partly confirm the conjecture that there are no significant differences in means of discontinuation and entry rates across treatment and control groups.

[Table 1-3 about here]

Another point of concern is that larger markets are more likely to experience a merger event due to a higher number of firms. In our econometric specification we control for the number of ongoing research projects in order to control for possible dynamics of certain markets which become more active over time. Although tables 1-3 suggest that significant differences in the number of projects across treatment and control groups exist, table 4 indicates that entry rates are not systematically associated with a higher number of projects in a given market in $t-1$. Although the discontinuation rate is significantly correlated with larger markets, the correlation is rather limited. Additionally, if the assumption of strict exogeneity holds, the market-specific effects, included in our econometric specification, partly take care of a possible self-selection of markets into the treatment group.

[Table 4 about here]

We include the number of ongoing projects in $t-1$ as a control variable. It describes the development intensity of a given market g in $t-1$. It accounts for time-varying changes in therapeutic fields and submarkets which are not captured by the set of indicator variables and should be widely unrelated to mergers. Those time-varying factors might be novel techniques and compounds, as for example biotechnological entities, introduced to a therapeutic field which makes failure more likely due to their novelty. Higher discontinuation rates due to increased risk of failure is rather associated with technical failure than to market structure and the impact of M&As. The correlation between number of projects in $t-1$, level of exposure and higher discontinuation rates raises one major concern. One might expect

that risky markets with many firms and development projects active are more likely to be exposed to a merger. This can be explained by the possibility that a market is lucrative but risky. In the case of a successfully launched product, the winner will earn high profits which advocates the investments, even if the likelihood of failing projects is relatively high. The self-selection into treatment can be indeed true by construction since the likelihood of the occurrence of a merger is increasing in the number of firms due to more different possibilities of merging pairs. Consequently, this would mean that markets with higher discontinuation rates in $t - \tau$ are more likely to be selected into the treatment groups (affected markets). This would cause a reverse causality problem which would bias our results for the treatment effect estimation. We tested whether reverse causality is a problem by estimating binomial models with the treatment effect indicator as dependent variable and lagged discontinuation rates as explanatory variables and used an iterative process over all treatment indicators and up to 4 lagged periods before a treatment. We do not find significant coefficients for any of the lagged discontinuation rates which suggests that a higher discontinuation rate in $t - \tau$, which is possibly associated with more development-intense markets, does not cause merger activity. Hence, we might conclude that we do not necessarily incorporate a reverse causality problem and our results are unbiased in this respect.

6 Results

6.1 Baseline Specification

Our baseline specification considers solely the treatment effect of M&As and neglects deal-specific variation. The results from estimating our econometric model are presented in tables 5 and 6. The dependent variable in table 5 is the discontinuation rate, defined as the number of discontinued product in market g in t divided by the number of ongoing projects in market g in $t-1$. The dependent variable in table 6 is the entry rate, defined as the number of newly started development projects in market g in t divided by the number of ongoing projects in

market g in $t-1$.[7] The regressions in columns (1)-(3) of each table are estimated as Tobit regression models. We chose Tobit-model regressions for the fact that we estimate rates which, by definition, cannot be smaller than 0 and for the discontinuation rate not be larger than 1. Therefore, regressions for the discontinuation rate feature a 2-sided Tobit model, regression for the entry rate use a 1-sided Tobit model. Despite the treatment indicators, all specifications include time effects in form of quarter-indicators and a control for the number of projects ongoing in submarket g in $t-1$. Robust standard errors, in parentheses below the coefficients, are based upon Hubert-White sandwich estimators. While our preferred estimation method is the specifications with full submarket fixed effects, we also report results from estimations without any market or therapeutic field effects and only therapeutic field effects. Column (1) of each table does not include any therapeutic field (ATC-2) or submarket (ATC-3) fixed effects. Column (2) includes therapeutic field fixed effects, column (3) full submarket-specific fixed effects.

In the analysis of the discontinuation rate we can observe that the coefficients for directly affected markets are all negative for all considered post-merger periods and across specifications. When controlling for therapeutic and pharmacological submarket fixed effects, the coefficients of the direct treatment indicator in the third and fourth quarter are negative and significant on 10 and 5 percent significance levels. For both specifications the coefficients are -0.022 and -0.023 respectively. This indicates that on average a submarket in which both merging firms are active the discontinuation rate is around 2,2% lower in the third and fourth quarter after a merger occurred relatively to markets without any merger. These results, even if the effect is very small and not highly significant, support our hypothesis that non-merging rivals react strategically to a merger and that the response is positive in terms of innovative effort. There is only little evidence that the discontinuation rate in indi-

[7]We define a newly started project as a project which appears for the first time in our database. This means it is considered as being started when a project is reported to start pre-clinical trials. We also tried other definitions as for example the entry in Phase I clinical trials because we were concerned that the regulations for filing pre-clinical trials might slightly vary across countries. A definition that a project started when entered Phase I clinical trials holds similar results. Considering entry into higher stages of development might be used to measure the intensive margin of the effect of M&As but this question is beyond the scope of this research.

rectly affected markets is influenced by a merger or acquisition. Given the specification with submarket-fixed effects, the discontinuation rate is significantly lower in the first quarter after a merger, relatively to non-affected markets.

[Table 5 about here]

In general, most of the quarter dummy-coefficients are significant, as are many of the therapeutic field and submarket indicators coefficients.

Controlling for the development intensity in $t-1$ is of particular interest for the avoidance of the above mentioned reverse causality problem. We observe a fairly stable coefficient of about 0.09 which indicates that markets with more development projects show on average a higher discontinuation rate. The coefficient partly captures the time-variant characteristics of a given submarket in terms of development intensity. We are concerned that markets with an increased risk in failure causes M&A activity. As described above, by including development intensity we partially control for the fact that many firms in a submarket potentially increase the risk of a self-selection bias. The number of ongoing projects as a proxy of the number of firms active we account for markets with many firms and the increased likelihood of being affected.

For the analysis of the entry rate we obtain mostly positive coefficients for the merger-treatment indicators across all specifications. Especially the coefficients for the second and third quarter after a directly affecting merger are positive and significant at a 5 and 10 percent significance level where the effect is persistent when controlling for therapeutic field fixed and submarket fixed effects. The coefficients lie between 0.026 and 0.03 and are fairly constant across specifications. The results indicate that markets which are directly affected have on average a 3% higher entry rate compared to non-affected markets. Indirectly affected markets show a significant higher entry rate immediately after the treatment, where the effect vanishes when submarket fixed effects are included. Additionally, signs for the coefficients when applying full submarket fixed effects are switching across the indirect-treatment indicators which may hint that the effect is very small or barely existent. Surprisingly, in the fourth

quarter after an indirect treatment the entry rate is significantly lower compared to non-affected markets.

[Table 6 about here]

The results for the effects of M&As on the entry rate confirms the results for the discontinuation rate. In sum we can state that we find some evidence that mergers and acquisitions do seem to have a positive impact on rivals' drug development activities relatively to their efforts in non-affected markets. On the one hand we find a lower rate of discontinuation in both directly and indirectly affected markets. On the other hand we estimated that in post-merger periods the entry rate is higher in at least directly and partially in indirectly affected markets. In general, the effects are larger for for directly affected markets than for indirectly affected markets which supports our expectations. Although the effects are very small, which can be expected when aggregating worldwide drug development efforts on pharmacological submarkets, the result of an overall positive effect of M&As on rivals' development activities are stable and significant across model specifications. These results support the hypotheses that directly and indirectly affected markets experience lower discontinuation and higher entry rates in post-merger periods where the effects are stronger in directly affected markets.

6.2 Treatment Effect Heterogeneity

The effect on development projects of experiencing changes in (future) market structure is likely to depend on the importance or severity of the merger. The combined market share of merging firms can serve as a good proxy for the importance of a transaction if the relevant product market is narrowly defined [OECD (2012)]. Although it is common knowledge that market shares do not necessarily reflect expected impact of M&As in product markets and demand elasticities between the merging firms' products should be considered, this method is not applicable for the drug development market we examine. For the estimation of product elasticities it is necessary to examine data on demand and prices. Due to the fact that this

data is not available for products which are still under development, we advocate the share of development projects, run by the merging firms, as a reasonable proxy for the importance of M&As.

In the analysis of treatment effect heterogeneity on the discontinuation rate of projects we observe, similar to the treatment effect estimation, negative effects for directly effected markets across all model specification with significant effects in the quarter of the transaction and after four quarters after a transaction. For the effect heterogeneity in directly affected markets the results show non-significant but positive effects which, despite the lack in significance, would suggest that mergers with a higher market share of the merging firms have a greater impact. In other words, the negative effect on the discontinuation rate is larger if a merger affects relatively more projects. Remarkably, the only significant coefficient for the treatment effect heterogeneity is in the third quarter after a merger. Comparing this to the treatment effect estimation from section 6.1, we can observe that the average treatment effect is not existing anymore but the heterogeneous effect is negative and significant. We might consider that the average treatment effect is mostly captured by the heterogeneous effect for the third quarter after a merger. If this is the case, the negative effect on the discontinuation rate in the third quarter after a merger is only existent if a transaction is sufficiently large.

A mixed picture can be found for the effect on indirectly affected markets. Given the specification with full submarket-fixed effects, we observe a lower discontinuation rate in the first quarter after a merger of 2.1%. For the effect heterogeneity the results show lower discontinuation rates in the quarter of the merger and three quarters after. Apparently, the average treatment effect is not significant but the greater the the importance of a merger is for a market the stronger is the negative effect.

[Table 7 about here]

Turning to the treatment effect heterogeneity for the entry rates, we find positive, but insignificant, coefficients in directly effected markets. Also the treatment effect indicators

interacted with the share of the merging firms does not seem to have any significant impact on the entry rate. In indirectly affected markets a slightly positive effect on entry can be found for the first and third quarter after a transaction where the severity of a merger does not seem to have any impact.

[Table 8 about here]

7 Conclusion

Strategic interactions between firms in a given market and M&As are a well known and thoroughly addressed topic in economic research. One important dimension, especially in high-technology sectors, are firms' decisions to invest in new products. Dynamic sectors, as it is the pharmaceutical industry, undergo multiple changes in markets structure and incorporate permanent product innovations. We address the question whether and how non-merging rivals react to M&As in the pharmaceutical sector by estimating effects of M&As on rivals' development projects in narrowly defined submarkets. We investigate the different effects given merging firms' development activities and their dependence on the importance and severity of the change in market structure.

Our results indicate that the discontinuation rate of development projects is 2.3% lower and the entry rate is 2.6% to 3.0% higher about 1 year after a merger occurred for markets in which both merging active develop products. We also find weak evidence that the discontinuation rate is 1.7% lower in indirectly affected markets. The delayed reactions can be explained by the time that takes the rivals to learn and draw conclusions about the expected effects of M&As in the field they are actively conductiong development projects. These results indicate that in sum there are positive effects of M&As on rivals' product development efforts. Additionally, we find some evidence for dependence of the effects on the importance of M&As. The negative effect on the discontinuation rate increases in merging firms' combined share in development projects or is even fully captured only by significantly large

transactions in directly affected markets. We do not find heterogeneous treatment effect depending on importance of M&As on the entry rate.

Our results can thus be summarized in the following three points: First, we find evidence that rivals discontinue less and start more projects in markets in which the future number of competitors is reduced. Second, the effect of M&As is stronger for directly affected markets than for indirectly affected markets. Third, there is only little evidence that the effect depends largely on the combined share of merging firms' development projects in a market.

The results are consistent with the possible explanations derived from the theoretical considerations on the effect of M&As on prices and the effect of price increases on inducing entry and exit.

An implication of our findings is that, although anti-competitive effects of M&As are often considered, the expected short-term effects are potentially offset or mitigate by rivals' reactions. The often claimed counterbalancing effects of new entry into markets which experienced mergers is supported by our analysis on market level although we do not have measurement whether the induced entry fully offsets the potential anti-competitive effects.

Nevertheless, our analysis incorporates some limitations. We use aggregated data on worldwide drug development projects in OECD countries. Competition authorities analyze competitive effects of M&As in narrowly defined product and geographic markets. Further research needs to be conducted whether our results on aggregated data holds for national markets. Additionally, the aggregation on market-level does not give any indication whether substantial differences between types of rivals drive the results. For effect heterogeneity on different firms a firm-market-level analysis can be applied in future research. Additionally, given our research design we cannot answer for example whether the positive effect is driven by large direct competitors or smaller specialized pharmaceutical firms. One additional limitation is that we cannot apply any quality measurement for development projects. Projects at the margin which are not discontinued after mergers occurred have the same quality since they might have been stopped without the change in market structure. At

any rate, our results show some positive impact on market-entry strategies in post-merger periods on market-level induced my M&As and may shed some light on strategic responses by non-merging rivals and the potential mitigation of anti-competitive effects.

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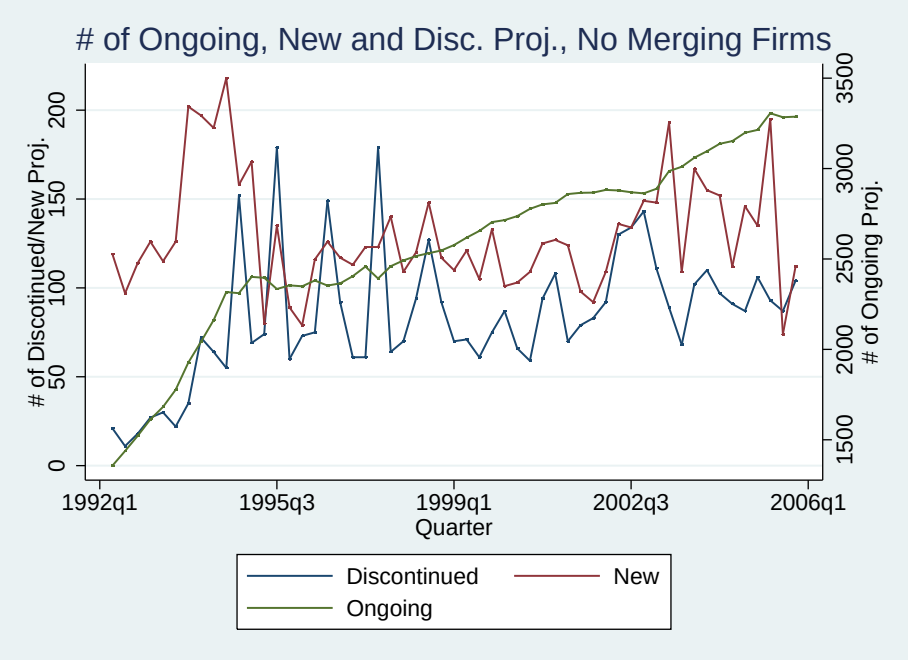

Figure 1: Number of Ongoing, Discontinued and New Projects

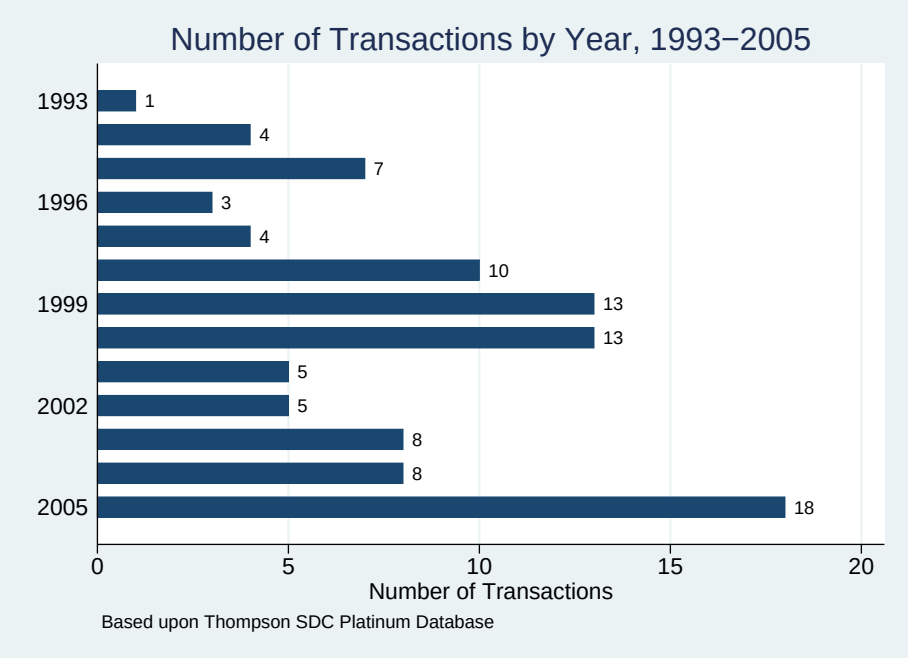

Figure 2: Number of Transactions by Year

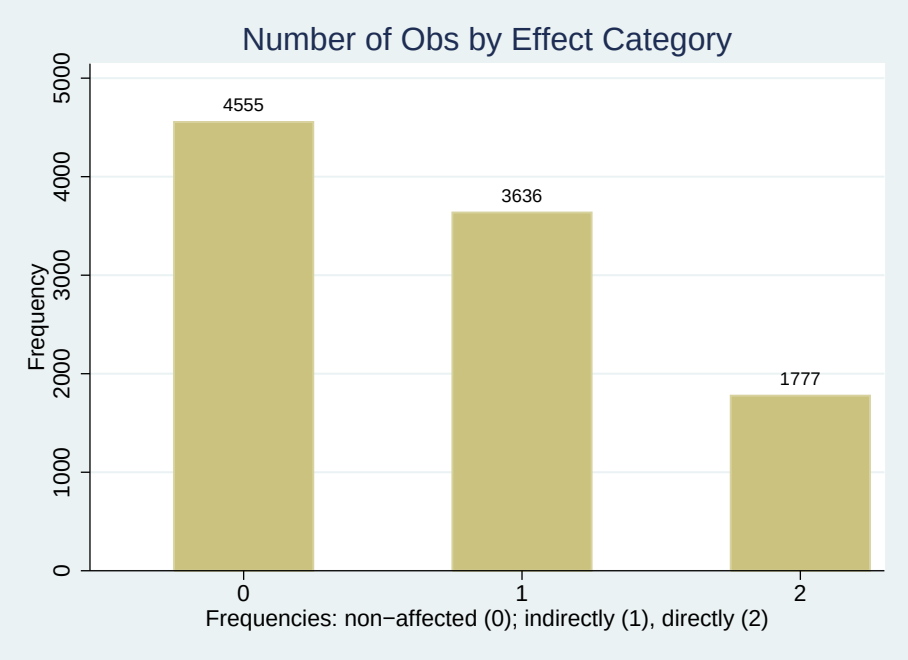

Figure 3: Distribution of Observations by Effect-Category

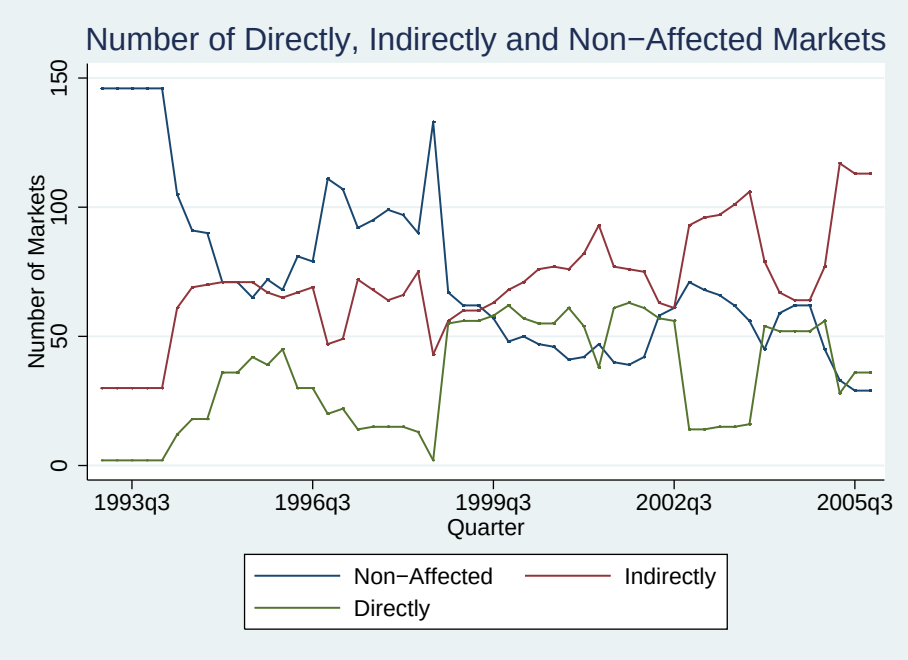

Figure 4: Distribution of Observations by Effect-Category over Time

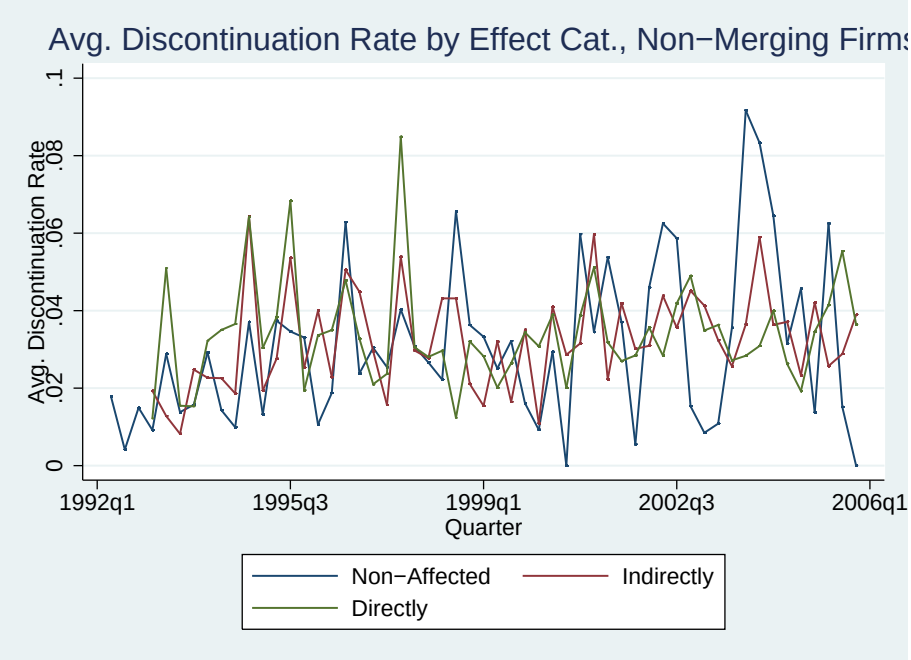

Figure 5: Average Discontinuation Rates by Effect-Category over Time

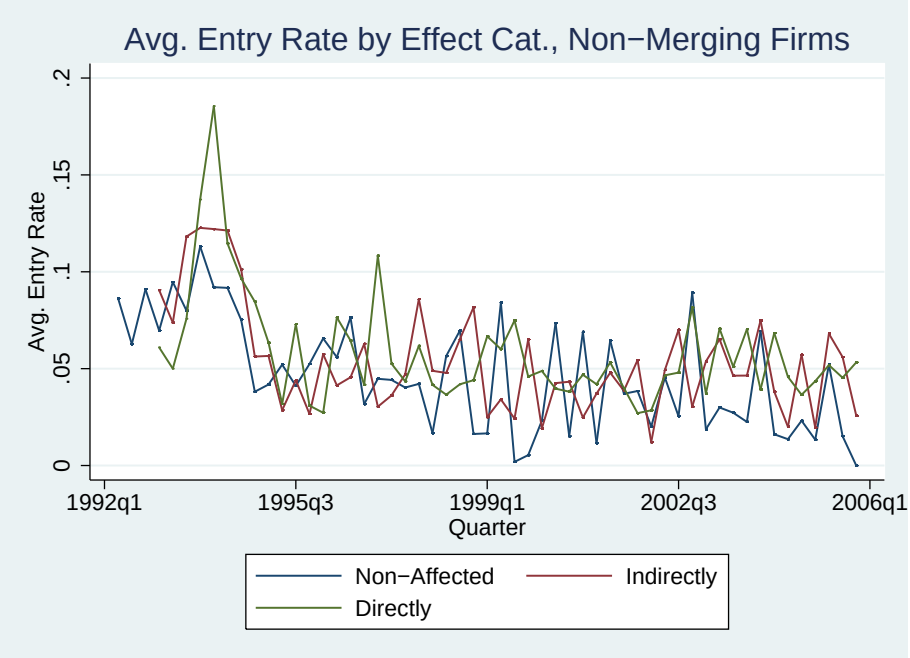

Figure 6: Average Entry Rates by Effect-Category over Time

Table 1: Summary Statistics for Non-Affected Markets

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**	**N**
Discontinuation Rate	0.028	0.114	0	1	3184
Entry Rate	0.057	0.167	0	2	3184
ln(# of projects in (t-1))	1.102813	.9557222	0	4.60517	4377

Table 2: Summary Statistics for Indirectly Affected Markets

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**	**N**
Discontinuation Rate	0.034	0.086	0	1	3368
Entry Rate	0.051	0.130	0	2	3368
ln(# of projects in (t-1))	2.022	1.073645	0	5.170484	3636

Table 3: Summary Statistics for Directly Affected Markets

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**	**N**
Discontinuation Rate	0.034	0.055	0	1	1772
Entry Rate	0.051	0.088	0	1.5	1772
ln(# of projects in (t-1))	3.313881	1.035663	0	5.537334	1777

Table 4: Correlations

	Disc. Rate	Entry Rate	ln(# of projects in (t-1))
Entry Rate	0.113***		
ln(# of projects in (t-1))	0.0194	-0.0204	
Effect Category	0.0292**	-0.0197	0.618***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: 2-Sided Tobit; Discontinuation Rate: Treatment Effect

	(1)	**(2)**	**(3)**
DIRECT in t+0	-0.007	-0.011	-0.012
	(0.012)	(0.012)	(0.012)
DIRECT in t+1	0.002	-0.003	-0.004
	(0.011)	(0.011)	(0.011)
DIRECT in t+2	-0.010	-0.014	-0.014
	(0.013)	(0.013)	(0.013)
DIRECT in t+3	-0.019	-0.022*	-0.023*
	(0.012)	(0.012)	(0.012)
DIRECT in t+4	-0.017	-0.022*	-0.023**
	(0.012)	(0.012)	(0.012)
INDIRECT in t+0	0.015	0.012	0.007
	(0.010)	(0.010)	(0.010)
INDIRECT in t+1	-0.008	-0.011	-0.017*
	(0.010)	(0.010)	(0.009)
INDIRECT in t+2	0.013	0.011	0.006
	(0.010)	(0.010)	(0.010)
INDIRECT in t+3	-0.007	-0.01	-0.015
	(0.010)	(0.010)	(0.010)
INDIRECT in t+4	0.01	0.007	0.000
	(0.010)	(0.010)	(0.010)
ln(# projects) in t-1	0.089***	0.094***	0.092***
	(0.004)	(0.005)	(0.011)
Constant	-0.371***	-0.385***	-0.331***
	(0.032)	(0.039)	(0.054)
Fixed Effects	No	Yes (ATC-2)	Yes (ATC-3)
Time Effects	Yes	Yes	Yes
Pseudo R^2	0.22	0.26	0.30
N	8324	8324	8324
Uncensored	2246	2246	2246
Left censored	6046	6046	6046
Right censored	32	32	32
Log(ℓ)	-2041.64	-1944.54	-1845.35

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: 1-Sided Tobit; Entry Rate: Treatment Effect

	(1)	**(2)**	**(3)**
DIRECT in t+0	0.002	0.004	0.000
	(0.013)	(0.013)	(0.012)
DIRECT in t+1	0.014	0.016	0.014
	(0.013)	(0.013)	(0.013)
DIRECT in t+2	0.027*	0.030**	0.026*
	(0.015)	(0.015)	(0.014)
DIRECT in t+3	0.027*	0.030**	0.030**
	(0.014)	(0.014)	(0.013)
DIRECT in t+4	0.007	0.010	0.012
	(0.014)	(0.014)	(0.013)
INDIRECT in t+0	0.034***	0.028**	0.017
	(0.011)	(0.011)	(0.011)
INDIRECT in t+1	0.033***	0.028**	0.018
	(0.012)	(0.012)	(0.011)
INDIRECT in t+2	0.012	0.007	-0.004
	(0.012)	(0.012)	(0.012)
INDIRECT in t+3	0.028**	0.023**	0.015
	(0.011)	(0.012)	(0.011)
INDIRECT in t+4	-0.013	-0.015	-0.022**
	(0.011)	(0.011)	(0.011)
ln(# projects) in t-1	0.087***	0.068***	-0.060***
	(0.004)	(0.005)	(0.013)
Constant	-0.496***	-0.465***	0.067
	(0.034)	(0.041)	(0.056)
Fixed Effects	No	Yes (ATC-2)	Yes (ATC-3)
Time Effects	Yes	Yes	Yes
Pseudo R^2	0.16	0.19	0.25
N	8324	8324	8324
Uncensored	2899	2899	2899
Left censored	5425	5425	5425
Log(ℓ)	-2772.47	-2659.8	-2474.94

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: 2-Sided Tobit; Discontinuation Rate: Treatment Effect Heterogeneity

	(1)	(2)	(3)		(1)	(2)	(3)
DIRECT in t+0	-0.023	-0.025*	-0.024*	DIRECTshare in t+0	0.367	0.291	0.224
	(0.015)	(0.015)	(0.014)		(0.273)	(0.280)	(0.269)
DIRECT in t+1	-0.008	-0.010	-0.008	DIRECTshare in t+1	0.225	0.125	0.072
	(0.014)	(0.014)	(0.013)		(0.222)	(0.225)	(0.223)
DIRECT in t+2	-0.026	-0.029*	-0.027	DIRECTshare in t+2	0.305	0.257	0.206
	(0.017)	(0.017)	(0.017)		(0.395)	(0.406)	(0.392)
DIRECT in t+3	-0.003	-0.003	-0.001	DIRECTshare in t+3	-0.350	-0.445*	-0.509**
	(0.014)	(0.014)	(0.014)		(0.259)	(0.256)	(0.246)
DIRECT in t+4	-0.031**	-0.034**	-0.033**	DIRECTshare in t+4	0.289	0.234	0.173
	(0.015)	(0.015)	(0.015)		(0.284)	(0.284)	(0.277)
INDIRECT in t+0	0.022**	0.020**	0.016	INDIRECTshare in t+0	-0.195	-0.232	-0.279*
	(0.010)	(0.010)	(0.010)		(0.149)	(0.148)	(0.153)
INDIRECT in t+1	-0.013	-0.015	-0.021**	INDIRECTshare in t+1	0.087	0.071	0.064
	(0.010)	(0.010)	(0.010)		(0.171)	(0.172)	(0.183)
INDIRECT in t+2	0.015	0.012	0.008	INDIRECTshare in t+2	-0.042	-0.049	-0.068
	(0.011)	(0.011)	(0.011)		(0.176)	(0.181)	(0.187)
INDIRECT in t+3	0.003	0.001	-0.003	INDIRECTshare in t+3	-0.314*	-0.357**	-0.400**
	(0.011)	(0.011)	(0.010)		(0.168)	(0.168)	(0.175)
INDIRECT in t+4	0.003	0.002	-0.005	INDIRECTshare in t+4	0.149	0.112	0.116
	(0.011)	(0.010)	(0.010)		(0.136)	(0.136)	(0.148)
ln(# projects) in t-1	0.090***	0.094***	0.091***				
	(0.004)	(0.005)	(0.011)				
Constant	-0.374***	-0.386***	-0.329***				
	(0.034)	(0.040)	(0.055)				
Fixed Effects	No	Yes (ATC-2)	Yes (ATC-3)				
Time Effects	Yes	Yes	Yes				
Pseudo R^2	0.22	0.26	0.3				
N	8324	8324	8324				
Uncensored	2246	2246	2246				
Left censored	6046	6046	6046				
Right censored	32	32	32				
Log(ℓ)	-2035.46	-1938.18	-1838.19				

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: 1-Sided Tobit; Entry Rate: Treatment Effect Heterogeneity

	(1)	(2)	(3)		(1)	(2)	(3)
DIRECT in t+0	-0.003	0.006	0.008	DIRECTshare in t+0	0.085	-0.077	-0.240
	(0.017)	(0.017)	(0.017)		(0.331)	(0.346)	(0.337)
DIRECT in t+1	-0.005	0.002	0.007	DIRECTshare in t+1	0.361	0.241	0.072
	(0.016)	(0.016)	(0.015)		(0.307)	(0.317)	(0.307)
DIRECT in t+2	-0.002	0.005	0.011	DIRECTshare in t+2	0.608	0.516	0.318
	(0.020)	(0.020)	(0.019)		(0.402)	(0.435)	(0.400)
DIRECT in t+3	0.001	0.008	0.015	DIRECTshare in t+3	0.503	0.427	0.264
	(0.022)	(0.023)	(0.022)		(0.456)	(0.499)	(0.472)
DIRECT in t+4	0.004	0.014	0.018	DIRECTshare in t+4	-0.007	-0.161	-0.23
	(0.022)	(0.024)	(0.023)		(0.510)	(0.561)	(0.553)
INDIRECT in t+0	0.028**	0.024*	0.013	INDIRECTshare in t+0	0.101	0.058	0.055
	(0.013)	(0.012)	(0.012)		(0.221)	(0.222)	(0.218)
INDIRECT in t+1	0.037***	0.033**	0.023*	INDIRECTshare in t+1	-0.112	-0.146	-0.148
	(0.013)	(0.013)	(0.012)		(0.207)	(0.210)	(0.213)
INDIRECT in t+2	0.013	0.009	-0.002	INDIRECTshare in t+2	-0.023	-0.059	-0.047
	(0.014)	(0.013)	(0.013)		(0.236)	(0.219)	(0.233)
INDIRECT in t+3	0.034***	0.031**	0.023*	INDIRECTshare in t+3	-0.212	-0.259	-0.255
	(0.013)	(0.013)	(0.012)		(0.204)	(0.210)	(0.213)
INDIRECT in t+4	-0.006	-0.007	-0.014	INDIRECTshare in t+4	-0.189	-0.239	-0.243
	(0.012)	(0.012)	(0.012)		(0.181)	(0.187)	(0.208)
ln(# projects) in t-1	0.088***	0.068***	-0.061***				
	(0.004)	(0.005)	(0.013)				
Constant	-0.503***	-0.467***	0.067				
	(0.037)	(0.043)	(0.059)				
Fixed Effects	No	Yes (ATC-2)	Yes (ATC-3)				
Time Effects	Yes	Yes	Yes				
Pseudo R^2	0.16	0.19	0.25				
N	8324	8324	8324				
Uncensored	2899	2899	2899				
Left Censored	5425	5425	5425				
Log(ℓ)	-2767.99	-2655.77	-2471.92				

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Mergers Considered

Target	**Acquirer**	**Year**
FARMITALIA CARLO ERBA	KABI PHARMACIA	1993
CYANAMID	AMERICAN HOME PRODUCTS	1994
SYNTEX	ROCHE	1994
BOOTS	KNOLL	1994
KODAK	SANOFI	1994
WELLCOME	GLAXO	1995
KABI PHARMACIA	UPJOHN	1995
BLOCK DRUG	SCHWARZ	1995
FISONS	RHONE-POULENC RORER	1995
MARION MERRELL DOW	HOECHST	1995
UNIVAX	NABI	1995
ACCESS	CHEMEX	1995
OCLASSEN	WATSON	1996
CIBA-GEIGY	SANDOZ	1996
PHARMACOPEIA	DAIICHI	1996
BOEHRINGER MANNHEIM	ROCHE	1997
TROPHIX	ALLELIX	1997
GREEN CROSS	YOSHITOMI	1997
NYCOMED	AMERSHAM	1997
OHMEDA	BAXTER	1998
SYNTHELABO	SANOFI	1998
ASTRA	ZENECA	1998
NEUREX	ELAN	1998
DEPOTECH	SKYEPHARMA	1998
THERATECH	WATSON	1998
SEQUUS	ALZA	1998
RHONE-POULENC RORER	HOECHST MARION ROUSSEL	1998
PENEDERM	MYLAN	1998
PHARMCHEMIE	TEVA	1998
ALLELIX	NPS	1999
WARNER LAMBERT	PFIZER	1999
UNIMED	SOLVAY	1999
AGOURON	WARNER LAMBERT	1999
CENTOCOR	JOHNSON & JOHNSON	1999
TANABE	MITSUBISHI	1999
US BIOSCIENCE	MEDIMMUNE	1999
ROBERTS	SHIRE	1999
PHARMACIA & UPJOHN	MONSANTO	1999
NEXSTAR	GILEAD SCIENCES	1999
SPARTA	SUPERGEN	1999
NORTH AMERICAN VACCINE	BAXTER	1999
NOVOPHARM	TEVA	1999
KINETIX	AMGEN	2000
CISTRON	GENZYME	2000
SMITHKLINE BEECHAM	GLAXO WELLCOME	2000
LIPOSOME	ELAN	2000
FUJIREBIO	UCB	2000
GELTEX	GENZYME	2000
PATHOGENESIS	CHIRON	2000
COULTER	CORIXA	2000
BIOCHEM	SHIRE	2000

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Table 9 – continued from previous page

Target	Acquirer	Year
KNOLL	ABBOTT	2000
DURA	ELAN	2000
SCHEIN	WATSON	2000
MITSUBISHI-TOKYO	WELFIDE	2000
IMMUNEX	AMGEN	2001
HOKURIKU	ABBOTT	2001
AVIRON	MEDIMMUNE	2001
ALZA	JOHNSON & JOHNSON	2001
DUPONT MERCK	BRISTOL-MYERS SQUIBB	2001
MATRIX	CHIRON	2002
TRIANGLE	GILEAD SCIENCES	2002
MEMORY	ROCHE	2002
ORAPHARMA	JOHNSON & JOHNSON	2002
PHARMACIA	PFIZER	2002
BIOGEN	IDEC	2003
SCIOS	JOHNSON & JOHNSON	2003
SANGSTAT	GENZYME	2003
APPLIED MOLECULAR EVOLUTION	LILLY	2003
POWDERJECT	CHIRON	2003
BEHRINGWERKE	CSL	2003
SICOR	TEVA	2003
IDENIX	NOVARTIS	2003
FUJISAWA	YAMANOUCHI	2004
TULARIK	AMGEN	2004
LAXDALE	AMARIN	2004
ZYCOS	MGI PHARMA	2004
ILEX ONCOLOGY	GENZYME	2004
ACCESS	KERYX	2004
AVENTIS	SANOFI-SYNTHELABO	2004
AESGEN	MGI PHARMA	2004
NIHON	RANBAXY	2005
TRANSKARYOTIC	SHIRE	2005
XENOVA	CELTIC PHARMA	2005
GUILFORD	MGI PHARMA	2005
ID BIOMEDICAL	GSK	2005
CORIXA	GSK	2005
IVAX	TEVA	2005
BONE CARE	GENZYME	2005
VICURON	PFIZER	2005
DAIICHI	SANKYO	2005
FOURNIER	SOLVAY	2005
EYETECH	OSI PHARMACEUTICALS	2005
PENINSULA	JOHNSON & JOHNSON	2005
INKINE	SALIX	2005
HEXAL	NOVARTIS	2005
CHIRON	NOVARTIS	2005
ORPHAN MEDICAL	JAZZ PHARMACEUTICALS	2005
NEOGENESIS	SCHERING-PLOUGH	2005