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The effect of pharmaceutical reimbursement status changes on wholesale prices in the Nordic pharmaceutical markets

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Abstract

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The effect and possible regulations affecting this relationship were first examined by a literature review. Then, Callaway and Sant'Anna (2021) and two-way fixed effects difference in differences analyses were conducted at introductions and removals of reimbursement statuses. The control groups consisted of untreated and matched pharmaceuticals from another country. The analyses were limited to six months preceding the treatment and six months following it with monthly country-product panel data.

The literature review highlighted mostly price-decreasing regulations utilized in or similar to the Nordics. The empirical analysis suggested sample dependently statistically significant price decreases associated with a reimbursement status that ranged between 12-36 % in Finland and 2-25 % in Sweden. No such association could be identified in Norway. Evidence on differences between branded and generic pharmaceuticals was limited, and thus it requires further research.

The inference and generalization of the results are limited by the requirements of the individual methods, the use of only pharmaceuticals with at least six months lasting reimbursement statuses, and the exclusion of unmatched products. The first problem is addressed by utilizing several estimation methods for robustness. The latter two problems can cause selection bias. Thus, it is recommended to use these results mostly in the context of multinational pharmaceuticals.

Keywords Difference in differences, Health economics, Pharmaceutical reimbursement, Price elasticity of demand, Price regulation

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Tiivistelmä

Tämä työ käsittelee apteekeissa myytyjen lääkkeiden korvattavuuden vaikutusta niiden tukkuhintoihin Suomessa, Norjassa ja Ruotsissa vuosina 2010–2017. Vaikutuksen ymmärtäminen selventää lääkkeiden hinnoittelun kannustimia. Tämä voi hyödyttää lääkkeiden korvattavuuden arviointia Pohjoismaissa.

Vaikutusta ja mahdollisia sääntelyitä, jotka vaikuttavat tähän yhteyteen, selvitettiin ensin kirjallisuuskatsauksessa. Sen jälkeen Callawayn ja Sant'Annan (2021) ja kaksisuuntaisten kiinteiden vaikutusten *difference in differences* analyyseilla tutkittiin vaikutusta lääkkeiden korvattavuuden poistamisten ja myöntämisten yhteydessä. Kontrolliryhmät koostuivat korvattavuudeltaan ennen korvausmuutosta vastaavista lääkkeistä toisessa maassa. Analyysit rajoitettiin kuuteen kuukauteen ennen ja kuuteen kuukauteen jälkeen korvattavuuden muutoksen kuukausittaisella maa-tuote-paneelidatalla.

Kirjallisuuskatsaus korosti useita lääkkeiden hintoja laskevia sääntelyitä, joita käytetään Pohjoismaissa tai jotka ovat samankaltaisia pohjoismaiselle lainsäädännölle. Empiirinen analyysi ehdotti otosriippuvaisesti tilastollisesti merkitseviä korvattavuuden yhteydessä olevia hinnanlaskuja, jotka sijoittuvat 12–36 prosentin välille Suomessa ja 2–25 prosentin välille Ruotsissa. Vastaavaa yhteyttä ei löydetty Norjasta. Geneeristen lääkkeiden ja alkuperäislääkkeiden välisten erojen selkeys jäi rajoitetuksi ja vaatii siis lisätutkimusta.

Tulkintaa ja tulosten yleistämistä rajoittavat yksittäisten käytettyjen metodien vaatimukset, vaatimus vähintään kuuden kuukauden kestävästä korvattavuudesta tutkittavilla lääkkeillä ja lääkkeiden, joille ei löytynyt sopivaa vastinetta kontrollimaasta, poissulkeminen analyysista. Ensimmäinen ongelmista huomioitiin käyttämällä useita estimaatiomenetelmiä. Kaksi viimeistä ongelmaa voivat aiheuttaa valintaharhan ja siksi tuloksia suositellaan sovellettavan lähinnä monikansallisten lääkkeiden kontekstissa.

Avainsanat *difference in differences,* terveystaloustiede, lääkekorvaus, kysynnän hintajousto, hintasääntely

The effect of pharmaceutical reimbursement status changes on wholesale prices in the Nordic pharmaceutical markets[1]

Matias Pousi

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Espoo, 08 February 2023

Matias Pousi

Contents

1 Introduction

Curbing pharmaceutical expenditures is a challenge that countries commonly face. The Nordic countries are no exception. Phenomena such as aging populations and an increasing number of new pharmaceuticals for formerly untreatable illnesses contribute towards the rising pharmaceutical expenditure. Figure 1 illustrates that pharmaceutical spending as a share of GDP has not decreased in Finland, Norway, or Sweden from the spending level at the beginning of the century. Thus, due to the overall increasing GDP over the 2000s, pharmaceutical spending has increased in real prices. Naturally, expenditure increases can pressure the payer to decrease spending, increase income, or preferably both. Because the governments subsidize pharmaceutical spending in the Nordic countries, several attempts to curb expenditure have been tried.

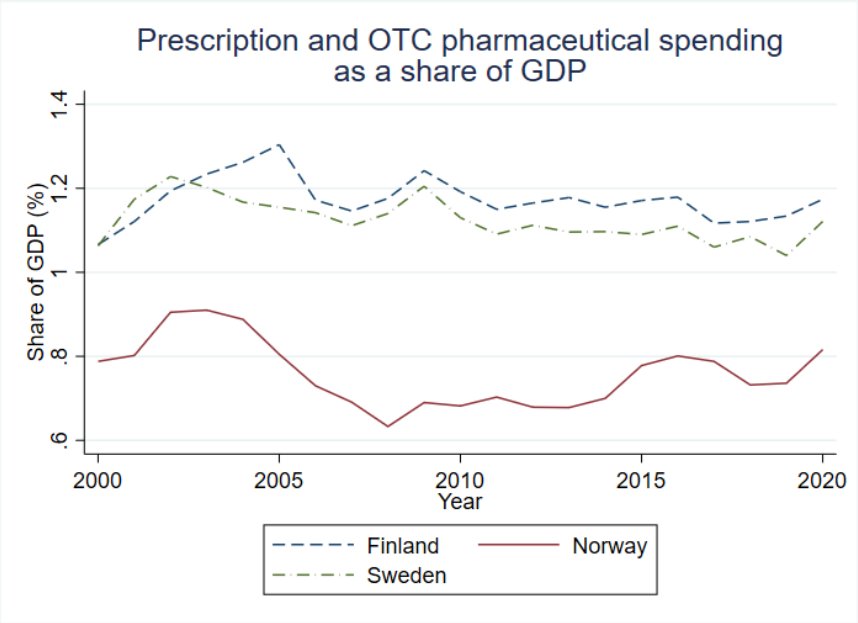

Figure 1: OECD (2022), Pharmaceutical spending (indicator). doi: 10.1787/998febf6-en (Accessed on 08 July 2022).

The multitude of changes in price regulations and attitudes towards them in Norway in the early 2000s illustrate the need and preference for simple and effective price and expenditure-curbing policies. For instance, Håkonsen et al. (2009) conducted a literature review and ten interviews with people who had "a prominent position, active participation in public debate, and involvement in the formation of pharmaceutical policies" (p. 278) to evaluate the impact of different regulations on pharmaceutical prices in Norway between 1994 and 2004. The policies evaluated were reference-based pricing, external reference pricing, generic substitution, and index pricing which was similar to internal reference pricing. Of these policies, which will be discussed more later on, external reference pricing was evaluated to be the most successful one due to clear and predictable price reductions.

Large pharmaceutical price regulation changes have occurred in other Nordic

countries too. However, also more focused expenditure minimization attempts have been tried. For example, the reimbursement rate of non-insulin diabetes medication was lowered in an attempt to decrease the governmental pharmaceutical expenditure in Finland in 2017 (Valtioneuvosto, 2016). The idea may appear simple but the dynamics of it for the agents involved can turn out to be surprisingly complex.

Altering the reimbursement rate of a pharmaceutical shifts the cost of medication to the patient from the government or vice versa. If these kinds of policies would not affect anything else, the outcome would be cost-neutral from the viewpoint of the society. However, the choice of allocating costs to the patients or the government may affect the behavior of the purchase decision maker - the consumer. This is especially true under large price elasticity of demand. A large price elasticity of demand suggests a decrease in consumption after a price increase, which the decrease or removal of reimbursement is from the viewpoint of the consumer. Naturally, these spending changes lead to adjustments of behavior of other agents in the market. Altering the wholesale price, which affects the retail price and the reimbursement, is a mechanism through which pharmaceutical companies can try to optimize their profits in the market under changes.

Changes in out-of-pocket costs relative to prices have been studied in varying settings. For example, Pavcnik (2002) showed that the prices of pharmaceuticals fell over 10 % in Germany in 2002 when a previously used flat prescription fee was replaced by a reimbursement with an upper limit. Thus, patients became varyingly more exposed to pharmaceutical prices. Findings like these could tempt decision-makers to decrease or even remove the reimbursement of pharmaceuticals in an attempt to decrease pharmaceutical prices.

However, a reimbursement status can be conditional and affect the profit-maximizing prices. Duggan and Scott Morton (2010) showed that pharmaceutical prices reimbursed through insurance granted by Medicare Part D could be decreased with price competition encouraging conditions compared to non-reimbursed pharmaceuticals in the USA. Hence, multiple aspects can affect pricing decisions. The price elasticity of demand, maximum price regulations, and additional conditions for the size of the reimbursement, e.g., reference pricing, are examples of this. These topics have been studied for example by Einav et al. (2018), Brekke et al. (2009), and Kortelainen et al. (2022).

Therefore, to come up with policy recommendations that would decrease the expenditure on pharmaceuticals, understanding the reaction of the whole market to overlapping regulations would be necessary. However, the market consists of individual agents, including firms. Therefore, providing information on the decision-making of firms is also valuable, and can be of great importance in the decision of either granting or removing reimbursement status for a pharmaceutical. Thus, the focus of this thesis is on the level of individual pharmaceuticals in the Nordic countries instead of markets which is left for future research.

This thesis contributes to the literature of health economics and industrial organization by focusing on the relationship between the wholesale price of retail pharmaceuticals and their reimbursement statuses. The research question is how large is the effect of a reimbursement status change on the pharmaceutical wholesale price in

Finland, Norway, and Sweden in 2010-2017. In addition, differences between branded and generic pharmaceuticals are examined.

To provide an answer to this question, a literature review and an empirical part with both Callaway and Sant'Anna (2021) and two-way fixed effects difference in differences analyses are included in the thesis. The empirical part and the examination of regulatory environments focus on three Nordic countries: Finland, Norway, and Sweden. By utilizing similarities between products and the reimbursement status changes occurring at different times between countries, the treatment and control groups are created by using country pairs for the samples. These groups are constructed by matching either on product-level, for a removal of a reimbursement status, or chemical substance and brand status level, for an introduction of a reimbursement status. The reason for this difference in matching strategies is the scarcity of observations with only product-level matching which stems from the focus on six months before and six months after the change in the reimbursement status. The Finnish outcome data, the pharmaceutical wholesale prices, is from FIMEA (2010-2017), the Norwegian outcome data is from Farmastat (2010-2017), and the Swedish outcome data is from IQVIA MIDAS Quarterly sales (2010-2017).

The structure of the rest of this thesis is the following. In chapter 2, some of the core concepts and regulations that are characteristic of the Nordic pharmaceutical markets are discussed. Chapter 3 includes a literature review of the effect of a reimbursement status on the prices of pharmaceuticals and the effects of the Nordic regulations on pharmaceutical prices. In chapter 4, the empirical approach is explained. In chapter 5, the results of the empirical analysis are covered. The conclusions conclude the thesis.

2 Background

This chapter clarifies the regulatory framework of pharmaceutical markets in the Nordic countries. The goal is not to delve deeply into each change in the reimbursement schemes but to provide an overview of the main aspects affecting the prices of reimbursed pharmaceuticals or pharmaceuticals considered for reimbursement.

2.1 Pharmaceutical classification

Pharmaceuticals are classified into five hierarchical levels with different categories based on their chemical substance in the ATC classification system. The classification is represented by codes including seven letters and numbers in total. The hierarchical levels are starting from the first one anatomical main group, therapeutic subgroup, pharmacological subgroup, chemical subgroup, and chemical substance. In the corresponding order, these add one letter, two numbers, one letter, one letter, and two numbers to the code. Each hierarchical level further specifies the intended use and properties of the pharmaceutical, finishing at the substance level. A clarifying example of rosuvastatin is in table 1. (WHO Collaborating Centre for Drug Statistics Methodology, 2018)

Table 1: ATC classification of rosuvastatin. (WHO Collaborating Centre for Drug Statistics Methodology, 2021)

Level	Code	Name
1st	C	Cardiovascular system
2nd	C10	Lipid modifying agents
3rd	C10A	Lipid modifying agents, plain
4th	C10AA	HMG CoA reductase inhibitors
5th	C10AA07	Rosuvastatin

Naturally, multiple pharmaceuticals may have the same chemical substance, and even more pharmaceuticals can share lower hierarchical levels of the ATC classification.

In the Nordic countries, Nordic article numbers (VNR) are assigned to pharmaceutical products. A VNR is a six-digit code which ranges from 000001 to 199999 and from 370000 to 599999 if the same code can signify the same product in another Nordic country. (VnrWiki [nodate]a) The product must share six specific commonalities to have the same Nordic article number. These are trade name, marketing authorization holder, pharmaceutical dosage form, strength, pack size, and type of package. (VnrWiki [nodate]b) Hence, in the Nordic countries, a VNR can be used to match pharmaceuticals between countries more precisely than with ATC classification, in fact, one-to-one. Nonetheless, both of the classification criteria are help identify pharmaceuticals in the Nordic context.

2.2 Applying for a reimbursement status

In Finland, the market authorization holder, an agent who has been granted the right to sell a pharmaceutical, applies for a reimbursement status and a reasonable wholesale price, a maximum price for a reimbursed pharmaceutical, to the Pharmaceuticals Pricing Board, Lääkkeiden hintalautakunta in Finnish (Sairausvakuutuslaki 1224/2004 [SVL] 6:4 §, 6:8 §). While determining a reasonable wholesale price, several factors are considered. These are prices of comparable products in Finland, prices of the pharmaceutical in other European Economic Area countries, treatment costs and benefits caused by the use of the pharmaceutical, the costs and benefits of alternative treatments, and the assets available for reimbursement. (SVL 6:7 §) The maximum time allowed for the Pharmaceuticals Pricing Board to process the reimbursement status application is 180 days given that the initial information required for the evaluation is sufficient (SVL 6:25 §).

In Norway, the market authorization holder applies for reimbursement for the pharmaceutical to the Norwegian Medicines Agency, Statens legemiddelverk in Norwegian. The evaluation of the reimbursement status is conducted by the pharmacoeconomic experts in the medicines agency, external clinical experts, and dialogues with the applicant. After this, the Norwegian Medicines Agency decides whether to grant the reimbursement status. A usual requirement for the reimbursement status is cost-effectiveness. Regulatory maximum prices for prescription pharmaceuticals may be too high for cost-effectiveness, which can lead to price negotiations. Norwegian Medicines Agency has 180 days to process a reimbursement application. (Weise, 2018)

In Sweden, the market authorization holder applies for reimbursement to the Dental and Pharmaceutical Benefits Agency, Tandvårds- och läkemedelsförmånsverket (TLV) in Swedish. The Dental and Pharmaceutical Benefits Agency considers three principles that state that the reimbursement status does not discriminate against any group, prioritization of severely ill, and cost-effectiveness. (Pontén et al., 2017) The maximum time allowed for TLV to process the reimbursement status application is 180 days, although the processing time is often shorter. (TLV, 2020)

Notably, the cost-effectiveness of a pharmaceutical is highlighted in all Nordic countries in the evaluation of the reimbursement status.

2.3 Removal of a reimbursement status

In Finland, if the pharmaceutical company wants to remove the reimbursement status of its pharmaceutical, the company has to notify the Pharmaceuticals Pricing Board at least three months before the planned removal date. Starting from the next quarter after the planned removal, the reimbursement status and the reasonable wholesale price, a maximum price for the pharmaceutical if it is under reimbursement, will be removed. (SVL 6:14 §)

The reimbursement status can be removed also by the initiative of the Pharmaceuticals Pricing Board. This can occur if the patent of the pharmaceutical expires, the pharmaceutical is used more broadly than initially stated, the reasons behind the

reimbursement decision disappear, new information invalidates arguments for the medicinal use of the pharmaceutical, the sales of the pharmaceutical have been considerably higher than evaluated initially, or the cost of the pharmaceutical is evaluated to increase considerably higher than initially evaluated due to a change during the period of validity of the wholesale price. (SVL 6:16 §)

In Norway, the Norwegian Medicines Agency can reassess at any time whether a reimbursed pharmaceutical is priced reasonably compared to the benefit the pharmaceutical provides. If there is a need for readjustments in the price or conditions, the Norwegian Medicines Agency notifies the market authorization holder of these. If new conditions are introduced, or if the price can't be changed to a reasonable level, a new reimbursement decision has to be made by the Norwegian Medicines Agency. This may lead to a rejection of the pharmaceutical reimbursement. (Forskrift om legemidler (legemiddelforskriften) 14:11 §)

In Sweden, the Dental and Pharmaceutical Benefits Agency may remove the reimbursement status of a pharmaceutical (Lag (2002:160) om läkemedelsförmåner m.m. 10 §). In addition, the market authorization holder may request the removal of the reimbursement status. (Lag (2002:160) om läkemedelsförmåner m.m. 12 §)

2.4 Reimbursement statuses

In Finland, prescription pharmaceuticals can be reimbursed (Kela 2016, 2022). There are three types of reimbursement statuses with differing reimbursement rates: basic, lower special, and higher special. Basic reimbursement rate was 40 %, lower special 65 %, and higher special 100 % in 2017. These reimbursement rates are currently in use. (Kela, 2017, 2022) In the 2010s, there were two changes in the rates. At the beginning of 2016, the basic reimbursement rate was increased to 40 % from 35 % (Kela 2016). At the beginning of 2013, the basic reimbursement rate was decreased from 42 % to 35 % and the lower special reimbursement rate was decreased from 72 % to 65 % (Antila et al., 2013, p. 16; Kela, 2013a).

There have also been other changes in the reimbursement schemes. In 2016, an initial deductible of 50 €, excluding children, was introduced. Before this, there was no initial deductible for the pharmaceuticals that belonged to the reimbursement schemes. (Kela, 2015a) However, other fixed costs still existed with certain limitations. For pharmaceuticals in the higher special reimbursement scheme, there is currently a payment of 4.5 € for each purchase. A fixed cost is also assigned for any reimbursed pharmaceutical purchase when the maximum annual threshold on medical expenses is exceeded. (Kela, 2022) This threshold was between 600 - 700 € during most of the 2010s (Aaltonen et al., 2019; Fimea and Kela, 2012, p. 16; Kela, 2013a, 2014, 2015b, 2016, 2017). The fixed cost after fulfilling the limit is currently 2.5 € but used to be 1.5 € before 2016. (Kela, 2013b, 2016, 2022).

In Norway, there are three reimbursement categories: general reimbursement, individual reimbursement, and pharmaceuticals for dangerous contagious illnesses. The general reimbursement rate was 61 % in 2017. General reimbursement includes pharmaceuticals that are pre-approved for reimbursement. In addition, pharmaceuticals for dangerous contagious illnesses are fully reimbursed and include products such

as vaccines against communicable diseases and pharmaceuticals for the treatment of e.g., HIV or hepatitis C. (Weise, 2018, p. 35) The reimbursement rate for general reimbursement used to be 62 % before 2016 during the whole 2010s. The out-of-pocket pharmaceutical payments were limited to 520 NOK or approximately 50 € per prescription. (Forskrift om endring i blåreseptforskriften § 8, 2015; Forskrift om endring i forskrift om stønad til dekning av utgifter til viktige legemidler mv. (blåreseptforskriften) § 8, 2009; Forskrift om stønad til dekning av utgifter til viktige legemidler mv. (blåreseptforskriften) § 8, 2007) The maximum annual co-payment was 2560 NOK from 2009 to 2012, 2620 NOK in 2013, 2670 from 2014 to 2016 and 1990 NOK in 2017 (Forskrift om egenandelstak 2 § 3, 2003; Forskrift om endring i forskrift om egenandelstak 2 § 3, 2008, 2012, 2013, 2016).

In Sweden, the reimbursement rate depends on the spending on pharmaceuticals during a year. Both over-the-counter (OTC) and prescription-only pharmaceuticals can be reimbursed even though most of the OTC pharmaceuticals are not. This is due to the free pricing of pharmaceuticals outside benefits scheme which some companies want to utilize. In addition, insulin and pharmaceuticals prescribed for preventing specific communicable diseases under Swedish Communicable Diseases Act are reimbursed fully without any co-payment. The possible reimbursement rates for general and limited reimbursement are 0, 50, 75, 90, and 100 %. (Pontén et al., 2017) The spending threshold including the reimbursed part of the spending for 50 % reimbursement was 1100 SEK, 75 % reimbursement was 2100 SEK, 90 % reimbursement was 3900 SEK, and full reimbursement was 5400 SEK (Socialstyrelsen, 2016). At the beginning of 2012, the corresponding thresholds changed to the ones used in 2017 from 900 SEK, 1700 SEK, 3300 SEK, and 4300 SEK (Socialstyrelsen, 2011, 2012).

2.5 Pricing of pharmaceuticals

The retail price of a reimbursed pharmaceutical is based on the wholesale price and the pharmacy markup in Finland. The prices of prescription pharmaceuticals are the same in all pharmacies in Finland. (Valtioneuvoston asetus lääketaksasta 713/2013) In addition to pharmacy-level regulation, there is also regulation for a reasonable wholesale price for reimbursed pharmaceuticals. The Finnish Pharmaceuticals Pricing Board decides these maximum prices for reimbursed pharmaceuticals. Non-reimbursed pharmaceutical prices are regulation-free. (Lääkkeiden hintalautakunta, [no date])

There are two main maximum wholesale price regulations for pharmaceuticals in Norway. The first one is a maximum price for all prescription pharmaceuticals. The maximum price is mainly determined by external reference pricing, which is covered in section 2.7. It was implemented in 2002. The second policy is called stepped price model. Its basic idea is to reduce pharmaceutical prices once the patent expires and other pharmaceuticals utilizing the same active substance enter the market, i.e., generic competition begins. This is done in two to three phases: at the beginning of generic competition, six months after this, and the possible last step at the earliest twelve months after this if the revenue exceeds certain predefined limits. The mandatory price cuts are calculated as percentages of before generic competition prices. Over-the-counter pharmaceutical prices are unregulated unless

the pharmaceutical is on the positive list of reimbursable pharmaceuticals. Maximum pharmacy markups limit the retail prices of prescription pharmaceuticals. (Statens Legemiddelverk, 2021; Weise, 2018)

In Sweden, TLV sets the maximum prices of reimbursed pharmaceuticals. All prescription pharmaceuticals that belong to benefits schemes face price regulation through pharmacy markups. However, if the pharmaceutical does not belong to the benefits scheme, its price is not regulated. The prices of over-the-counter pharmaceuticals are not regulated. The prices of the reimbursed pharmaceuticals are the same across Sweden. (Pontén et al., 2017)

Sweden also has two policies that alter the prices of pre-existing pharmaceuticals. The first one, called takpriser, states that once the price of a generic competitor falls below 30 % of the price before the generic competition began, the maximum price within the same group of pharmaceuticals is set to 35 % of the price of the branded pharmaceutical before the competition. This price ceiling applies to both generic competitors and the branded pharmaceutical. The second regulatory price decrease is done by a so-called 15-year rule. Its idea is to decrease the pharmaceutical prices by 7.5 % occasionally if the pharmaceutical has at most weak competition and it has been 15 or more years in the market. These price reductions have been applied to select pharmaceuticals in 2014, 2016 and 2017. (TLV, 2022a)

2.6 Generic substitution

Generic substitution is a regulation that enforces pharmacies to at least offer the cheapest substitute for a prescribed pharmaceutical if the pharmaceutical belongs to a list of substitutable pharmaceuticals. In Finland, if the pharmaceutical is only under generic substitution but not under reference pricing, the patient can decline the substitution and still receive the reimbursement. However, in Sweden and Norway, refusing the substitution to the cheapest alternative will provide reimbursement only up to the cheapest offered price. (Kela, 2020; TLV, 2022b; Weise, 2018) Generic substitution was implemented in Finland in 2003, in Sweden in 2002, and in Norway in 2001 (Aalto-Setälä, 2008; Granlund, 2010; Håkonsen et al., 2009).

2.7 Reference pricing

External reference pricing is utilized in Norway. In external reference pricing, the prices of the same kind of pharmaceuticals are observed in other countries. The reference price is defined based on those prices. In Norway, the external reference price defines the maximum wholesale price of prescription-only pharmaceuticals by calculating the average highest wholesale price in the three countries with the lowest prices among nine selected European countries. (Weise, 2018)

Internal reference pricing has been used in Finland since 2009 (Kela, 2018). The idea of internal reference pricing is that the maximum price up to which reimbursement can be applied is defined endogenously in the country, for example by the price of the lowest-priced competitor of the pharmaceutical. If a consumer wants a product that has a higher price, they have to pay the difference in price. In Norway, stepped

price model resembles internal reference pricing. Hence, pharmaceuticals in Norway face price regulation both internally based on the price before the generic competition began and externally based on pharmaceutical prices in other countries.

In Sweden, generic substitution is intertwined with internal reference pricing. Through generic substitution, the maximum reimbursement has depended on the prices of generic competitors since 2002. Since October 2009, Sweden has also had "products-of-the-month" which are determined by monthly auctions to find the cheapest alternative within products in a generic substitution group at the national level. The auction winner is used as the default recommendation with two backup alternatives if the winner is unavailable in a pharmacy. (Pontén et al., 2017)

3 Literature Review

A mechanism through which reimbursement status changes could affect the prices of pharmaceuticals is straightforward. If a pharmaceutical is reimbursed, a consumer is not paying the full price if they have fulfilled the deductible. Hence, the wholesale price elasticity of demand may be smaller than without reimbursement. Therefore, optimal pricing decisions can differ between reimbursed and non-reimbursed pharmaceuticals from the viewpoint of a firm.

This chapter covers literature on price elasticity of demand, pricing responses to reimbursement changes, and regulations affecting or restricting these decisions.

3.1 Price elasticity of demand

Einav et al. (2018) measured the out-of-pocket price elasticity of demand for over 150 different pharmaceuticals in the United States. Einav et al. (2018) utilized the discontinuities of pharmaceutical insurance introduced by Medicare Part D which is a federal insurance program that subsidizes prescription pharmaceutical insurance to the elderly. In the sample that Einav et al. (2018) used, the unweighted average of out-of-pocket price elasticity was -0.24 with a standard deviation of 0.51. For 108 unweighted therapeutic classes, the estimated price elasticity was -0.15 with a standard deviation of 0.15. These results imply that the consumption of pharmaceuticals would be higher with smaller out-of-pocket prices, which is not surprising. However, it is important to stress that the demand for pharmaceuticals is not perfectly inelastic.

The price elasticity of demand estimates differ across studies for several reasons. The price elasticity of demand depends on the shape of the demand curve, which may differ due to e.g., demographic differences and regulatory frameworks, and one's position in the demand curve. Studies also include different pharmaceuticals that might have heterogeneous price elasticities, as the standard deviations in Einav et al. (2018) imply.

Ellis et al. (2017) estimated the elasticity for pharmaceuticals to be between -0.51 and -0.44 by using forward and backward myopic prices as lower and upper bounds. This result implies larger price elasticity than in Einav et al. (2018) with caveats that contribute to the differences. Firstly, the samples between the studies differ. Einav et al. (2018) utilized Medicare Part D, which considered the elderly, while Ellis et al. (2017) studied people between ages of 0 and 64. In addition, Ellis et al. (2017) estimated the price elasticity to be smaller for children and more ill people. Therefore, these results from the two studies seem to contribute to the hypothesis that more vulnerable groups have a lower price elasticity of demand.

A meta-regression conducted by Gemmill et al. (2007) also provides similar results for the price elasticity of demand of prescription pharmaceuticals. According to the meta-regression that included results from 22 different studies ranging from the 1980s to the early 2000s, the mean price elasticity of demand was -0.209. Gemmil et al. (2007) obtained these results especially from the United Kingdom, the United States, and Canada. However, some European countries, such as Belgium and Italy, were included in addition to Australia.

However, considerably larger price elasticities of demand are present in the literature. Dubois and Lasio (2018) studied the effect of pharmaceutical price regulation on the demand and the prices of anti-ulcer drugs from 2003 to 2013 in France with a structural model. Dubois and Lasio (2018) used less regulated countries, the United States and Germany, as the control group. In this setting, a maximum reimbursed price was set for pharmaceutical groups that had little generic penetration in France. Exceeding the price threshold would have led to missing part of the reimbursement. Dubois and Lasio (2018) estimated the price elasticity of demand for anti-ulcers and found out that the elasticity was on average -3.6 in France. This large price elasticity of demand is explained partly by the regulation assigning high out-of-pocket payments for the consumer when the maximum reimbursement price is exceeded. Hence, the availability of substitutes and regulations encouraging price decreases seem to enable even quite elastic demand for pharmaceuticals.

One should note that these estimates are not necessarily representative of the Nordics as the pharmaceutical markets differ across countries due to demography, supply, and regulations. However, despite these differences, it does not seem implausible that the price elasticity of pharmaceuticals could be large enough to be recognizable in the Nordic countries due to the price regulations covered in chapter 2.

3.2 Pricing response to out-of-pocket cost changes

If the price elasticity of demand is large enough, changes in the reimbursement statuses could affect the pricing of pharmaceuticals through co-payment-dependent demand. Pavcnik (2002) and Duggan and Scott Morton (2010) study the effects of co-payment changes on prices by utilizing reforms of reimbursement or insurance schemes.

According to Pavcnik (2002), a flat prescription fee was replaced by a reference price -based maximum reimbursement in Germany in 1989. This reform meant that the prices of these pharmaceuticals became more exposed to the patients as a flat prescription fee does not provide a price signal for the patient in terms of out-of-pocket costs. Hence, this setting in Germany provided an incentive to alter the prices of the pharmaceuticals. In other words, this change resembled a decrease in the reimbursement rate especially for high-priced pharmaceuticals. The analysis was conducted on antidiabetics and antiulcerants of which the latter faced significant new competition due to the entry of generic competitors in 1991. Because of this, the analysis was conducted separately for antidiabetics and antiulcerants.

Pavcnik (2002) had two main approaches. The first one was a regression of logarithmic retail prices on a dummy variable representing whether reference pricing is in use in Germany, an interaction term of this dummy and a branded pharmaceutical dummy, product fixed effects, and time in the form of either a time trend or a year indicator. The second approach considered the same dependent variable with a product-specific instead of country-wide reference pricing dummy and year indicators as the time variable.

By using a control group of pharmaceuticals similar in technology, regulatory shocks, and demand shocks, but not under reference pricing, Pavcnik (2002) found that the prices dropped around 11 % for generic antidiabetics and an additional 26 %

for branded ones based on the second regression. For antiulcerants, Pavcnik (2002) had to use the first regression due to a lack of a proper control group. Pavcnik (2002) also controlled for competition, which seemed to be important for the antiulcerants but the results for antidiabetics appeared to be less sensitive for this. Overall, Pavcnik (2002) found that the price decreases were approximately between 10 % and 26 %. The price changes were larger among branded pharmaceuticals, and especially among the branded pharmaceuticals that faced noticeable generic competition. Hence, based on Pavcnik (2002), as a consumer becomes more exposed to the non-reimbursed price of pharmaceuticals, pharmaceutical companies decrease the pharmaceutical prices, as would be optimal with large price elasticity of demand.

However, the prices may react in an opposite way in certain regulatory environments. Duggan and Scott Morton (2010) studied the impact of Medicare part D on pharmaceutical prices. Duggan and Scott Morton (2010) noticed that prices of several pharmaceuticals included in the subsidized insurance did not increase unlike their closest comparisons outside it. The finding relied on the assumption that the main variable of interest was equal to its maximum value. This variable was the fraction of prescriptions filled in 2002-2003 for those who were enrolled in the program out of all prescriptions. In reality, in which this is not the case, the effects were proportionally smaller. Under the assumption, the avoided price increase that other pharmaceuticals faced was approximately 13 %. According to Duggan and Scott Morton (2010), the reason for these price change differences was especially the insurers' use of formularies, which identified substitutes for patented pharmaceuticals. Hence, the pricing incentives created for the pharmaceutical companies somewhat resembled a higher price elasticity of demand because the insurer assigned higher out-of-pocket costs to the consumers for more expensive alternative pharmaceuticals by excluding the most expensive pharmaceuticals from the insurance.

However, for pharmaceuticals with few substitutes and protected pharmaceutical categories, such as HIV and cancer drugs, the formularies were required to include all of the alternatives. This nullified the bargaining power of the insurer. For the protected pharmaceuticals, the results suggested that the price decreases associated with Medicare part D inclusion disappeared and the prices of these pharmaceuticals increased approximately at the same rate as pharmaceuticals outside the reform, although the coefficients suggesting this were not statistically significant. However, the coefficient of the interaction variable of small category dummy and medicare market share in 2002-2003 was of different sign and approximately twice as large compared to the main independent variable of interest, medicare market share in 2002-2003. This implied a price increase in the small category even when the negative, but statistically insignificant, dummy variable of the small category was considered. Hence, the results suggested that without insurers' or consumers' increased bargaining power, increased co-payment encouraged the pharmaceutical companies to price their pharmaceuticals higher.

Both Pavcnik (2002) and Duggan and Scott Morton (2010) illustrate the negative relationship between pharmaceutical prices and co-payments ceteris paribus. However, the role of competition and underlying regulations or bargaining power on the demand side is highlighted in both studies. These factors make it difficult to determine how

reimbursement status changes affect the prices in addition to the possible geographical and timing differences with the modern Nordic pharmaceutical markets. Hence, further examination of the regulations in the Nordic pharmaceutical markets can help understand the effects.

3.3 Regulations affecting prices

As established earlier, the Nordic pharmaceutical markets have regulations that are targeted not only for pharmaceuticals or prescription pharmaceuticals but also specifically for reimbursed pharmaceuticals. These regulations affect the sets of available and optimal pricing choices for pharmaceutical companies.

For example, Martikainen et al. (2005) studied the prices of eight new and reimbursable pharmaceuticals in Belgium, Denmark, Finland, France, Ireland, the Netherlands, Spain, Sweden, and the United Kingdom. All pharmaceuticals were authorized in 2000 by the European Commission. The study was conducted by a questionnaire that was sent to pricing and reimbursement authorities at the end of 2002. Martikainen et al. (2005) found that the wholesale prices were lowest in the countries with more strict price controls, namely Belgium, Finland, France, and Spain.

The study of Martikainen et al. (2005) was conducted with a small sample and in a different regulatory environment compared to today, but it illustrates the goal of this part of the literature review - to summarize a relationship between pharmaceutical prices and the local regulatory environment in which the companies operate. This knowledge is crucial in understanding how the incentives regarding the pricing of reimbursed pharmaceuticals function in practice.

Section 3.3 is structured the following way: First, consumers' reactions to deductibles are discussed. Then, the effects of maximum price regulations on pharmaceutical prices are summarized. Finally, the effects of both generic substitution and reference pricing on pharmaceutical prices are elaborated.

3.3.1 Deductibles

Spending-based non-linearities in the reimbursement rates of pharmaceuticals can affect the effect of a pharmaceutical reimbursement status change on the demand and the price. In Finland and Norway, the out-of-pocket spending required for full reimbursement is important as it affects the marginal reimbursement rate a consumer faces. In Sweden, the marginal reimbursement rate varies more compared to Norway and Finland. The importance of deductibles is highlighted in Sweden because the out-of-pocket payments can vary drastically in the vicinity of the spending thresholds. Hence, informed consumers' wholesale price elasticity of demand could fall close to zero once a threshold is exceeded. Thus, heterogeneity in the price elasticity of demand between consumers is expected based on personal annual spending. The studied change in the deductible in Brot-Goldberg et al. (2010) illustrates this.

Brot-Goldberg et al. (2017) examined a switch from free healthcare insurance to a high-deductible plan with non-linearities in a firm with over 120000 $ median income. After the switch, the employees received a lump sum which reflected the

average expected out-of-pocket cost caused by the insurance change. The study focused on healthcare services, but it also examined diabetes, cholesterol, depression, and hypertension pharmaceuticals. Brot-Goldberg et al. (2017) examined six years of which four were prior to the change with the same sample of employees each year. Brot-Goldberg et al. (2017) adjusted the spending based on the age of the sample and medical price inflation to keep it comparable between years.

Brot-Goldberg et al. (2017) found a decrease in spending after the deductible change. The decrease was mostly explained by a decrease in the quantity consumed. Brot-Goldberg et al. (2017) did not find evidence of price shopping in the years following the insurance plan switch. The decreases in quantities consumed between the last non-treatment year and the first treatment year ranged between 18 and 48 % depending on the indication. Diabetes medication had the largest decrease. However, Brot-Goldberg et al. (2017) found a difference between the decreases in quantities of generic pharmaceuticals and brands. The decrease in branded pharmaceuticals was approximately 30 %, while it was 12 % for generics. Whether these results are generalizable is still ambiguous as the sample of Brot-Goldberg et al. (2017) is limited to people with a high income-level, and Ellis et al. (2017) suggested smaller price elasticity of demand for more vulnerable groups compared to others.

Thus, if one assumes that the out-of-pocket price elasticity of demand for pharmaceuticals remains below zero, the demand should be negatively correlated with the deductible. If the consumer consumes either expensive pharmaceuticals or multiple pharmaceuticals, the annual out-of-pocket share is likely to remain low. Hence, expensive and frequently used pharmaceuticals or pharmaceuticals that are often used by people with several other prescriptions are likely to face higher marginal reimbursement rates. Consequently, this decreases the incentives of pharmaceutical companies to decrease the price of the pharmaceuticals, given that they face little competition. Therefore, among these types of pharmaceuticals, the changes in the reimbursement status may incentivize drastic price increases under deductibles and a lack of price regulation.

3.3.2 Price cap regulation

The price cap, i.e., maximum price, regulation can be a difficult policy to balance. Low maximum prices for reimbursed pharmaceuticals can keep the prices low in the short term and overrule the price-increasing incentives which reimbursed retail prices encourage. However, low maximum prices can discourage the entry of generic competition and limit future price decreases.

High maximum prices may encourage competition but appear ineffective in constraining prices otherwise. In addition, if launch prices were higher than could be sustained by future demand, the price decreases might be drastic soon after launch and affect studies including these pharmaceuticals in their samples. This kind of situation could occur if a pharmaceutical company is able to justify a high price in the reimbursement evaluation.

Ekelund and Persson (2003) examined how prices of new pharmaceuticals developed in differently regulated pharmaceutical markets in Sweden and the United States

between 1987 and 1997. The United States was less regulated than Sweden. Price negotiations for pharmaceuticals entering the market were either required or preferred as they were mandatory for including the pharmaceutical in the reimbursement scheme in Sweden. Notably, in Sweden, price increases beyond introductory prices were limited. Ekelund and Persson (2003) examined the prices through summary statistics and regressions. The pharmaceuticals were divided into three subcategories by the therapeutic gain they provided.

Ekelund and Persson (2003) found that the mean prices of these chemical entities tended to decrease more in Sweden than their counterparts in the United States. In Sweden, the mean prices relative to the initial price after four years were 0.78, 0.86, and 0.85 in the descending order of therapeutic gain. The corresponding rates in the United States were 0.95, 1.08, and 1.23. Hence, the prices of pharmaceuticals tended to decrease more in the more regulated market where price caps and negotiations with the regulator were present.

Shajarizadeh and Hollis (2015) focused on demand uncertainty in the presence of price increases limited to inflation in Canada. The uncertainty in their model considered the novelty of the drugs that reflected the newness of the therapeutic class or safety warnings after approval. In addition, information on the demand for the pharmaceutical in the United States was considered in the analysis. By using new dosage forms of patented pharmaceuticals as the control group and more novel pharmaceuticals as the treatment group, Shajarizadeh and Hollis (2015) conducted a difference in differences regression. Shajarizadeh and Hollis (2015) found that high launch prices relative to prices after launch were more common among pharmaceuticals with uncertain demand. Thus, the prices of branded pharmaceuticals can be expected to decrease more than generic pharmaceuticals after launch because the branded pharmaceutical establishes the market. The results of Shajarizadeh and Hollis (2015) and Ekelund and Persson (2003) also suggest that high launch prices and price decreases after launch are common when possibilities for price increases are limited.

Herr and Suppliet (2017) estimated the effect of tiered co-payments on pharmaceutical prices in the German reference price market. In July 2006, the tiered co-payment-like regulation was implemented to reference priced pharmaceuticals by introducing threshold prices for groups of pharmaceuticals under which no co-payment was required. By using quarterly data between 2007 and 2010, Herr and Suppliet (2017) applied a two-way fixed effects difference in differences approach by using the pharmaceuticals which faced the regulation change in the last quarter of 2010 as the control group. Herr and Suppliet (2017) found that generic pharmaceuticals faced a price decrease of approximately 5 %, meanwhile the price of branded pharmaceuticals increased by approximately 4 % due to the regulation change. However, one should be cautious in the interpretation of these results because recent literature, such as Goodman-Bacon (2021), has discussed the problems of two-way fixed effect approaches in estimating the treatment effect under staggered treatment and treatment effect heterogeneity. Hence, the estimates in Herr and Suppliet (2017) may not be as reliable if no homogeneity of treatment effect across the treatment timing groups is assumed.

Nonetheless, as discussed in Herr and Suppliet (2017), if a price of a pharmaceutical

exceeds a threshold in Germany, the out-of-pocket pharmaceutical price increases further as it becomes less reimbursed. The Nordic countries have regulations that resemble this mechanism through reference pricing and the negotiated maximum prices which may not be exceeded if there is no intention to remove the reimbursement status. However, the German example of tiered co-payments is arguably smaller. The co-payment in Germany for pharmaceuticals with a price under the reference price is generally 10 % according to Herr and Suppliet (2017). In order to achieve a similar reimbursement rate, extensive annual spending is required in the Nordic countries. Nonetheless, the findings of Herr and Suppliet (2017) suggest that at least some pharmaceutical companies are willing to reduce the prices of generics to decrease the out-of-pocket share of the price.

Even though price cap regulations related to reimbursement can have price-decreasing effects, they may also introduce adverse effects on the market. According to a theoretical model of Brekke et al. (2011) which considers the competition of a generic and a branded pharmaceutical under price cap regulation, a lower price cap reduces the market share of a generic competitor. This is explained by a decreased price gap between the branded and generic product given that the price cap is binding for the more expensive branded product. As Brekke et al. (2011) stated, this dampens the generic competition because the profits of the generic competitor decrease due to a smaller market share caused by forcefully increased price competition. Brekke et al. (2011) also noted that a small share of co-payment should lead to weaker effects of price cap regulation.

3.3.3 Generic substitution

Generic substitution has been implemented in all Nordic countries, albeit in slightly differing forms. Aalto-Setälä (2008) studied the effect of generic substitution on pharmaceutical prices in Finland from March 2003 to April 2004. Aalto-Setälä (2008) used a two-stage least squares approach utilizing the predicted number of competitors by the size of the substitution group. Aalto-Setälä (2008) found that the number of competitors and a requirement for prescription were statistically significant predictors for price decreases, while branded pharmaceuticals with more than four competitors faced smaller price decreases. According to Aalto-Setälä (2008), the reason for the importance of a prescription requirement might be that non-prescription pharmaceuticals that were on the substitution list did not legally require pharmacies to suggest a substitution. The overall estimated price decrease of the substitutable pharmaceuticals was around 10 %, according to Aalto-Setälä (2010).

Unlike Aalto-Setälä (2008), Kortelainen et al. (2022) did not find a statistically significant price-decreasing effect for the Finnish generic substitution reform without reference pricing. Kortelainen et al. (2022) studied the effects of pharmaceutical price regulation reforms on prices and market outcomes in the Nordic countries excluding Iceland. Kortelainen et al. (2022) estimated these effects by choosing another Nordic country, Denmark in this case, as a control group for a difference in differences estimation. Hence, generic substitution appears to have a limited effect on the prices of reimbursed pharmaceuticals without economic consequences for the rejection of

substitution by the consumer.

Granlund (2010) studied the effects of generic substitution reform on prices and welfare in Sweden in October 2002. Before this reform, a reference price covered 110 % of the price of the cheapest substitute. The implementation of generic substitution switched the threshold to 100 % of the price of the cheapest substitute. Hence, consumers faced a larger share of the price as an out-of-pocket payment in addition to the increase in the requirements of pharmacies suggesting cheaper alternatives for prescribed pharmaceuticals. Granlund (2010) studied the effect on prices by using pharmaceutical price data extending from January 1997 to October 2007 with all pharmaceuticals sold in Sweden. Granlund (2010) utilized monthly panel data in a regression with product fixed effects in which the dependent variable was the natural logarithm of the price. Besides the product fixed effects, other independent variables used were an indicator variable for the reform, a time varying modification of the indicator variable to capture the adjustment process to the reform, a dummy variable for the presence of generic competition, and a trend variable. Granlund's (2010) results suggested that the price decrease caused by the reform was 10 % in 2002-2007. However, the whole price decline was not instantaneous as it adjusted over time. In addition, there was heterogeneity in the price decreases. The prices of branded pharmaceuticals with generic competition at the time of the reform declined the most, 14 %, while branded pharmaceuticals with no generic competition, generics, and other pharmaceuticals faced price decreases of 10 %, 9 %, and 5 %, respectively.

Thus, the generic substitution seems to decrease the price of reimbursed pharmaceuticals, at least in Sweden. In addition, it can't be ruled out that the price of reimbursed pharmaceuticals declined in Norway due to the similarities between Norwegian and Swedish generic substitution. Besides the direct implications of generic substitution, the importance of the competitive environment and brand status is highlighted in Aalto-Setälä (2008) and Granlund (2010). Thus, controlling for competition in analyses that concern generic substitution can be important.

3.3.4 Reference pricing

On top of generic substitution, Nordic countries use reference pricing. Brekke et al. (2011) analyzed the effect of a change from price cap regulation to internal reference pricing on pharmaceutical prices in Norway both theoretically and empirically. The reference price reform happened in Norway in 2003. The reference price was calculated as the sales-weighted average of pharmaceuticals with the same chemical substance, package size, and dosage. In 2005, this reference price model was replaced by the stepped price model. By conducting linear regression analyses with molecule and period fixed effects using product-level panel data and a control group of molecule-wise similar pharmaceuticals under price cap regulation, Brekke et al. (2011) found that the branded pharmaceutical prices decreased over 30 % and the generics price over 20 % under reference pricing. This result complemented the results of the theoretical model.

Kaiser et al. (2014) examined the effect of the change from external to internal reference pricing in Denmark in 2005. They focused on price and welfare changes with statins. For prices, Kaiser et al. (2014) used six fixed effects regressions to

determine the effects of the reform on prices. The estimates suggested that due to the replacement of external reference pricing by internal reference pricing, the prices of pharmaceuticals included in the reform faced a price decrease of approximately 20 %. The price decreases were the largest among generic pharmaceuticals and the smallest among branded pharmaceuticals.

Contrary to the results of Kaiser et al. (2014), Kortelainen et al. (2022) found through a difference in differences approach with Finland as the control group that the prices of pharmaceuticals increased approximately 10 % due to the shift from external reference pricing to internal reference pricing in Denmark. Kortelainen et al. (2022) suggested that the results of Kaiser et al. (2014) are biased due to including the effect of the overall declining prices of pharmaceuticals in Denmark during that period. However, Kortelainen et al. (2022) also found that the prices declined approximately 15 - 20 % due to the implementation of internal reference pricing in Finland in which no prior reference pricing was implemented.

Hence, it seems that reference pricing can have a price-decreasing impact on reimbursed pharmaceuticals. However, the effects of external and internal reference pricing seem to differ, as the estimates regarding Denmark in Kortelainen et al. (2022) show.

4 Empirical approach

Based on the previous literature, the sign of the effect of having a reimbursement status on the price is unknown. Pavcnik (2002) showed that pharmaceutical prices fell when they became more exposed to consumers, while Duggan and Scott Morton (2010) pointed out that the sign of the price changes can be altered with sufficient regulations when the prices become less exposed. Due to a lack of pre-existing literature, it is questionable whether these conditions are satisfied in the Nordic regulatory environment despite literature on price-decreasing regulations. Thus, an empirical approach is needed to answer how large is the effect of a reimbursement status change on the wholesale prices of pharmaceuticals.

The empirical part of this thesis considers the effects of introductions and removals of reimbursement statuses on the wholesale prices of retail pharmaceuticals in Finland, Norway, and Sweden. This chapter provides necessary information on the approach and the data before the results are presented.

4.1 Approach

The possible effects of reimbursement status changes are examined by observing removals and introductions of pharmaceutical reimbursement statuses. In this empirical approach, reimbursement statuses are treated similarly without regard to reimbursement rates.

This section covers the sample creation process and the methods utilized in the analysis.

4.1.1 Sample selection

The choice of countries included in the samples is justified by two main reasons. Firstly, even though there are differences between specific implementations of the Nordic pharmaceutical market regulations, there are common regulatory concepts, such as reference pricing and generic substitution, in use. Secondly, the reason for the exclusion of the other Nordic countries is the availability of reimbursement status data which was the most extensive in Finland, Norway, and Sweden. Additionally, the combinations of Finland, Norway, and Sweden allow the inclusion of multiple treatment-control-country pairs with reasonably similar regulatory environments. For the introductions of reimbursement statuses, treatment-control-country pairs are excluded if Norway would be the control country. The reasons for this decision will be elaborated further in subsection 4.4.1 Parallel trends assumption.

The samples consist of country-product-month-level observations of pharmaceutical products between 2010 and 2017. The reasons for this time frame are data availability limitations after 2017 and large changes in regulations before 2010, such as the reference pricing reform in Finland in April 2009 and the introduction of the nationwide auction system in Sweden in October 2009. While controlling for these changes could be possible to some extent, the current time frame should allow an

approach that provides a more accurate sample compared to the regulatory framework of 2022 with lesser concern for the exact form of modeling these changes.

To keep the number of products larger and the sample constant across relative periods to treatment, only six consecutive monthly observations both before and after the treatment are examined and required for the products to be present in the data. In addition, there can be no additional changes in the reimbursement status during that period. Variation in the reimbursement status outside the treatment timing would cause difficulties for the difference in differences methods chosen.

The products in control groups of all difference in differences approaches face similar restrictions to their treated counterparts. However, they are not allowed to have the treatment during the consecutive 12-month observation period.

The analysis examines the treated pharmaceuticals as uniform groups despite their differing reimbursement rates. There are several reasons why this decision has been made. Firstly, exact data of the possible reimbursement rates was easily available only with the Finnish data set. By examining national laws, it is possible to find approximately the ATC codes which can be fully reimbursed in Sweden and Norway. However, the accuracy of these methods can still be uncertain. In addition, the Swedish and Norwegian samples used in the analysis did not have a large share of these possibly fully reimbursed pharmaceuticals. Secondly, even if these possible reimbursement rates could be identified accurately, there can be conditions that affect the size of the reimbursement rate. For example, for a pharmaceutical, the full reimbursement could be granted only for a certain purpose, and a lower reimbursement rate would be applied on other occasions.

Besides the possible concerns of identifying the correct reimbursement rate in theory, the realized reimbursement rate in practice is a concern. Regulations implemented in the reimbursement schemes may decrease the realized reimbursement rate for the patient. Reference pricing in Finland and generic substitution in Norway and Sweden are examples of these. In addition, in each of these countries, it is possible that differing shares of patients spend differing amounts on the pharmaceuticals they use due to their health conditions. Thus, different pharmaceuticals may face different realized reimbursement rates simply through different shares of deductible fulfilling patients. Hence, finding accurate realized reimbursement rates for the pharmaceuticals from the wholesale data at hand is impossible. Therefore, the chosen approach of treating reimbursed pharmaceuticals as a uniform group likely results in inaccuracies but is not at least arguably much worse than trying to utilize for instance the highest available reimbursement rates for the pharmaceuticals.

4.1.2 Matching

This thesis uses two matching methods. The more accurate method is one-to-one matching based on the month and the VNR code of the product between countries. This method can be applied to removals of reimbursement statuses in each country. However, due to small available sample sizes, it is not reasonable to try to obtain estimates for introductions of reimbursement statuses by this method.

A similar approach with different control groups is utilized to obtain larger sample

sizes and to enable the analysis of introductions of reimbursement statuses. The control groups are created by matching by month, ATC 5th level, and brand status, i.e., being a branded pharmaceutical or not being a branded pharmaceutical. The reason behind demanding matches with both ATC 5th level and brand status is an attempt of keeping the distributions of ATC 5th level observations at least somewhat similar between the treatment and control groups. Simply matching by ATC 5th level leads to occasional dominance in terms of the number of control group observations of a single ATC 5th level. Hence, the additional restriction of brand status may alleviate this problem on some occasions. However, it is apparent from the data that this is still not sufficient to remove the problem. Thus, in terms of the parallel trends assumption, this approach may be problematic and will be examined later in more depth.

Even though this approach isn't without its faults, the method provides at least a reference point for the product-level matched results. A sample that large wouldn't be available with an examination period this long for introductions of reimbursement statuses with product-level matching.

4.1.3 Variables

Wholesale prices are consumer price index deflated to exclude price changes caused by inflation. In addition, they are reported in national currency to exclude the possibility of exchange rate changes causing price changes without actual price changes on a national level. The dependent variable is the natural logarithm of these wholesale prices.

The treatment variable indicates either a pharmaceutical having a reimbursement status or not having a reimbursement status, depending on the specification. For the introductions of reimbursement statuses, the variable is equal to 0 when the pharmaceutical is not reimbursed and 1 when it is. For the removals of reimbursement statuses, the variable is equal to 0 when the pharmaceutical is reimbursed and 1 when it is not.

The control variables included are the natural logarithms of the number of products with the same ATC 5th and ATC 2nd levels in the same country to represent the different levels of competition the pharmaceutical faces, the same variables but with non-zero values only for non-branded products, a dummy variable for whether there are non-branded products in the ATC 5th level market, and the annual spending threshold to receive full reimbursement deflated by the consumer price index. The threshold of 2017 is normalized to 1.

The control variables focus mostly on the competition a pharmaceutical faces. Different regulations and the data structure make it difficult to find control variables that could have time-variant values in each country and would not be clearly endogenous to the reimbursement status. Time-invariant variation is already accounted for in the product-country fixed effects. Following the example of Brekke et al. (2011), both therapeutic and chemical substance competition are accounted for in the model. The form of natural logarithm for these competition variables is because it does not seem plausible that the number of competitors would explain wholesale prices exponentially. For example, Herr and Suppliet (2017) also used this form of competition controls

within substitution groups. The additional competition variables for non-branded pharmaceuticals are justified because the literature review mentioned the different responses of branded and generic pharmaceuticals to regulations and competition on several occasions. Generic competition could affect the prices within the ATC 5th or lower levels due to the regulations or price competition. Hence, including a control variable for this might be necessary.

Finally, normalized and consumer price index deflated annual spending thresholds to receive full reimbursement during that year for reimbursed pharmaceuticals could be associated with more spending in the presence of lower thresholds, possibly leading to higher prices. This is also an attempt to take into account parts of the national regulation which might not be fully captured by the fixed effects. However, due to multicollinearity concerns, which will be covered in section 4.4 Assumptions, this control variable is used only to a limited extent in the analyses. Additionally, the effect examined includes the effects of regulations associated with a reimbursement status on wholesale prices.

4.1.4 Clustering

The standard errors are clustered at the ATC 5th, i.e., chemical substance, level in all models presented. The reason for this is that there might be shocks that are common for the products that share the same chemical substance, and the within-market dynamics may lead to correlation between the changes within the ATC 5th level market. Either narrower clusters, such as in Pavcnik (2002) and Herr and Suppliet (2017) that use product-level clustering or broader clusters, as in Duggan and Scott Morton (2010) with therapeutic subcategory clusters, could be argued for. However, in the Nordic context, ATC 5th level seems sufficient. For instance, Kortelainen et al. (2022) estimated average price spillovers to be statistically insignificant and the point estimates to be close to zero in non-treated ATC 5th level markets that had therapeutic competition with the treated markets in the cases of Finnish generic substitution and reference price reforms, Norwegian stepped price reform, and Swedish auction-based reference price reform.

Additionally, some regulations are considered at the chemical substance or narrower level in the Nordic countries, such as substitution groups for generic substitution. Therefore, even though clustering the standard errors does not solve heteroskedasticity and serial correlation by itself, the bias they may introduce to standard errors should be lessened by this decision, giving more robustness for the statistical significance of the coefficients.

Despite the arguments, the statistical significance of some of the estimates could change with different levels of clustering. However, this examination was excluded due to large standard errors and heterogeneity in point estimates. Thus, examining the statistical significance of the results would have provided little value for the study.

4.1.5 Two-way fixed effects

One approach in this thesis relies on matching products from a treatment country and a control country and running regressions with a two-way fixed effects (TWFE) model with country-product and monthly fixed effects. The results of this approach will be briefly discussed in the main text and will be presented to a larger extent in the Appendix. The reason for this is the failure of assumptions due to staggered treatment and heterogeneous treatment effects, which will be covered more broadly in section 4.4 Assumptions.

The baseline model for the TWFE approach is the following:

$$ln(p_{i,c,t}) = \alpha_{i,c} + \lambda_t + D_{i,c,t}\delta + \epsilon_{i,c,t} \tag{1}$$

where $p_{i,c,t}$ is the consumer price index deflated wholesale price of product i in country c in month t in national currency, $\alpha_{i,c}$ product-country fixed effect, λ_t monthly fixed effect, $D_{i,c,t}$ a dummy variable which is equal to one when the observation is treated, indicating either having or not having a reimbursement status depending on the specification, and zero otherwise. $\epsilon_{i,c,t}$ is the error term.

In addition to the examination which equation 1 provides, another model is examined. That is,

$$ln(p_{i,c,t}) = \alpha_{i,c} + \lambda_t + D_{i,c,t}\delta + D_{i,c,t} * NonBrand_{i,c} * \delta_{NonBrand} + X_{i,c,t}\beta + \epsilon_{i,c,t} \tag{2}$$

which is otherwise identical to equation 1 but now there is an additional interaction term of the treatment dummy $D_{i,c,t}$ and brand status dummy $NonBrand_{i,c}$ which is equal to one if the pharmaceutical isn't branded and zero otherwise. Hence, if the price response of branded and non-branded pharmaceuticals to the reimbursement status change differ, the regressions using the specification of equation 2 should capture this as differing from zero coefficient $\delta_{NonBrand}$. In addition, control variables $X_{i,c,t}$ are included in some regressions.

Notably, the terms generic and non-branded are used interchangeably in the rest of this thesis as there are no non-branded pharmaceuticals that are not generic in the matched samples of reimbursement status removals. In the reimbursement status introduction samples, parallel imports appear only in Sweden with the samples which include either a Swedish treatment or a Swedish control group.

4.1.6 Callaway and Sant'Anna (2021) staggered treatment DID

The recent literature has critiqued TWFE regressions with staggered treatment. For example, Goodman-Bacon (2021) derived a decomposition for the coefficient of the treatment variable. Under differing treatment timings and treatment effect heterogeneity across units, the decomposition illustrates the existence of unwanted terms possibly contaminating the inference of the coefficient of the treatment variable as average treatment effect on the treated. According to Goodman-Bacon (2021), the coefficient of the treatment variable in TWFE can be decomposed into a weighted average of average treatment effects on the treated between each cohort, i.e., units with simultaneous

treatment timing. Between these cohorts, the treatment effects may be different or evolve over time. This may cause problems in the estimation due to improper weighting in TWFE, possibly even through negative weights. Negative weights can be especially problematic because a large enough negative weight can change even the sign of the coefficient of the treatment variable from the true average treatment effect on the treated if the weight is assigned to a large enough treatment effect. Meanwhile, Sun and Abraham (2021) showed that similar problems persist in event study settings through effects from other periods contaminating the coefficients of the treatment variables under treatment effect heterogeneity and staggered treatment timing.

To address these problems also found by other studies, Callaway and Sant'Anna (2021) developed an estimator which can estimate both the aggregate average treatment effect on the treated and the average treatment effects on the treated (ATT) for periods relative to treatment. The estimator can represent the results in an event study like form without the concerns mentioned above. The average treatment effects on the treated are presented and can be interpreted in a simple form which resembles canonical difference in differences, i.e., two groups and pre- and post-treatment periods. The aggregation of these ATTs is calculated as a weighted average of the average treatment effects on the treated of differing treatment timing groups for a chosen number of periods after treatment. The weights are assigned based on generalized propensity scores and, therefore, are always also non-negative.

In addition to these benefits, the Callaway and Sant'Anna (2021) estimator has benefits compared to the TWFE estimation methods in terms of assumptions, such as parallel trends. These will be covered in section 4.4 Assumptions.

The Callaway and Sant'Anna (2021) estimation utilizes the same data structure as the TWFE approach. The time identifier in the baseline Callaway and Sant'Anna (2021) estimation is calendar months and the cross-sectional identifier is on product-country level.

Due to the nature of the research setting and the underlying data, estimates of the Callaway and Sant'Anna (2021) approach will be the focus of this thesis. However, the estimates of the TWFE approach are not completely ignored despite their weaknesses because Callaway and Sant'Anna (2021) estimation has problems with the parallel trends assumption and utilizing the whole samples. Therefore, the Callaway and Sant'Anna (2021) estimates might not be strictly better than the results of TWFE estimation. Thus, these methods and their results are presented to complement each other.

4.1.7 Alternate time periods

Callaway and Sant'Anna (2021) estimation and both of the equations 1 and 2 also have alternate specifications where months are not in calendar time but relative to the treatment timing. Hence, this approach is more akin to the approach of canonical difference in differences in which there is a common dummy for treatment and control groups indicating pre-treatment and post-treatment periods. With clearly rather strong and possibly unreasonable assumptions, this approach treats the sample as if all of the treated products would have the same treatment timing. It is notable that this approach

is possible only with the product-level one-to-one matching because identifying exact matches with the other approach is impossible.

The equations for the TWFE approach in this case are

$$ln(p_{i,c,h}) = \alpha_{i,c} + \tau_h + D_{i,c,h}\delta + \epsilon_{i,c,h} \quad (3)$$

$$ln(p_{i,c,h}) = \alpha_{i,c} + \tau_h + D_{i,c,h}\delta + D_{i,c,h} * NonBrand_{i,c} * \delta_{NonBrand} + X_{i,c,h}\beta + \epsilon_{i,c,h} \quad (4)$$

where τ_h represents fixed effect of the relative time to treatment as months extended to the corresponding control group product as well. That is, h is the relative time to treatment in months. Otherwise than the replacement of λ_t with τ_h, equations 3 and 4 correspond to equations 1 and 2. Naturally, these models require different parallel trends assumptions than equations 1 and 2.

4.2 Data

The data used in the analysis is derived from Nordic sales datasets. Table 2 describes the sources of this sales data, the years they cover, and the years that are used in this thesis.

Table 2: Original sources of the data utilized in the thesis.

Country	Source	Years	Years used
Finland	FIMEA	1998-2017	2010-2017
Norway	Farmastat	2000-2018	2010-2017
Sweden	IQVIA MIDAS Quarterly sales	2006Q2-2017	2010-2017

Table 3 describes the samples used in the analyses of removals of reimbursement statuses with the approach that matches the same products between countries. The first column, Treatment, describes the country in which treated observations are observed. Products describes the number of pharmaceuticals that could be included in the sample if they found a match in the control country in column Control. Column Matched products describes the number of matched products in the treatment country. Matched obs (T) describes the number of observations that are included in the treatment group while Matched obs (C) describes the number of observations that are included in the control group. Column Estimation period shows which years and months are included in the matched samples. Finally, column Share of brand obs tells the share of all observations in the matched sample that are marked as branded pharmaceuticals.

Table 3 illustrates the problems of product-level matching. Even though arguably a reasonable number of possible products suit the definition of available products for the analysis, the number of matched products is rather low. Depending on the treatment and control group, it is possible to match only slightly above 10 - 20 % of the products.

Table 4 describes the ATC 5th level and brand status matching samples with the same columns as table 3. In table 4, a noticeable difference compared to table 3 is that the treatment and control groups are of different sizes, partly due to the matching method. In addition, it should be emphasized that the values in the Products

Table 3: Description of samples with product-level matching. Outcome data source: Farmastat, FIMEA and IQVIA MIDAS Quarterly sales. 2010m1-2017m8.

Treatment	Products	Control	Matched products	Matched obs (T)	Matched obs (C)	Estimation period	Share of brand obs
Finland	183	Norway	26	312	312	2010m1-2017m6	87 %
Finland	183	Sweden	42	504	504	2010m2-2017m7	94 %
Norway	207	Finland	25	300	300	2010m1-2017m4	62 %
Norway	207	Sweden	24	288	288	2010m2-2017m4	71 %
Sweden	627	Finland	98	1176	1176	2010m11-2017m8	76 %
Sweden	627	Norway	86	1032	1032	2010m1-2017m6	77 %

column also differ from table 3. This is because the analysis in table 4 focuses on introductions, not removals, of reimbursement statuses. Hence, the selection of available pharmaceuticals for matching is also different. By this method, the share of pharmaceuticals that find a match varies between 15 - 25 %.

The shares of branded pharmaceuticals vary between the samples in both tables 3 and 4. Notably, in table 3, the share of branded pharmaceutical observations is over 60 % in each sample, while in table 4, the Finnish and Swedish treatment samples have approximately 40 % branded observations. Thus, it is to be expected that aggregate estimates are driven by the variation in the branded pharmaceuticals, especially when removals of reimbursement statuses are analyzed.

Table 4: Description of samples with ATC 5th and brand status level matching. Outcome data source: Farmastat, FIMEA and IQVIA MIDAS Quarterly sales. 2010m1-2017m12.

Treatment	Products	Control	Matched products	Matched obs (T)	Matched obs (C)	Estimation period	Share of brand obs
Finland	115	Sweden	17	204	1108	2010m2-2017m2	36 %
Norway	328	Finland	55	660	684	2010m1-2017m6	87 %
Norway	328	Sweden	83	996	780	2010m1-2017m10	70 %
Sweden	456	Finland	109	1308	3972	2010m4-2017m12	42 %

4.3 Descriptive statistics

Even though examining the price changes within a country without comparison groups won't provide enough evidence for causal inference, it may still be useful for understanding how the prices of all available products for the analysis develop without restricting the samples with the matching criteria.

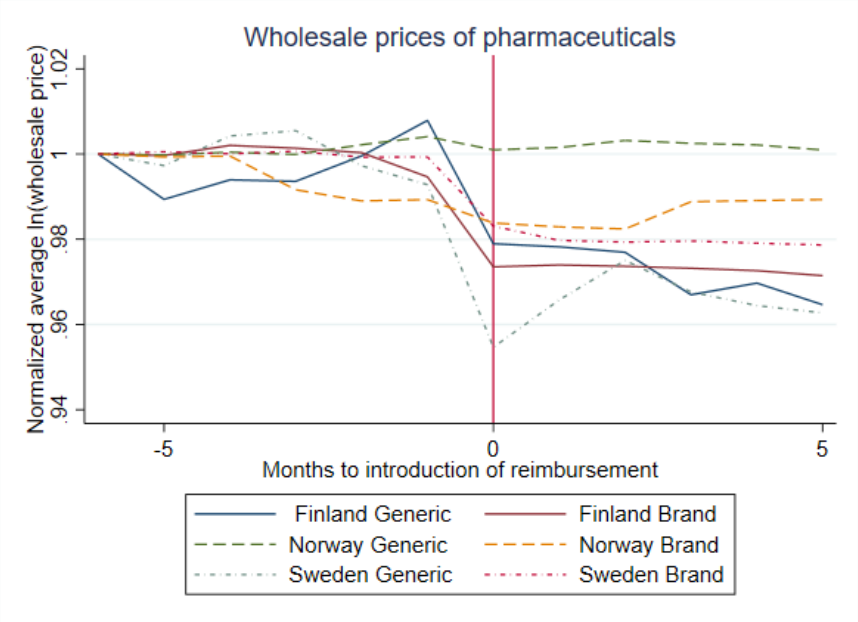

Figure 2: Logarithmic wholesale price of pharmaceuticals without matching based exclusion from the sample at the introduction of a reimbursement status. Outcome data source: Farmastat (2010m1-2017m12), FIMEA (2010m2-2017m12) and IQVIA MIDAS Quarterly sales (2010m1-2017m12)

Figure 2 describes the unweighted average logarithmic wholesale prices normalized by the sixth month preceding the introduction of a reimbursement status of pharmaceuticals valid for the analysis months after and before the introduction of a reimbursement status. It is noticeable among both branded and non-branded pharmaceuticals in Finland that the wholesale price decreases after the introduction of a reimbursement status. In Norway, it appears that there are price decreases overall among the branded pharmaceuticals which get a reimbursement status. However, at least based on this figure, there is no clear visible evidence of price decreases at the treatment time. Among the Swedish branded pharmaceuticals, price decreases appear when a reimbursement status is granted for the pharmaceutical.

Figure 3 is similar to figure 2. However, it represents the removals of reimbursement statuses instead of the introductions. In Finland, generic and branded pharmaceutical wholesale prices seem to increase after removal of a reimbursement status. In Norway, price changes seem to be moderate, and based on the figure, there is little association between the price and removal of a reimbursement status for branded pharmaceuticals. However, the prices of generics appear to increase after removal of a reimbursement

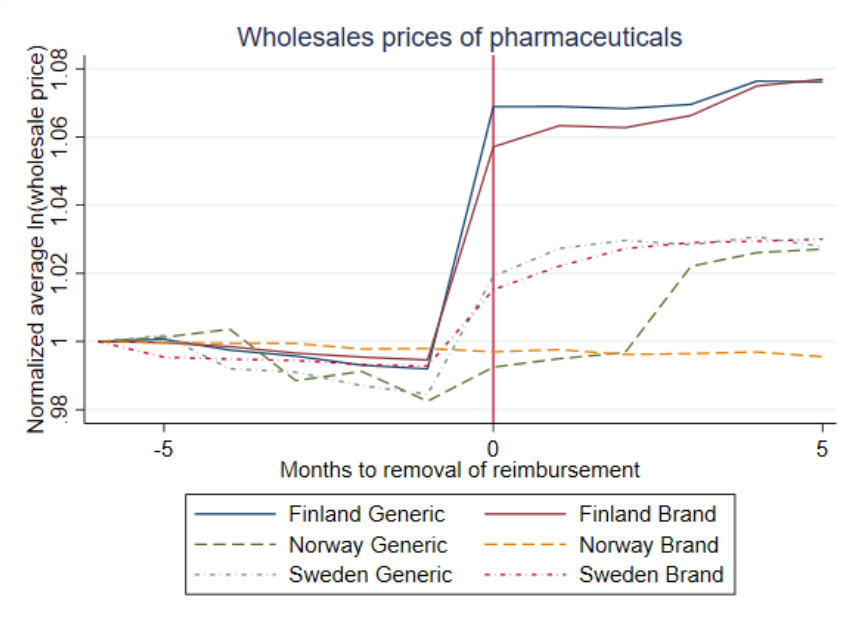

Figure 3: Logarithmic wholesale price of pharmaceuticals without matching based exclusion from the sample at the removal of a reimbursement status. Outcome data source: Farmastat (2010m1-2017m10), FIMEA (2010m1-2017m12) and IQVIA MIDAS Quarterly sales (2010m1-2017m12)

status, but not immediately. In Sweden, both branded and generic pharmaceuticals face price increases after removal of a reimbursement status.

Table 5 describes the pre- and post-treatment period mean and median logarithmic wholesale prices, mean differences, and mean difference in differences of each reimbursement status removal sample in consumer price index deflated national currency. Table 5 suggests price increases in the Finnish treatment group samples and in the Swedish treatment group sample with the Norwegian control group.

Table 5: Logarithmic wholesale prices in consumer price index deflated national currency in reimbursement status removal samples. Outcome data source: Farmastat, FIMEA and IQVIA MIDAS Quarterly sales. 2010m1-2017m8.

Treatment	Mean (Pre, Post)	Diff Mean	Median (Pre, Post)	Control	Mean (Pre, Post)	Diff Mean	Median (Pre, Post)	DiD Mean
Finland	(2.64, 3.04)	0.40	(2.63, 2.87)	Norway	(5.06, 5.12)	0.06	(5.04, 5.13)	0.34
Finland	(3.17, 3.39)	0.22	(2.92, 3.14)	Sweden	(5.64, 5.63)	-0.01	(5.39, 5.38)	0.23
Norway	(5.13, 5.12)	-0.01	(5.16, 5.17)	Finland	(2.96, 2.90)	-0.06	(2.93, 2.97)	0.05
Norway	(5.35, 5.36)	0.01	(5.30, 5.29)	Sweden	(5.63, 5.65)	0.02	(5.63, 5.63)	-0.01
Sweden	(5.98, 5.96)	-0.02	(6.25, 6.12)	Finland	(3.65, 3.61)	-0.04	(3.58, 3.56)	0.02
Sweden	(5.48, 5.66)	0.18	(5.44, 5.49)	Norway	(5.23, 5.18)	-0.05	(5.07, 5.08)	0.23

Compared to the whole samples without the exclusion of unmatched products in figure 3, the wholesale price changes in the Finnish treatment samples seem to reflect

at least in sign the changes of the unmatched Finnish sample. When it comes to the Swedish treatment samples, only the Norwegian control group sample suggests price increases after the removal of a reimbursement status. This is notable because figure 3 suggests price increases after the removal of a reimbursement status for both generic and branded Swedish pharmaceuticals. Therefore, if there is a sample bias, it should be more likely to exist within the Swedish treatment group with the Finnish control group than with the Norwegian control group, at least by this metric. Otherwise, the unmatched and matched samples seem to resemble each other, especially for branded pharmaceuticals.

4.4 Assumptions

Next, the assumptions necessary for identification will be discussed for Callaway and Sant'Anna (2021) and TWFE difference in differences. In addition to the assumptions which will be discussed in this section, Callaway and Sant'Anna (2021) estimation requires that the treatment is irreversible, the outcomes, covariates, and the treatment are independent and identically distributed across products, and a non-zero share of population becomes treated at each period in which treatment is assigned to some of the units. Additionally, the generalized propensity score cannot be equal to one. These are not considered core causes of concern due to the nature of the data and models.

4.4.1 Parallel trends assumption

For difference in differences approaches, parallel trends assumption between treatment and control groups is a core identifying assumption for causal inference. Therefore, the observations of the control country should reflect a similar trend, but not necessarily the exact same values, as in the treatment country before treatment and after the treatment as if the treatment had not occurred in the treatment country. However, differences in the regulations between countries can be a threat to this sort of assumption.

A clear difference between Callaway and Sant'Anna (2021) and two-way fixed effects approaches is the parallel trends assumption. While traditional TWFE difference in differences requires parallel trends between all periods, the assumption of Callaway and Sant'Anna (2021) approach can be satisfied with less strict conditions. Callaway and Sant'Anna (2021) define two alternate parallel trends assumptions. One for the use of observations that never receive the treatment and one for the use of observations that have not yet received treatment as the comparison group. The assumption which is of interest in this thesis is the former one. This study utilizes in some specifications one-to-one matching on product-month-level. Thus, at least ideally, the better comparison would be the pharmaceuticals in the control group country instead of all untreated pharmaceuticals. Callaway and Sant'Anna (2021) use the following notation for their conditional parallel trends assumption:

$$E[Y_t(0) - Y_{t-1}(0)|X, G_g = 1] = E[Y_t(0) - Y_{t-1}(0)|X, C = 1] a.s. \quad (5)$$

in which $Y_t(0)$ is the untreated outcome in period t, X includes the covariates, G_g is equal to one if the units become treated in period g and zero otherwise, and C is a

dummy variable for the never treated group. Notably, equation 5 should hold so that for each $g \in \mathcal{G}$ and $t \in \{2, ..., \mathcal{T}\}$ such that $t \geq g - \delta$, where $\mathcal{G}$ is the support of G excluding the never-treated, $\mathcal{T}$ is the last period observed, and δ is equal to the number of anticipation periods relative to the treatment which is equal to zero in this thesis.

Thus, as Callaway and Sant'Anna (2021) state, unlike with TWFEDID methods, this parallel trends assumption doesn't require parallel trends to hold before treatment when there is a lack of anticipation of treatment. However, the parallel trends assumption should hold in the post-treatment periods to have a sufficient comparison group. Unfortunately, post-treatment parallel trends is unobservable. Thus, one may question parallel trends in the post-treatment period if there is a rejection of parallel trends in the pre-treatment period and no counterargument could be made, even though pre-treatment parallel trends are not technically required.

Depending on the method of constructing control groups and whether periods are presented as months or numbers of months after the treatment, the parallel trends assumption requires different approaches. If calendar months are used as the time fixed effects, the assumption is that the treatment and control groups develop similarly over time. However, if the number of months preceding and following the treatment is used, as in section 5.2 Robustness checks, it should be assumed that possible time trends are weak enough in the sample to not have an impact on the coefficients of the treatment variable even if they are not explicitly modeled. There is a possibility that this is an unreasonable assumption. However, only 12 consecutive months are observed for any individual pharmaceutical, and product-country fixed effects handle the time-invariant variation between products. Thus, this assumption might not be as likely to completely fail as expected with data consisting of longer periods of examination.

ATC 5th level and brand status matching requires a broader assumption of parallel trends than only between products. ATC 5th level and brand status matching imposes an assumption that pharmaceuticals with the same ATC 5th level and brand status share parallel trends as a group between the treatment and control countries. In addition, due to the matching method, some deviations in the ATC 5th level product distribution between the treatment and control groups shouldn't affect the comparisons made. This seems to be a difficult assumption to satisfy due to the differences between pharmaceuticals across chemical substances, as illustrated by price elasticity of demand in the literature review.

The approach of utilizing a different country than the treatment country as the control group imposes an assumption that there are no cross-country dependencies between the prices of the treatment and control countries. This is necessary because otherwise the post-treatment parallel trends assumption could be threatened as the trend of the control group wouldn't reflect the price development of the unobserved untreated treatment group in the post-treatment period. An obvious threat to this assumption that stems from the regulations is the external reference pricing in Norway. The price cap for even non-reimbursed prescription pharmaceuticals is defined by the average of the three lowest prices in a select set of countries including both Sweden and Finland under this regulation. Thus, the price changes in Finland and Sweden could affect the prices in Norway, especially if the price cap is binding or close to binding in Norway.

One should be cautious in using Norway as a control group, especially when a reimbursement status is granted to a pharmaceutical in the treatment group. The external reference pricing of both reimbursed and non-reimbursed pharmaceuticals in Norway does not have a clear counterpart in Finland and Sweden. Therefore, the prices of non-reimbursed pharmaceuticals in Norway have less room for price changes than their counterparts in Finland and Sweden, at least for price increases. Thus, the parallel trends assumption might not be satisfied. Therefore, Norway should be avoided as a control group in these cases.

The same problem might hinder the interpretation of analyses that have Norway as the treatment country and pre-treatment observations do not have reimbursement statuses. The post-treatment control group values might not satisfy parallel trends because the control group prices can have more room to vary than their Norwegian counterparts would have. The binding price cap is illustrated by the Norwegian reimbursement status introduction sample with the Finnish control group. The pharmaceutical wholesale prices are on average 94.5 % of the price cap before the introduction of the reimbursement status and 95.7 % after it. Hence, the vast majority of these observations lie in the vicinity of the price cap. Despite this, these analyses are included in the thesis unlike the ones utilizing non-reimbursed Norwegian pharmaceuticals as control groups. Otherwise, these analyses on the Norwegian pharmaceuticals couldn't be conducted. However, they require caution in interpretation.

In Finland, Sweden, and Norway there are conditions for reimbursement that set a maximum price for reimbursed pharmaceuticals. Hence, one could argue that these kinds of underlying conditions could imitate external reference pricing in Norway. This should hold under the assumption that the external reference pricing is not considerably stricter than the price cap conditions for the reimbursement status. However, applying for a reimbursement status for a pharmaceutical in each country still leads to an evaluation process which can include price comparison to the same or similar pharmaceuticals in other countries. The cross-national dependence of prices is likely only a small cause of concern because there are many countries for price comparisons. The cross-country price comparison is also only one factor of the price cap for reimbursed pharmaceuticals.

Despite the possible concerns of using another Nordic country as a control group for the parallel trends assumptions, there is at least one clear advantage compared to using only observations in one country and matching by some alternative criteria. Especially within a chemical substance, an introduction of a reimbursement status or its removal could likely affect the sales and pricing incentives of the pharmaceutical's substitutes through legislation or competition. This could arguably introduce a more problematic control group. The accuracy of the matching and parallel trends assumption could suffer if less similar pharmaceuticals in the same country were used to decrease possible price dependencies between control and treatment groups.

However, there still remains concern with the current approach. Similar kinds of problems are not completely ruled out if a pharmaceutical in the control country faces changes in its reimbursement status but is excluded from the sample due to this change or does not fit the sample criteria due to e.g., ATC classification differences.

In these cases, the observations in the control country can have unobserved spillover effects within the market, and, therefore, threaten the validity of the parallel trends assumption.

4.4.2 Anticipation of treatment

In this empirical approach, it is assumed that there are no price changes due to the anticipation of the treatment. This means that the treatment does not affect the prices of the treatment country before the treatment happens. If this were to occur, the parallel trends assumption would not hold because the products of the treatment group would not follow the trend set by the control group in the pre-treatment period. However, if it were known how early the anticipation begins relative to treatment timing, it would be possible to avoid the concern.

The anticipation of the treatment is likely not a cause of concern in this thesis. Firstly, the regulations which restrict the pricing decisions of reimbursed pharmaceuticals concern only reimbursed pharmaceuticals and stop restricting prices only after the reimbursement status is removed. Hence, if the pharmaceutical company is not satisfied with the maximum price under reimbursement, it can raise its price over the price cap only after the reimbursement status has been removed. Thus, it can't try to increase the price excessively under reimbursement. Therefore, the possibilities to implement anticipatory behavior into pricing decisions are limited. Secondly, given that pharmaceutical companies choose prices rationally, they respond to these restrictions only when necessary because they are assumed to maximize their profits before and after the treatment. Thus, no anticipation of the treatment should exist under the assumption of rationality if the consumers do not change their behavior considerably in anticipation of the treatment.

4.4.3 Homogeneous treatment effects

Homogeneity of the treatment effects is a crucial assumption for TWFE difference in differences approaches if the treatment is staggered. As recent literature has pointed out, the estimated treatment effect on the treated can be considerably different from the true effect due to treatment effect heterogeneity. Specifically, Sun and Abraham (2021) noted that if the treatment effects are not homogeneous across periods, the terms with treatment effects from different periods relative to treatment are not removed and thus result in misleading treatment variable coefficients.

Unfortunately, the assumption of treatment effect homogeneity is not plausible in the samples used. One reason for this is that there should exist heterogeneity between ATC codes. For example, according to Einav et al. (2018), pharmaceutical therapeutic classes' price elasticity was -0.15 with a standard deviation of 0.15. Even though these results are not from the Nordics, they should be sufficient to illustrate the differences in demand and consequently pricing behavior between different kinds of pharmaceuticals under the assumption of rationality. In addition, as stated before, the realized reimbursement rates of pharmaceuticals can widely differ in the Nordic countries. Hence, the assumption of homogeneity of the treatment effect is likely to be

one of the failing assumptions and leading to misestimation of the average treatment effect on the treated with TWFEDID.

Luckily, the approach of Callaway and Sant'Anna (2021) is not constrained by this assumption. Therefore, by utilizing this method, these problems can be avoided.

4.4.4 OLS assumptions

Traditional linear regression assumptions should also either hold or be handled in a way in which they are not a cause of concern for the TWFE approach. Firstly, the linearity assumption of the variable of interest, the treatment dummy, is satisfied by default because the treatment variable is always equal to either 0 or 1. Therefore, the relationship between the logarithmic wholesale price and the treatment dummy is linear.

Secondly, three assumptions possibly affecting the standard errors of the estimates have to be addressed. These are homoskedasticity, the independence of the error terms, and error terms being normally distributed. Homoskedasticity means that the error terms should have constant variances. The independence of error terms states that the error terms shouldn't be correlated with each other. This might be violated because the data includes several observations of the same product due to the structure of the panel data which is inherent to the approach chosen. Assuming homoskedasticity and independence of error terms is likely unrealistic in the setting. However, these problems are addressed by clustering standard errors. This should adjust the standard errors to be less under- or overestimated. Clustering of standard errors is similarly utilized with the Callaway and Sant'Anna (2021) approach to address the assumption of independence and identical distribution of the treatment. The error terms not being normally distributed and affecting the estimated standard errors can be a problem. However, this is likely only a small concern due to the sample containing several hundreds of observations in each regression.

Thirdly, linear regressions require a lack of perfect correlation between explanatory variables. Otherwise, it would be difficult to identify which variable is responsible for a certain kind of variation in the dependent variable. Thus, multicollinearity can lead to the misestimation of individual coefficients. However, because the coefficients of interest are only the coefficients of the treatment variables, it is sufficient that the treatment variables don't perfectly correlate with the other independent variables. The correlations between the treatment variables and the control variables are not alarmingly large besides the arguable exception of the annual spending thresholds for receiving full reimbursement. These may contain only little variation within the observations of individual products. Thus, in some models, this control variable is excluded and used in the model only after other control variables are already in use. This allows examination of the coefficient of the treatment variable both with and without this control variable. Nonetheless, it is not important to correctly estimate the possible effects of individual control variables if they overall remove variation that shouldn't be credited to the treatment variables.

5 Results

This chapter presents the main results of the approach described in chapter 4 Empirical approach. The discussion of the main results is followed by robustness checks.

5.1 Main results

First, the TWFE difference in differences approach is briefly covered. Then, Callaway and Sant'Anna (2021) estimates will be presented. Both estimation methods will also include examinations on the heterogeneity between branded and generic pharmaceuticals.

5.1.1 TWFEDID

The reason for the brevity of the discussion of the TWFE estimates is the failure of the homogeneous treatment effects assumption. The TWFE regression tables are in the Appendix.

Both introductions and removals of reimbursement statuses were analyzed by using TWFE regressions with treatment and control country-pairs as described in chapter 4 Empirical approach. TWFE regressions were run with the treatment variable and monthly and product-country fixed effects, with an additional treatment variable for generics, and with sets of control variables.

To summarize the TWFE regression results as a reference point for further analyses, the estimates for Finnish and Swedish treatment groups suggest lower prices associated with an introduction of a reimbursement status and higher prices associated with the removal of a reimbursement status. The estimates suggest 12 - 28 % lower prices for pharmaceuticals under reimbursement in Finland and 2.4 - 20 % lower prices in Sweden. For Norway, the sign of the estimated treatment effect on the treated is vaguer.

The TWFE regressions suggest overall either a weaker or similar association between treatment status and wholesale prices for generic pharmaceuticals compared to branded ones. Exceptions to this are introductions and removals of reimbursement statuses in Sweden with Finnish pharmaceuticals as the control group.

5.1.2 Callaway and Sant'Anna (2021) estimation

Using the estimator developed by Callaway and Sant'Anna (2021), the results are often similar to TWFE in scale, although there are some differences. The differences likely occur not only due to the staggered treatment and treatment effect heterogeneity affecting the estimates of TWFE estimation but also because Callaway and Sant'Anna (2021) estimator in Stata can't utilize these whole samples in analyses using calendar months as the time variables. The reason for this is likely the length of the estimation periods and that both the observations and treatment timings are spread across the estimation period. Hence the number of observations available for the treatment timing group -specific between months difference in differences estimations is limited. In addition, these estimations don't utilize control variables because including these

Table 6: Callaway and Sant'Anna (2021) ATT estimates on ln(wholesale price). Country-products as cross-sectional identifier. Months as time-series identifier. No control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat, FIMEA and IQVIA MIDAS Quarterly sales. 2010m1-2017m12.

Treatment Reimbursement	Country Treatment	Country Control	ATT All	ATT Branded
Introduction	Finland	Sweden	-0.107***	-0.129**
			(0.031)	(0.047)
Introduction	Norway	Finland	0.008	0.008
			(0.008)	(0.008)
Introduction	Norway	Sweden	0.070	0.119
			(0.067)	(0.086)
Introduction	Sweden	Finland	-0.183***	-0.111*
			(0.048)	(0.056)
Removal	Finland	Norway	0.453**	0.485**
			(0.155)	(0.178)
Removal	Finland	Sweden	0.249**	0.258*
			(0.095)	(0.101)
Removal	Norway	Finland	0.081	-0.019
			(0.060)	(0.026)
Removal	Norway	Sweden	0.032	0.007
			(0.040)	(0.009)
Removal	Sweden	Finland	0.064	0.051
			(0.050)	(0.033)
Removal	Sweden	Norway	0.275***	0.211***
			(0.077)	(0.063)

Standard errors in parentheses

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

would decrease the sample size, which could increasingly endanger the validity of the estimates.

First, the estimates of introductions of reimbursement statuses will be presented for each pair of countries. Then, estimates in the cases of removals of reimbursement statuses are covered.

The ATTs of reimbursement status introductions on Finnish and Swedish pharmaceutical prices suggest price decreases for the treated pharmaceuticals based on column ATT All in table 6. The price decreases are 10 % in Finland with the Swedish control

group and 17 % in Sweden with the Finnish control group. For Norwegian products, the estimates suggest small price increases due to the introduction of reimbursement. Because of the standard errors and scales of the estimates, no clear relationship between wholesale prices and reimbursement statuses can be found in Norway with these samples.

To find at least suggestive evidence on the difference between branded and generic pharmaceuticals, Callaway and Sant'Anna (2021) estimation is also applied to samples that cover only the branded pharmaceuticals in the treatment and control groups. The estimates are presented in column ATT Branded in table 6. Given the size of the standard errors in both estimates, with all pharmaceuticals and with only branded ones, it is difficult to find differences between the ATTs of reimbursement status introductions on wholesale prices, excluding the one with the Swedish treatment group. Contrary to the 17 % price decrease with all pharmaceuticals, the estimate for only branded ones suggests an 11 % price decrease.

In column ATT All of table 6, the ATT estimates of reimbursement status removals are positive in each country. However, the scales of the estimates differ depending on the treatment country and the control groups used. Hence, these differences seem sample dependent. With different restrictions for the samples, the estimated changes could be different. The sample dependency may be explained by small sample sizes and expected treatment effect heterogeneity between products.

For the Finnish pharmaceuticals, the estimates suggest a 57 % price increase with the Norwegian control group and 28 % with the Swedish control group. This difference in the ATT is driven not only by the trend of the control group but also by the pharmaceuticals that are matched and included in the samples. The point estimates for the strictly branded pharmaceuticals suggest 5 percentage points higher price increases with the Norwegian control group and one percentage point higher price increases with the Swedish control group compared to the estimates including both branded and generic pharmaceuticals.

Similarly to the introductions of reimbursement statuses, the removals of reimbursement statuses have statistically insignificant ATTs on wholesale prices of less than 10 % with both Finnish and Swedish control groups in Norway. Thus, the interpretation of these estimates remains vague. The estimates for strictly branded pharmaceuticals also suggest close to non-existent price changes with both control groups.

The ATT estimates of removals of reimbursement statuses on wholesale prices in Sweden have heterogeneity between the samples. With the Finnish control group, the estimate corresponds to a 7 % price increase, while with the Norwegian control group, it is 32 %. Only the latter estimate is statistically significant with 95 % confidence level. These differences resemble the difference of these samples discussed in section 4.3 Descriptive statistics. The estimates for only branded pharmaceuticals seem to follow this difference too. However, the sample with the Norwegian control group seems to suggest a weaker price response, an increase of 23 %, to the removal of a reimbursement status compared to the estimate with both generic and branded pharmaceuticals. Thus, with both introductions and removals of reimbursement statuses, branded pharmaceuticals seem to have smaller price changes than generics in

Sweden with the Norwegian control group. However, it is noteworthy that the control groups differ between the columns.

5.2 Robustness checks

The robustness checks focus on event study estimates, pre-treatment joint significance of treatment variable coefficients, and the use of relative time to treatment as the time fixed effect or time-series identifier. By examining the effect through event studies, it can be possible to understand how the price changes associated with the treatment develop over time. Additionally, deviations from zero in the coefficients of interaction variables of the treatment and relative time to the treatment in the pre-treatment period might be an indication of anticipation of treatment, which has not been assumed.

5.2.1 TWFE event studies

Even though the faults of the TWFE regressions in this thesis have been mostly covered in a general sense, it is sensible to examine the core identifying assumptions with an event study setting.

The model for the TWFE event study regressions is

$$ln(p_{i,c,t}) = \alpha_{i,c} + \lambda_t + \Sigma_{h=-6}^{-2} d_{i,c,h}\delta_h + \Sigma_{h=-0}^{5} d_{i,c,h}\delta_h + X_{i,c,t}\beta + \epsilon_{i,c,t} \quad (6)$$

in which $\alpha_{i,c}$ is the product-country fixed effects, λ_t is the month fixed effects, $d_{i,c,h}$ is a dummy variable which is one if the observation is h months after the treatment for the product in the treatment country and zero otherwise, $X_{i,c,t}$ includes the control variables excluding the spending threshold, and $\epsilon_{i,c,t}$ is the error term. The coefficient of the treatment dummy of the first month preceding the treatment is omitted from the regressions. The treatment occurs in period $h = 0$. The standard errors of the model are clustered at the ATC 5th level.

The figures of the treatment coefficients and their confidence intervals are presented in the Appendix. If the possible contamination of these coefficients is ignored, only a few individual pre-treatment coefficients are statistically significant and hint a possible violation of parallel trends. In addition, Wald tests conducted on the pre-treatment coefficients do not detect violations of pre-treatment parallel trends null hypothesis either, excluding the introductions of reimbursement statuses in Finland. Further examination of the results and development of the prices is left outside of this thesis due to the validity concerns of the TWFE approach.

Parallel trends can also be examined with only pre-treatment data because observed parallel trends has to hold only with the pre-treatment data. TWFE requires parallel trends to hold for all periods but it is not possible to measure how well it holds in the post-treatment period due to unobserved untreated treatment group outcomes. This method of examining the parallel trends assumption relies on the following event study regression model

$$ln(p_{i,c,t}) = \alpha_{i,c} + \lambda_t + \Sigma_{h=-6}^{-2} d_{i,c,h}\delta_h + X_{i,c,t}\beta + \epsilon_{i,c,t} \quad (7)$$

which is otherwise similar to equation 6 but now the terms $\Sigma_{h=0}^{5} d_{i,c,h}\delta_h$ are removed due to the lack of post-treatment data. The treatment occurs in period $h = 0$. The standard errors are clustered at the ATC 5th level again.

These regressions are run only with the pre-treatment treatment country observations and product or ATC and brand status monthly matching control observations. The treatment variable coefficients of these regressions are presented in the Appendix. The results of these TWFE regressions do not differ wildly from the ones with the full samples.

5.2.2 Callaway and Sant'Anna (2021) event studies

The same Callaway and Sant'Anna (2021) estimation as in subsection 5.1.2 provided ATT estimates for the months relative to treatment in addition to the pre- and post-treatment aggregate estimates presented in column ATT All of table 6. These relative to treatment aggregated ATTs are presented in this subsection.

In the cases of introductions of reimbursement statuses, the pre-treatment estimated average treatment effects on the treated are statistically insignificant individually in all of the examined countries. However, differences between the estimated price changes are visible in the post-treatment period.

In the setting of the Finnish treatment group with the Swedish control group, the post-treatment ATT varies between -0.09 and -0.13 in figure 4. For the Norwegian treatment group with the Finnish control group, none of the months relative to the treatment month seem to suggest price changes associated with the introduction of a reimbursement status. The post-treatment estimates are similarly small or non-existent with the Swedish control group, although the three last months following the treatment leave room for interpretation with notably large confidence intervals for which the upper limit extends to over 0.4. These Norwegian treatment samples are presented in figures 5 and 6. Estimates of the Callaway and Sant'Anna (2021) estimation of the Swedish treatment group and the Finnish control group in figure 7 suggest that the associated post-treatment price changes vary between -0.17 and -0.20.

Next, removals of reimbursement statuses will be examined. The pre-treatment price changes are not statistically significant and the point estimates are close to zero with the Finnish treatment group and the Norwegian control group. However, the post-treatment effects are statistically significant and indicate a rising trend of prices as the estimate of each period varies between 0.42 and 0.53. The Swedish control group has similar findings, although the post-treatment average treatment effects on the treated are estimated to vary only between 0.23 and 0.27. The corresponding figures are 8 and 9.

For the sample of the Norwegian treatment group with the Finnish control group, none of the estimated ATTs are statistically significant, either before or after treatment. However, the point estimates of the three latest months relative to treatment are arguably rather high which seems to be the cause for the aggregated ATTs to be at 0.08 and not closer to zero despite the lack of statistical significance as seen in figure 10. With the Swedish control group in figure 11, the results look mostly similar. However, the high estimated average treatment effects on the treated are arguably present only in

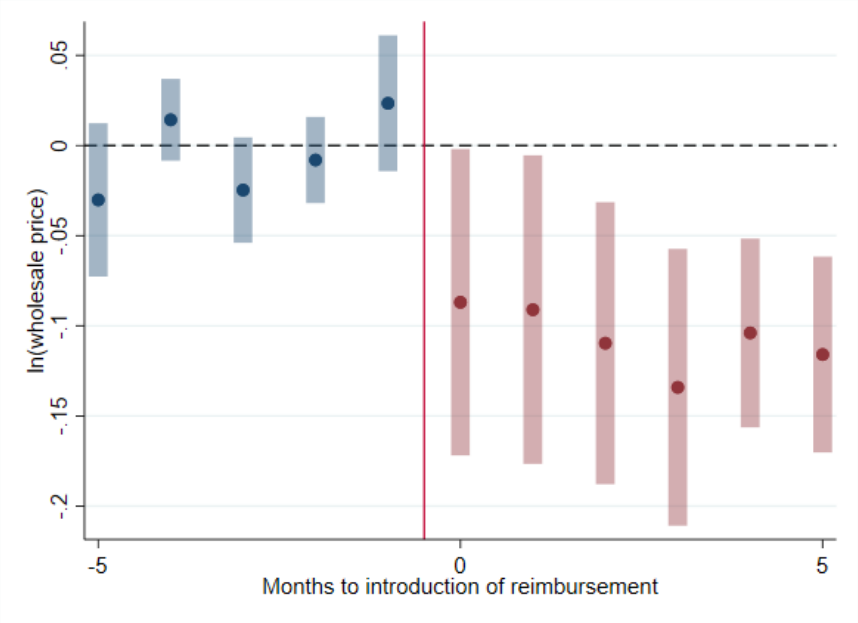

Figure 4: Callaway and Sant'Anna (2021) estimation. Introductions of reimbursement statuses in Finland with Sweden as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m2.

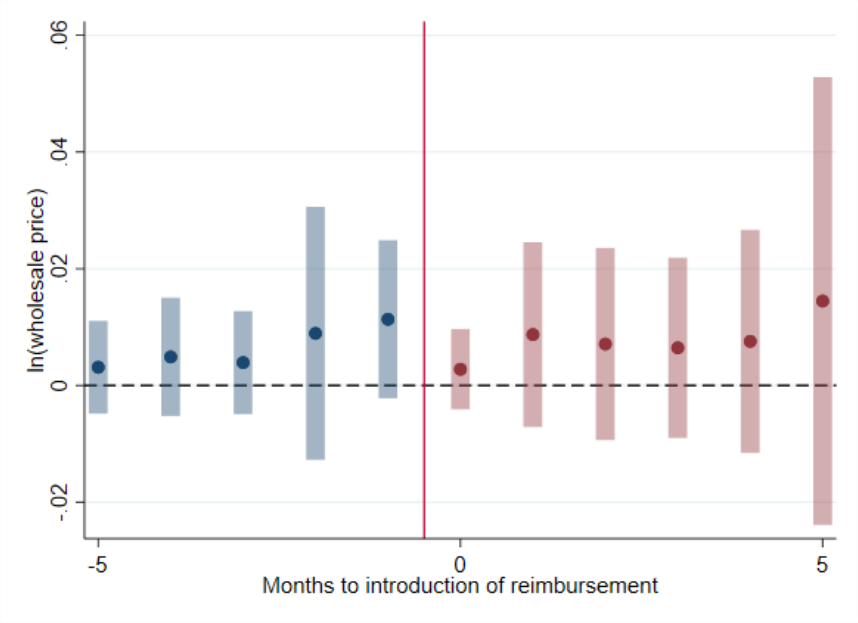

Figure 5: Callaway and Sant'Anna (2021) estimation. Introductions of reimbursement statuses in Norway with Finland as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

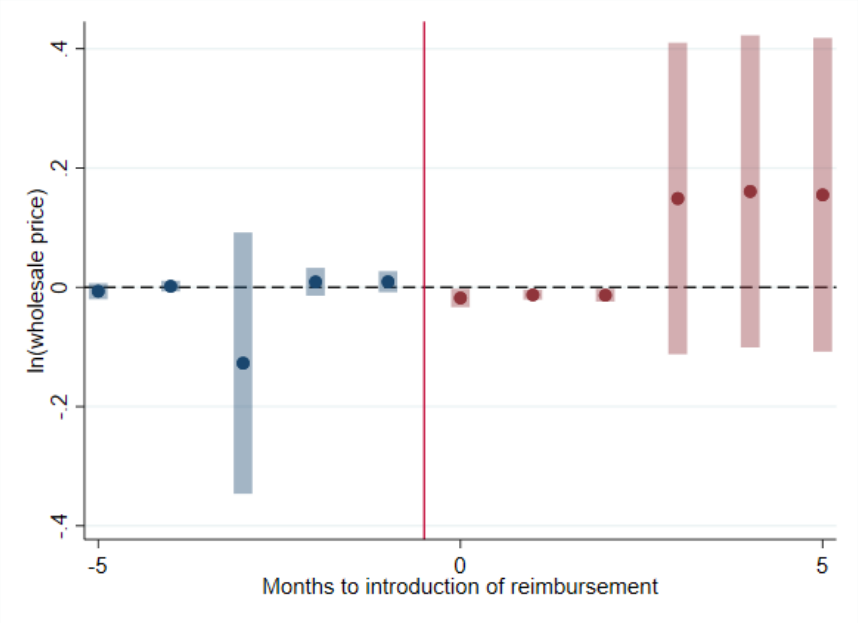

Figure 6: Callaway and Sant'Anna (2021) estimation. Introductions of reimbursement statuses in Norway with Sweden as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m10.

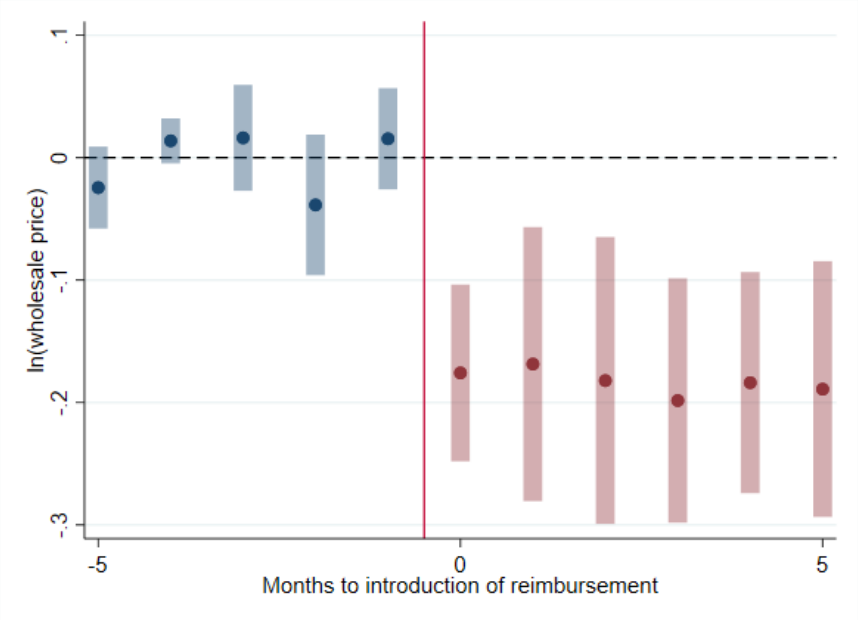

Figure 7: Callaway and Sant'Anna (2021) estimation. Introductions of reimbursement statuses in Sweden with Finland as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m4-2017m12.

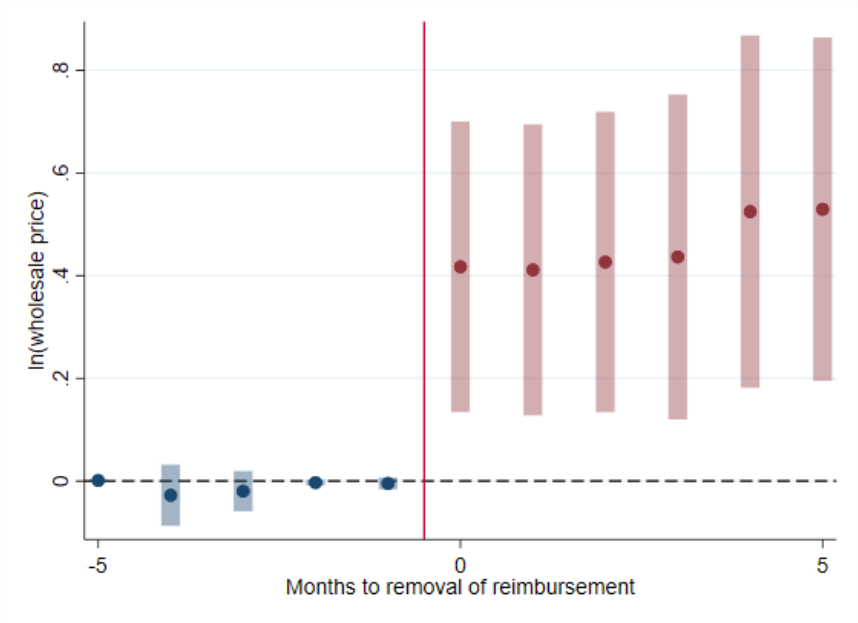

Figure 8: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Finland with Norway as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

the fourth and fifth months after treatment. The ATT for the fifth month after treatment seems to be statistically significant, although only barely so. These differences in the latter periods can raise the concern of whether the possible effect changes over time in Norway.

The pre-treatment estimated ATTs are statistically insignificant for the Swedish treatment group with both Finnish and Norwegian control groups, as can be seen in figures 12 and 13. In addition, the estimated ATTs with the Finnish control group are statistically insignificant post-treatment as well. However, with the Norwegian control group, the estimated effects are statistically significant. These results seem to reflect the mean price developments of each sample since the mean price of the Swedish treatment group with the Finnish control group didn't increase after matching, unlike with the Norwegian control group. Nonetheless, both control group approaches seem to suggest a positive effect of the removals of reimbursement statuses on logarithmic wholesale prices. In addition, the estimates seem to increase notably after the first month of being treated. With the Finnish control group, the first post-treatment month change in the logarithmic wholesale price is estimated to be approximately 0.028, while it varies between 0.065 and 0.097 during the following months relative to treatment. With the Norwegian control group, the first treated month change is approximately 0.18. In the following periods, it varies between 0.27 and 0.31.

However, even though the pre-treatment estimated average treatment effects on the treated, or realistically the association between these, suggest statistical insignificance, the null hypothesis of pre-treatment estimates being jointly equal to 0 is clearly rejected

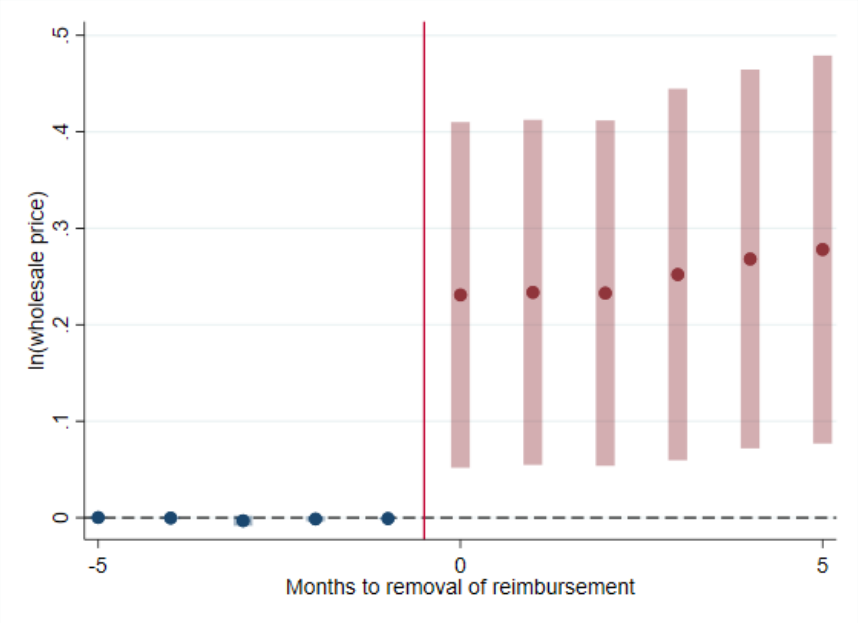

Figure 9: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Finland with Sweden as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m7.

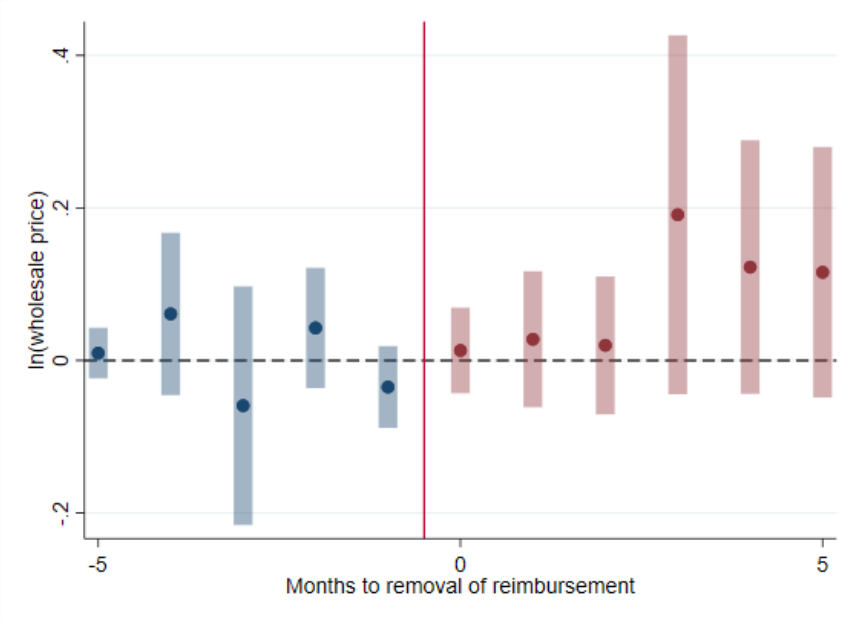

Figure 10: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Norway with Finland as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m4.

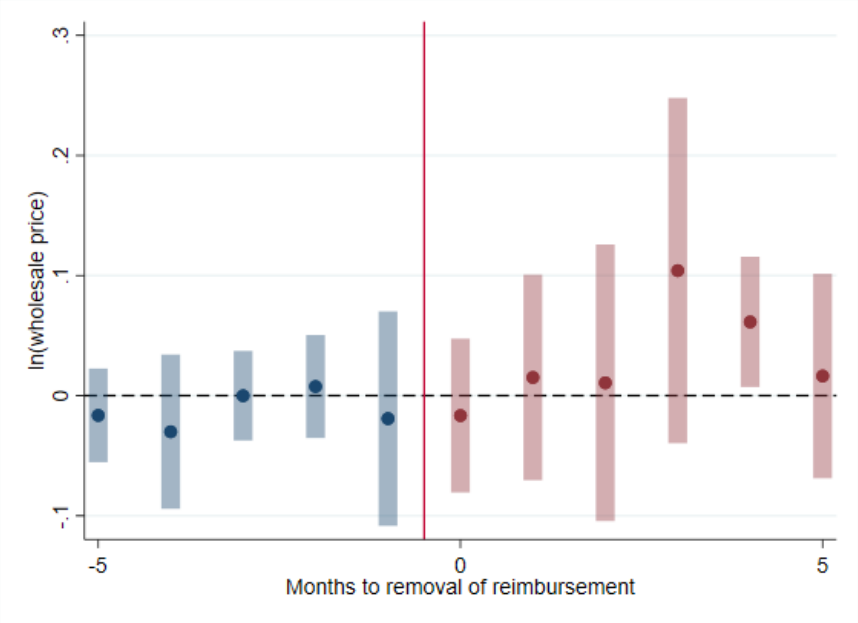

Figure 11: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Norway with Sweden as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m2-2017m4.

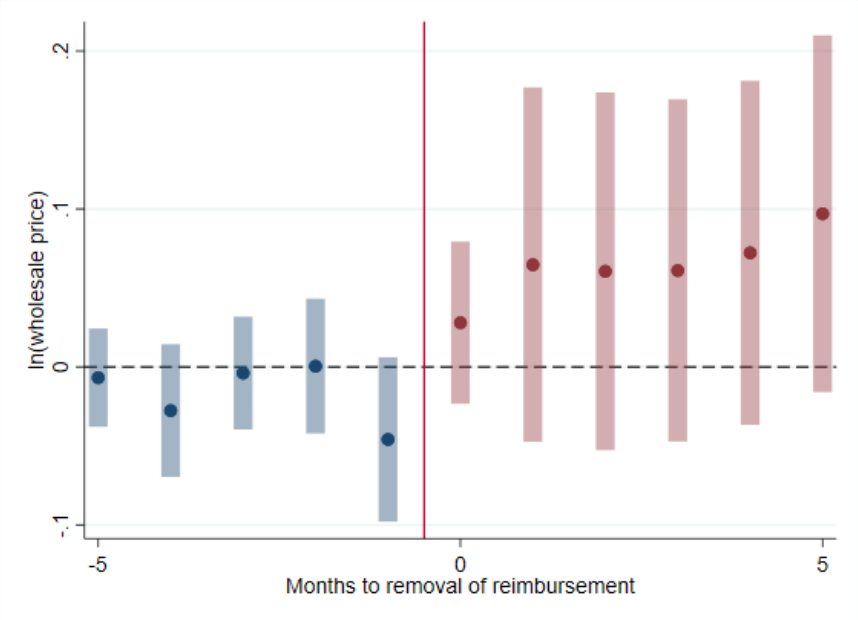

Figure 12: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Sweden with Finland as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m11-2017m8.

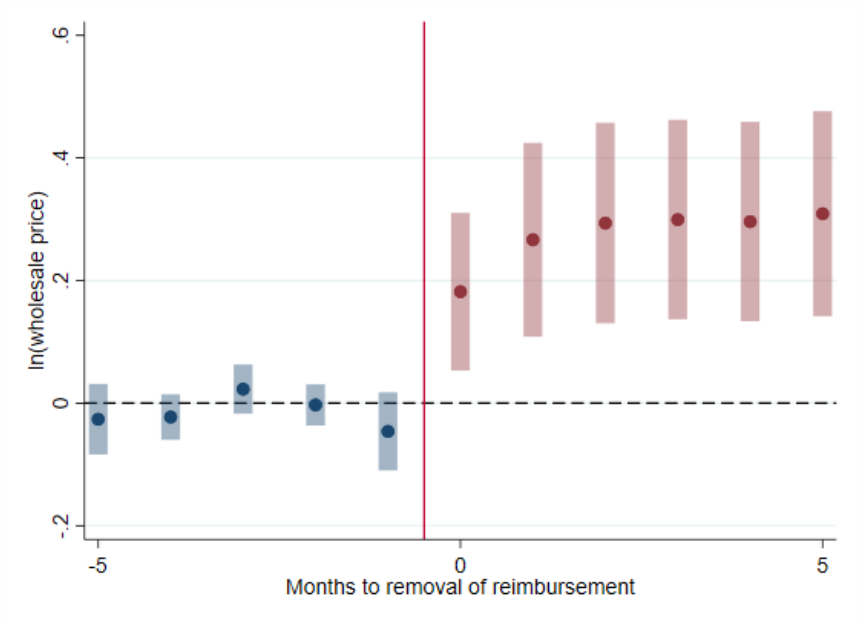

Figure 13: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Sweden with Norway as the control group. No control variables. ATC 5th level clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m6.

by the chi-squared tests with p-values corresponding to 0.00 with each sample. This is a clear indication that at least the pre-programmed Callaway and Sant'Anna (2021) estimator does not find the pre-treatment period parallel trends. One explanation could be that some of the observations are automatically excluded from the final samples. Hence, the designed setting of either product-level or ATC 5th level and brand status matching fails in these analyses. The variation in inclusion of observations is revealed by examining the number of observations in the pre-treatment periods of the utilized sample after the estimation. A possible explanation for the exclusion of some of the observations is that the observations are rather spread out over the eight-year period of the samples. Thus, there are occasionally only few observations to use in the estimation. These deviations from the original samples could cause the parallel trends to fail, regardless of whether there is one in the underlying complete sample.

Naturally, the failure of pre-treatment parallel trends could also be caused by the failure of the matching design if the pharmaceuticals don't follow similar pricing patterns before treatment across the countries. Nonetheless, even though pre-treatment parallel trends is not a requirement for causal inference in Callaway and Sant'Anna (2021) estimation, a rejection of the pre-treatment null hypothesis this strong is such a strong indication of a lack of parallel trends that it would be very difficult to justify the parallel trends to suddenly hold in the post-treatment period. Therefore, these results can't be interpreted with strictly causal inference in mind.

Table 7: Callaway and Sant'Anna (2021) ATT estimates on ln(wholesale price). Country-products as cross-sectional identifier. Months relative to treatment as time-series identifier. ATC 5 clustered standard errors. Outcome data source: Farmastat, FIMEA and IQVIA MIDAS Quarterly sales. 2010m1-2017m8.

Treatment	Country Treatment	Country Control	ATT No controls	ATT Controls
Removal	Finland	Norway	0.407**	0.407**
			(0.139)	(0.140)
Removal	Finland	Sweden	0.239**	0.241**
			(0.092)	(0.092)
Removal	Norway	Finland	0.066	0.077
			(0.057)	(0.055)
Removal	Norway	Sweden	0.057	0.037
			(0.048)	(0.041)
Removal	Sweden	Finland	0.070	0.069
			(0.049)	(0.048)
Removal	Sweden	Norway	0.284***	0.300***
			(0.077)	(0.079)

Standard errors in parentheses

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

5.2.3 Periods relative to treatment

Because the parallel trends hypothesis in the pre-treatment period failed with the Callaway and Sant'Anna (2021) estimator, another specification is used for the Callaway and Sant'Anna (2021) estimation. Namely, the calendar time monthly time variable is replaced by the number of months relative to treatment. This approach does not identify the possible shocks that appear over time in both examined countries. However, the approach balances the data in terms of time and allows the Callaway and Sant'Anna (2021) method to utilize the complete samples. Therefore, even though this approach includes arguably unreasonable assumptions, it suffers from different kinds of problems compared to the original approach. Thus, it can work as a robustness check for the results, although not as a definitive one. This approach is available only for the approaches that utilize one-to-one product-level matching because the relative time to treatment has to be identifiable for control group observations.

ATTs of removals of reimbursement statuses on logarithmic wholesale prices are presented in column ATT No controls in table 7.

The estimates presented in column ATT No controls in table 7 suggest a 50 % wholesale price increase associated with removals of reimbursement statuses in Finland when Norwegian pharmaceuticals are used as the control group. When Swedish

pharmaceuticals are used as the control group, the price increase for the Finnish pharmaceuticals is 27 %. For the Norwegian pharmaceuticals, the price changes are lower, 6-7 %, with the Finnish or Swedish control groups. Meanwhile, the wholesale prices of Swedish pharmaceuticals seem to increase by 7 % in the sample with the Finnish control group and 33 % with the Norwegian control group. These estimates differ only up to four percentage points compared to the estimates in column ATT All in table 6, excluding the Finnish treatment group with the Norwegian control group which has seven percentage points lower price increase with the relative time variable.

Notably, many of these estimations don't have their pre-treatment period parallel trends assumptions rejected by the chi-squared statistic, unlike with the calendar months as time-series identifiers. The chi-squared statistics for the pre-treatment coefficients to be jointly zero correspond to p-values of 0.21 for the Finnish treatment group with the Norwegian control group and 0.31 with the Swedish control group. For the Swedish treatment group with the Finnish control group, the statistic is 0.15 and with the Norwegian control group, it is 0.60. However, the Norwegian treatment groups have their pre-treatment parallel trends rejected as the p-value is 0.003 with the Finnish control group and 0.019 with the Swedish control group. Hence, by these metrics, pre-treatment parallel trends can be rejected only for the Norwegian treatment samples, unlike with calendar months as the time variable. Figures of these event studies are in the Appendix.

Column ATT Controls in table 7 includes the same estimates as in column ATT No Controls. However, they are estimated with control variables because using a selection of controls doesn't decrease the sample size when relative time to treatment is used as the time variable. The logarithmic number of firms on the ATC 5th and ATC 2nd level markets for both generics and all pharmaceuticals, in addition to the generic competition dummy, are included in the analyses of both of the Finnish treatment groups and the Swedish treatment group with the Finnish control group. The analyses with the Norwegian treatment groups exclude the ATC 2nd level firm variables compared to the previous ones. The analysis of the Swedish treatment group with the Norwegian control group further excludes the generic competition dummy.

Comparing the estimates with and without control variables, it is clear that there is little to no difference between these ATTs. The largest differences are present with the Swedish treatment group and the Norwegian control group, and the Norwegian treatment group with the Swedish treatment group. Even these differences reflect only 2 percentage point differences in price increases between the estimates with and without control variables. When it comes to the rejection of pre-treatment parallel trends, there is little change compared to the estimates without control variables. Only the Norwegian treatment group with the Swedish control group has a change in the statistical significance of the pre-treatment treatment coefficients being jointly zero with a 95 % confidence level, although only barely so.

These relative to treatment time variable analyses are also conducted with the TWFE regressions for reference. With TWFE, the calendar time monthly fixed effects are replaced by the relative to treatment fixed effects. To summarize, the estimates provided by this specification are similar in sign and mostly in scale compared to the TWFE regressions utilizing monthly fixed effects. The regression tables and figures

are available in the Appendix.

6 Conclusions

This thesis attempted to estimate the effect of a reimbursement status on a pharmaceutical's wholesale price in Finland, Norway, and Sweden. Even though the literature review could not identify the sign of the effect or association, it discussed several price-reducing regulations for reimbursed pharmaceuticals. TWFE and Callaway and Sant'Anna (2021) difference in differences estimates suggest that having a reimbursement status is associated with $12 - 36$ % lower wholesale price in Finland and $2 - 25$ % lower price in Sweden, although no strictly causal relationship could be found. The evidence from Norway is more ambiguous on whether an association between a wholesale price and a reimbursement status exists. Compared to generic pharmaceuticals, the estimates for branded pharmaceuticals cautiously indicate a stronger price response to reimbursement status changes in Finland and a similar or weaker response in Sweden.

Both two-way fixed effects and Callaway and Sant'Anna (2021) difference in differences methods were used to complement their individual weaknesses with the samples and settings used. For the staggered treatment, the method of Callaway and Sant'Anna (2021) was the more suitable one in theory because recent literature has shown that staggered treatment and treatment effect heterogeneity can cause misestimation of average treatment effects on the treated with TWFE. However, the pre-built Callaway and Sant'Anna (2021) estimation in Stata was not able to utilize the complete matched samples and rejected the pre-trend parallel trends assumption. Additionally, for the samples with one-to-one matching between countries, approaches with normalized periods around treatment times were used. This made the treatment appear simultaneous across products and decreased the number of periods, allowing Callaway and Sant'Anna (2021) estimation to utilize the whole samples. With this approach, parallel trends rejections based on the joint statistical significance of pre-treatment estimates happened only in analyses with Norwegian treatment groups. However, this structure misallocates calendar time variation in prices and can affect the estimates.

The interpretations based on these results are limited by the design of the analysis. An introduction of a reimbursement status and removal of a reimbursement status can require an application or an action from the pharmaceutical company. Thus, the results can't be inferred as introducing a reimbursement status to a random company. In addition, the requirement of finding matches, especially with one-to-one matching, can rule out pharmaceuticals from the analysis if the pharmaceutical company has differing strategies in entering the market in different countries. Deviating from the properties of a pre-existing product in another country, such as trade name or package size, leads to differing product numbers between countries (VnrWiki [nodate]b). This causes the matching to fail and the exclusion of these pharmaceuticals from the analysis. Additionally, requirements for a pharmaceutical to have sales for 12 consecutive months, either being or not being reimbursed for the first 6 months and then changing the reimbursement status for at least 6 months further decreases the sample size. Therefore, the sample might include only pharmaceuticals that are prone to particular pricing strategies and reflect a too small segment of pharmaceuticals

to provide a general inference of the effect of reimbursement statuses on wholesale prices. Thus, there is a threat of selection bias for the treated pharmaceuticals.

Regulations between 2010 and 2017 can cause inference difficulties. Even though the largest reforms regarding the reimbursement schemes happened before 2010 in Finland, Norway and Sweden, minor ones occur during the examination period. These include reforms such as reimbursement rate changes in Finland and Norway and adjustments to the sizes of deductibles in order to receive a full reimbursement in each country.

Despite the generalization difficulties, there are available explanations in the literature and the regulations for why the results could hold more generally. In contrast to the regulations for reimbursed pharmaceuticals in Finland and Sweden, the lack of price regulation for pharmaceuticals without reimbursement statuses supports the existence of price decreases associated with a reimbursement status. Thus, there is a resemblance of the price increase restraining results of Medicare Part D when insurance companies had possibilities to select which pharmaceuticals to reimburse and therefore affect the incentives of pharmaceutical pricing as presented in Duggan and Scott Morton (2010). The mechanism of reimbursement dependent demand affecting pricing incentives is also supported by the price elasticity of demand estimates of Dubois and Lasio (2018). In the Nordics, Granlund (2010) found price decreases associated with the generic substitution reform in Sweden, while Kortelainen et al. (2022) presented a price-decreasing effect among pharmaceuticals that were included in the internal reference pricing reform in Finland in 2009. Hence, it is not surprising that wholesale price changes occur in Finland and Sweden when reimbursement statuses change.

A possible explanation for the minor price responses to the reimbursement status changes of the Norwegian products is the external reference pricing which is applied to all Norwegian prescription pharmaceuticals. Hence, non-reimbursed pharmaceutical prices in Norway can be bound above, which leaves less room for price variation compared to the Swedish and Finnish counterparts. This can both affect the estimates and threaten the parallel trends assumption between the countries.

Larger price changes to reimbursement status changes of brands compared to generics is supported by the literature. For example, Brekke et al.'s (2011) and Pavcnik's (2002) findings of the more drastic price decreases of branded pharmaceuticals compared to generics at the introduction of reference pricing illustrate this higher responsiveness to the underlying regulations associated with the reimbursement status. In addition, price caps of reimbursed pharmaceuticals should be more likely to bind branded pharmaceuticals than generic ones. This is due to an assumption of higher perceived value for branded pharmaceuticals and consequently higher initial price, as in e.g., Brekke et al. (2011). Whether the reason for the Swedish pharmaceuticals having larger changes for generics compared to brands is sample selection is left for future studies.

Based on the estimates, the price decrease associated with an introduction of a reimbursement status in Finland and Sweden might be a tempting argument for more lenient reimbursement decision criteria. However, it is likely that the regulations for reimbursed pharmaceuticals, such as reference pricing and price cap for eligibility for reimbursement, are the driving factors for the price decreases. Therefore, less strict

regulations for reimbursement could lead to price development of an opposite sign, as with pharmaceuticals with little competition included in Medicare Part D in Duggan and Scott Morton (2010).

The unfound association between pharmaceutical prices and reimbursement statuses in Norway could be an argument for stricter price regulations outside the reimbursement schemes. Studies have found an association between lower wholesale prices and stricter price regulations, such as Kortelainen et al. (2022) with the introduction of internal reference pricing in Finland and Martikainen et al. (2005) with between-country comparisons. However, both Brekke et al. (2011) and Håkonsen et al. (2009) have raised the concern about strict policies delaying or preventing the entry of new pharmaceuticals into the market. Therefore, to encourage generic competition and innovation, overly strict regulations should be avoided.

A regulator could attempt to allow reimbursement for pharmaceuticals in the short to medium term even with slightly more lenient terms to get pharmaceuticals under stronger price regulation. However, the regulator should be open about the possibilities of encouraging generic competition when more competitors enter the market. These ideas are worth considering especially for branded pharmaceuticals as their price responses to changes in reimbursement statuses seem to be stronger compared to generics, at least in Finland. The answer to how large these price cap exceptions should be is left for future studies.

For future research, aggregating the observations could be preferable. More aggregated data in terms of periods, such as quarters instead of months, could allow the inclusion of more products in the samples. Hence, estimation methods for staggered treatment under treatment effect heterogeneity with calendar time could be better utilized. Additionally, aggregating the observations to ATC 5th market level, as in Kortelainen et al. (2022), could help avoid unobserved within-market spillovers compared to the product-level approach. Market-level outcomes would also allow an examination of market-level expenditure development as the reimbursement statuses of pharmaceuticals change. This would help the regulators in expenditure-minimizing decision-making.

The price changes should differ between different ATC classes. For example, Einav et al. (2018) showed that the estimated price elasticities of demand differ across therapeutic classes, and Brot-Goldberg et al. (2017) found indication-specific consumption reductions when the deductible increased. Thus, understanding which ATC classes of pharmaceuticals are prone to be agreed for larger price decreases to obtain a reimbursement status could be important in the reimbursement status evaluation. This would reduce the expenditure of both the consumers and the governments. However, these types of aggregations of pharmaceuticals have to be kept broad enough for large enough sample sizes but narrow enough for the identification of differing groups. This turned out difficult with the samples used in this thesis and was thus left out.

This thesis contributes to the study gap of the effect of pharmaceutical reimbursement status changes on wholesale prices by providing several estimates in the Nordic context. Even though pre-existing studies consider the effects of specific regulations on pharmaceutical prices, a more aggregate understanding of the interaction of these

simultaneously applied regulations for reimbursed pharmaceuticals is considerably less represented in the literature. Finally, the thesis suggests within its limitations that the Nordic regulations for reimbursed pharmaceuticals are sufficient for preventing the realization of price-increasing incentives caused by pharmaceutical reimbursements.

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A Appendix

- Variable explanations for the TWFE regression tables:
  - Reimbursement = Dummy variable that equals one if a pharmaceutical has a reimbursement status. Otherwise, the variable equals 0.
  - No Reimbursement = Dummy variable that equals one if a pharmaceutical doesn't have a reimbursement status. Otherwise, the variable equals 0.
  - Reimbursement * G = Dummy variable that equals one if a pharmaceutical has a reimbursement status and is not a branded pharmaceutical. Otherwise, the variable equals 0.
  - No Reimbursement * G = Dummy variable which equals one if a pharmaceutical doesn't have a reimbursement status and is not a branded pharmaceutical. Otherwise, the variable equals 0.
  - ln(#ATC5 Pharm) = Natural logarithm of the number of pharmaceuticals with the same ATC 5th level code in the same country.
  - ln(#ATC5 Pharm) * G = Natural logarithm of the number of pharmaceuticals with the same ATC 5th level code in the same country for non-branded pharmaceuticals. Otherwise, the variable equals 0.
  - ln(#ATC2 Pharm) = Natural logarithm of the number of pharmaceuticals with the same ATC 2nd level code in the same country.
  - ln(#ATC2 Pharm) * G = Natural logarithm of the number of pharmaceuticals with the same ATC 2nd level code in the same country for non-branded pharmaceuticals. Otherwise, the variable equals 0.
  - Generic competition = Dummy variable which equals one if there are non-branded pharmaceuticals with the same ATC 5th level code in the country.
  - Full reimbursement limit = Annual spending threshold required to be eligible for full reimbursement deflated by consumer price index and the spending of 2017 normalized to 1.

Table A1: TWFE regressions of introductions of reimbursement statuses. Finland treatment. Sweden control. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m2.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
Reimbursement	-0.125*	-0.188*	-0.182*	-0.204*
	(0.0474)	(0.0750)	(0.0697)	(0.0784)
Reimbursement * G		0.215	0.209	0.229
		(0.132)	(0.114)	(0.124)
ln(#ATC5 Pharm)			0.0489	0.0567
			(0.0798)	(0.0819)
ln(#ATC5 Pharm) * G			0.383	0.225
			(0.691)	(0.673)
ln(#ATC2 Pharm)			-0.319	-0.354
			(0.594)	(0.626)
ln(#ATC2 Pharm) * G			-0.574	-0.279
			(0.746)	(0.709)
Generic competition			0.0719	0.0779
			(0.0739)	(0.0672)
Full reimbursement limit				-0.592
				(0.628)
Constant	4.789***	4.750***	7.320*	7.461*
	(0.0296)	(0.0429)	(2.920)	(3.074)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	1312	1312	1312	1312
R^2	0.201	0.223	0.227	0.230
Adjusted R^2	0.155	0.177	0.178	0.180

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A2: TWFE regressions of introductions of reimbursement statuses. Norway treatment. Finland control. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
Reimbursement	0.0195	0.0195	0.0203	0.0189
	(0.0110)	(0.0135)	(0.0144)	(0.0148)
Reimbursement * G		0.00000206	-0.0146	-0.0142
		(0.0225)	(0.0180)	(0.0182)
ln(#ATC5 Pharm)			0.00800	0.00551
			(0.0143)	(0.0155)
ln(#ATC5 Pharm) * G			0.376	0.378
			(0.430)	(0.428)
ln(#ATC2 Pharm)			-0.0240	-0.0252
			(0.0796)	(0.0801)
ln(#ATC2 Pharm) * G			-0.306*	-0.305*
			(0.128)	(0.128)
Generic competition			0.00190	0.00163
			(0.0173)	(0.0172)
Full reimbursement limit				-0.0562
				(0.0615)
Constant	4.088***	4.088***	4.268***	4.344***
	(0.00829)	(0.00797)	(0.353)	(0.392)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	1344	1344	1344	1344
R^2	0.124	0.124	0.142	0.143
Adjusted R^2	0.066	0.065	0.081	0.081

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A3: TWFE regressions of introductions of reimbursement statuses. Norway treatment. Sweden control. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m10.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
Reimbursement	0.0190	0.0235	0.0238	0.0111
	(0.0141)	(0.0193)	(0.0193)	(0.0197)
Reimbursement * G		-0.0120	-0.0126	-0.00516
		(0.0287)	(0.0281)	(0.0280)
ln(#ATC5 Pharm)			0.0136	-0.00278
			(0.0293)	(0.0254)
ln(#ATC5 Pharm) * G			0.208	0.224
			(0.139)	(0.138)
ln(#ATC2 Pharm)			0.0231	0.0291
			(0.195)	(0.193)
ln(#ATC2 Pharm) * G			-0.127	-0.134
			(0.251)	(0.250)
Generic competition			0.0327	0.0364
			(0.0194)	(0.0196)
Full reimbursement limit				-0.268
				(0.171)
Constant	5.772***	5.766***	5.607***	5.925***
	(0.0203)	(0.0260)	(0.654)	(0.706)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	1776	1776	1776	1776
R^2	0.696	0.697	0.699	0.701
Adjusted R^2	0.685	0.685	0.686	0.688

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A4: TWFE regressions of introductions of reimbursement statuses. Sweden treatment. Finland control. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m4-2017m12.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
Reimbursement	-0.186***	-0.117*	-0.124**	-0.114*
	(0.0445)	(0.0457)	(0.0456)	(0.0451)
Reimbursement * G		-0.114	-0.107	-0.112
		(0.0817)	(0.0806)	(0.0814)
ln(#ATC5 Pharm)			0.0326	0.0330
			(0.0658)	(0.0660)
ln(#ATC5 Pharm) * G			-0.0714	-0.0905
			(0.139)	(0.139)
ln(#ATC2 Pharm)			0.187	0.202
			(0.236)	(0.240)
ln(#ATC2 Pharm) * G			-0.0503	-0.0498
			(0.347)	(0.354)
Generic competition			0	0
			(.)	(.)
Full reimbursement limit				-0.727
				(1.086)
Constant	2.717***	2.752***	1.998*	2.825
	(0.0551)	(0.0549)	(0.934)	(1.631)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	5280	5280	5280	5280
R^2	0.112	0.119	0.120	0.122
Adjusted R^2	0.096	0.103	0.104	0.105

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A5: TWFE regressions of removals of reimbursement statuses. Finland treatment. Norway control. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

	(1)	(2)	(3)	(4)
	ln(wholesale price)	ln(wholesale price)	ln(wholesale price)	ln(wholesale price)
No Reimbursement	0.321**	0.318*	0.327**	0.330*
	(0.109)	(0.117)	(0.113)	(0.118)
No Reimbursement * G		0.0199	-0.0604	-0.0588
		(0.309)	(0.248)	(0.247)
ln(#ATC5 Pharm)			-0.349	-0.373
			(0.284)	(0.327)
ln(#ATC5 Pharm) * G			-0.506	-0.482
			(0.565)	(0.590)
ln(#ATC2 Pharm)			0.587	0.583
			(0.679)	(0.669)
ln(#ATC2 Pharm) * G			2.060*	2.065*
			(0.823)	(0.820)
Generic competition			0.198	0.202
			(0.210)	(0.213)
Full reimbursement limit				-0.361
				(0.918)
Constant	4.303***	4.298***	0.659	1.079
	(0.139)	(0.134)	(2.866)	(2.164)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	624	624	624	624
R^2	0.669	0.669	0.686	0.687
Adjusted R^2	0.615	0.614	0.631	0.631

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A6: TWFE regressions of removals of reimbursement statuses. Finland treatment. Sweden control. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m7.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	0.228*	0.240*	0.251*	0.234**
	(0.0907)	(0.0943)	(0.0994)	(0.0842)
No Reimbursement * G		-0.248**	-0.252**	-0.240**
		(0.0852)	(0.0792)	(0.0708)
ln(#ATC5 Pharm)			-0.158	-0.159
			(0.106)	(0.106)
ln(#ATC5 Pharm) * G			0.371	0.361
			(0.190)	(0.183)
ln(#ATC2 Pharm)			0.620	0.611
			(0.369)	(0.362)
ln(#ATC2 Pharm) * G			-1.039**	-1.059**
			(0.375)	(0.369)
Generic competition			-0.0634	-0.0641
			(0.0772)	(0.0784)
Full reimbursement limit				-0.713
				(1.025)
Constant	4.536***	4.543***	2.196	2.942*
	(0.152)	(0.153)	(1.420)	(1.414)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	1008	1008	1008	1008
R^2	0.320	0.326	0.347	0.349
Adjusted R^2	0.253	0.259	0.278	0.279

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A7: TWFE regressions of removals of reimbursement statuses. Norway treatment. Finland control. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m4.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	0.0577	0.0433	0.0534	0.0529
	(0.0467)	(0.0227)	(0.0286)	(0.0289)
No Reimbursement * G		0.0362	0.0745	0.0745
		(0.0825)	(0.0938)	(0.0944)
ln(#ATC5 Pharm)			0.00655	0.0104
			(0.0255)	(0.0259)
ln(#ATC5 Pharm) * G			-0.0617	-0.0627
			(0.434)	(0.434)
ln(#ATC2 Pharm)			-0.299	-0.290
			(0.311)	(0.311)
ln(#ATC2 Pharm) * G			-1.291	-1.302
			(1.330)	(1.341)
Generic competition			0.0266	0.0263
			(0.0218)	(0.0207)
Full reimbursement limit				-0.152
				(0.317)
Constant	4.088***	4.091***	8.220**	8.342*
	(0.0923)	(0.0901)	(2.694)	(2.837)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	600	600	600	600
R^2	0.201	0.202	0.226	0.226
Adjusted R^2	0.076	0.076	0.094	0.093

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A8: TWFE regressions of removals of reimbursement statuses. Norway treatment. Sweden control. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m2-2017m4.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	-0.0152	-0.00396	-0.00408	-0.00494
	(0.0140)	(0.0101)	(0.0109)	(0.0112)
No Reimbursement * G		-0.0322	-0.0318	-0.0317
		(0.0303)	(0.0412)	(0.0414)
ln(#ATC5 Pharm)			-0.0306	-0.0304
			(0.0238)	(0.0235)
ln(#ATC5 Pharm) * G			0.154	0.153
			(0.236)	(0.237)
ln(#ATC2 Pharm)			0.0236	0.0230
			(0.0936)	(0.0927)
ln(#ATC2 Pharm) * G			-0.608	-0.607
			(0.664)	(0.665)
Generic competition			0.00374	0.00360
			(0.0159)	(0.0157)
Full reimbursement limit				-0.0555
				(0.127)
Constant	5.603***	5.604***	6.335***	6.396***
	(0.0689)	(0.0675)	(0.917)	(0.890)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	576	576	576	576
R^2	0.176	0.177	0.179	0.179
Adjusted R^2	0.049	0.048	0.041	0.039

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A9: TWFE regressions of removals of reimbursement statuses. Sweden treatment. Finland control. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m11-2017m8.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	0.0244	0.0677*	0.0631*	0.0650*
	(0.0340)	(0.0293)	(0.0296)	(0.0313)
No Reimbursement * G		-0.170	-0.146	-0.148
		(0.113)	(0.104)	(0.105)
ln(#ATC5 Pharm)			-0.0342	-0.0350
			(0.0402)	(0.0395)
ln(#ATC5 Pharm) * G			0.326	0.327
			(0.356)	(0.356)
ln(#ATC2 Pharm)			-0.0142	-0.0128
			(0.0821)	(0.0847)
ln(#ATC2 Pharm) * G			-2.072	-2.071
			(1.190)	(1.190)
Generic competition			-0.139*	-0.139*
			(0.0688)	(0.0686)
Full reimbursement limit				-0.117
				(0.356)
Constant	4.926***	4.945***	7.928***	8.039***
	(0.0272)	(0.0303)	(1.615)	(1.610)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	2352	2352	2352	2352
R^2	0.051	0.070	0.092	0.092
Adjusted R^2	0.021	0.040	0.061	0.061

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A10: TWFE regressions of removals of reimbursement statuses. Sweden treatment. Norway control. ATC 5 clustered standard errors. Data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m6.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	0.227**	0.221**	0.229**	0.197***
	(0.0715)	(0.0816)	(0.0824)	(0.0537)
No Reimbursement * G		0.0353	0.0192	0.0290
		(0.154)	(0.149)	(0.147)
ln(#ATC5 Pharm)			0.0589	0.0970
			(0.101)	(0.118)
ln(#ATC5 Pharm) * G			-0.439	-0.482
			(0.315)	(0.317)
ln(#ATC2 Pharm)			-0.520	-0.512
			(0.352)	(0.342)
ln(#ATC2 Pharm) * G			-0.279	-0.277
			(0.934)	(0.922)
Generic competition			0.0189	-0.0128
			(0.0726)	(0.0716)
Full reimbursement limit				0.872
				(0.889)
Constant	5.472***	5.474***	8.629***	7.511***
	(0.0692)	(0.0675)	(1.603)	(2.055)
Product FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	2064	2064	2064	2064
R^2	0.238	0.238	0.248	0.257
Adjusted R^2	0.203	0.203	0.212	0.221

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A11: TWFE regressions of removals of reimbursement statuses. Finland treatment. Norway control. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

	(1)	(2)	(3)	(4)
	ln(wholesale price)	ln(wholesale price)	ln(wholesale price)	ln(wholesale price)
No Reimbursement	0.343**	0.353**	0.345**	0.350**
	(0.111)	(0.125)	(0.109)	(0.110)
No Reimbursement * G		-0.0816	-0.134	-0.122
		(0.320)	(0.247)	(0.245)
ln(#ATC5 Pharm)			-0.711	-0.735
			(0.424)	(0.429)
ln(#ATC5 Pharm) * G			0.359	0.379
			(0.664)	(0.669)
ln(#ATC2 Pharm)			1.979	1.953
			(1.378)	(1.355)
ln(#ATC2 Pharm) * G			0.0143	0.0813
			(1.519)	(1.488)
Generic competition			0.295	0.280
			(0.238)	(0.222)
Full reimbursement limit				-0.641
				(0.428)
Constant	3.815***	3.815***	-4.860	-3.964
	(0.0716)	(0.0716)	(5.389)	(5.020)
Product FE	Yes	Yes	Yes	Yes
Event time FE	Yes	Yes	Yes	Yes
Observations	624	624	624	624
R^2	0.207	0.208	0.285	0.289
Adjusted R^2	0.191	0.191	0.264	0.267

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A12: TWFE regressions of removals of reimbursement statuses. Finland treatment. Sweden control. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m7.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	0.235*	0.247*	0.265*	0.249*
	(0.0938)	(0.0984)	(0.109)	(0.0948)
No Reimbursement * G		-0.238*	-0.245*	-0.234*
		(0.0990)	(0.0988)	(0.0891)
ln(#ATC5 Pharm)			-0.244	-0.243
			(0.171)	(0.170)
ln(#ATC5 Pharm) * G			0.258	0.245
			(0.180)	(0.169)
ln(#ATC2 Pharm)			0.781	0.753
			(0.580)	(0.550)
ln(#ATC2 Pharm) * G			-0.707	-0.703
			(0.529)	(0.519)
Generic competition			0.00809	0.0297
			(0.0483)	(0.0640)
Full reimbursement limit				-0.532
				(0.691)
Constant	4.405***	4.405***	1.358	2.031
	(0.0239)	(0.0239)	(2.363)	(1.898)
Product FE	Yes	Yes	Yes	Yes
Event time FE	Yes	Yes	Yes	Yes
Observations	1008	1008	1008	1008
R^2	0.130	0.136	0.174	0.177
Adjusted R^2	0.119	0.125	0.159	0.161

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A13: TWFE regressions of removals of reimbursement statuses. Norway treatment. Finland control. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m4.

	(1)	(2)	(3)	(4)
	ln(wholesale price)	ln(wholesale price)	ln(wholesale price)	ln(wholesale price)
No Reimbursement	0.0651	0.0477	0.0455	0.0448
	(0.0487)	(0.0369)	(0.0363)	(0.0358)
No Reimbursement * G		0.0434	0.0613	0.0626
		(0.0827)	(0.100)	(0.100)
ln(#ATC5 Pharm)			0.00539	0.00760
			(0.0331)	(0.0344)
ln(#ATC5 Pharm) * G			-0.0496	-0.0509
			(0.398)	(0.398)
ln(#ATC2 Pharm)			-0.0140	-0.00813
			(0.144)	(0.141)
ln(#ATC2 Pharm) * G			-0.418	-0.423
			(0.991)	(0.991)
Generic competition			-0.00436	-0.00434
			(0.0137)	(0.0134)
Full reimbursement limit				-0.115
				(0.187)
Constant	4.085***	4.085***	5.034**	5.151*
	(0.0251)	(0.0255)	(1.702)	(1.786)
Product FE	Yes	Yes	Yes	Yes
Event time FE	Yes	Yes	Yes	Yes
Observations	600	600	600	600
R^2	0.041	0.044	0.047	0.047
Adjusted R^2	0.022	0.023	0.017	0.016

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A14: TWFE regressions of removals of reimbursement statuses. Norway treatment. Sweden control. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m2-2017m4.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	-0.00723	-0.0314	-0.0269	-0.0266
	(0.0103)	(0.0317)	(0.0246)	(0.0240)
No Reimbursement * G		0.0724	0.0549	0.0548
		(0.0835)	(0.0665)	(0.0666)
ln(#ATC5 Pharm)			-0.0189	-0.0191
			(0.0316)	(0.0321)
ln(#ATC5 Pharm) * G			0.429	0.430
			(0.376)	(0.378)
ln(#ATC2 Pharm)			-0.0491	-0.0495
			(0.0735)	(0.0732)
ln(#ATC2 Pharm) * G			-1.128	-1.128
			(0.996)	(0.998)
Generic competition			-0.0222	-0.0222
			(0.0181)	(0.0180)
Full reimbursement limit				0.0161
				(0.0920)
Constant	5.493***	5.493***	7.126***	7.110***
	(0.0220)	(0.0215)	(1.316)	(1.310)
Product FE	Yes	Yes	Yes	Yes
Event time FE	Yes	Yes	Yes	Yes
Observations	576	576	576	576
R^2	0.015	0.019	0.034	0.034
Adjusted R^2	-0.006	-0.003	0.002	0.001

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A15: TWFE regressions of removals of reimbursement statuses. Sweden treatment. Finland control. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m11-2017m8.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	0.0220	0.0672*	0.0603	0.0611
	(0.0351)	(0.0312)	(0.0316)	(0.0331)
No Reimbursement * G		-0.184	-0.157	-0.158
		(0.115)	(0.105)	(0.106)
ln(#ATC5 Pharm)			-0.0598	-0.0591
			(0.0365)	(0.0370)
ln(#ATC5 Pharm) * G			0.368	0.368
			(0.372)	(0.372)
ln(#ATC2 Pharm)			0.0558	0.0572
			(0.0780)	(0.0798)
ln(#ATC2 Pharm) * G			-2.073	-2.073
			(1.193)	(1.194)
Generic competition			-0.0578	-0.0582
			(0.0571)	(0.0574)
Full reimbursement limit				-0.0411
				(0.161)
Constant	4.857***	4.857***	7.431***	7.466***
	(0.0154)	(0.0148)	(1.537)	(1.542)
Product FE	Yes	Yes	Yes	Yes
Event time FE	Yes	Yes	Yes	Yes
Observations	2352	2352	2352	2352
R^2	0.020	0.046	0.066	0.066
Adjusted R^2	0.015	0.040	0.058	0.058

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A16: TWFE regressions of removals of reimbursement statuses. Sweden treatment. Norway control. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m6.

	(1) ln(wholesale price)	(2) ln(wholesale price)	(3) ln(wholesale price)	(4) ln(wholesale price)
No Reimbursement	0.232**	0.233*	0.244*	0.260*
	(0.0780)	(0.0906)	(0.0940)	(0.0998)
No Reimbursement * G		-0.00886	-0.0420	-0.0482
		(0.161)	(0.165)	(0.164)
ln(#ATC5 Pharm)			-0.122	-0.111
			(0.109)	(0.107)
ln(#ATC5 Pharm) * G			-0.282	-0.286
			(0.266)	(0.264)
ln(#ATC2 Pharm)			-0.412	-0.384
			(0.400)	(0.389)
ln(#ATC2 Pharm) * G			-0.231	-0.247
			(0.829)	(0.835)
Generic competition			0.0512	0.0473
			(0.0656)	(0.0670)
Full reimbursement limit				-0.371**
				(0.128)
Constant	5.400***	5.400***	8.312***	8.580***
	(0.0274)	(0.0274)	(1.772)	(1.695)
Product FE	Yes	Yes	Yes	Yes
Event time FE	Yes	Yes	Yes	Yes
Observations	2064	2064	2064	2064
R^2	0.099	0.099	0.113	0.117
Adjusted R^2	0.094	0.094	0.105	0.109

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

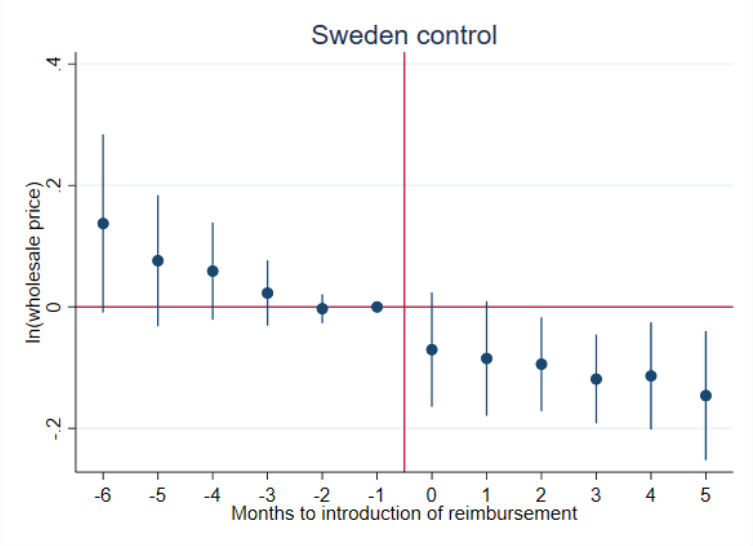

Figure A1: TWFE. Introductions of reimbursement statuses in Finland. All competition control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m2.

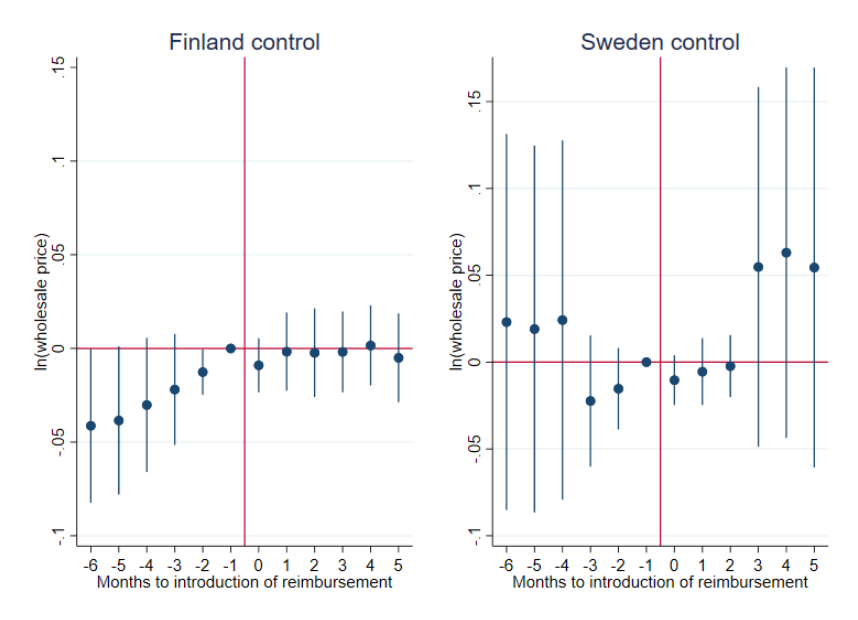

Figure A2: TWFE. Introductions of reimbursement statuses in Norway. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat (2010m1-2017m10), FIMEA (2010m1-2017m6) and IQVIA MIDAS Quarterly sales (2010m1-2017m10).

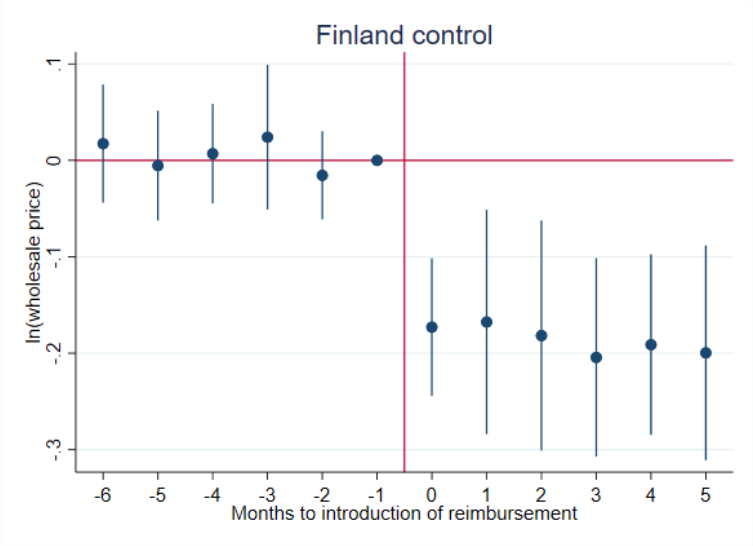

Figure A3: TWFE. Introductions of reimbursement statuses in Sweden. All competition control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m4-2017m12.

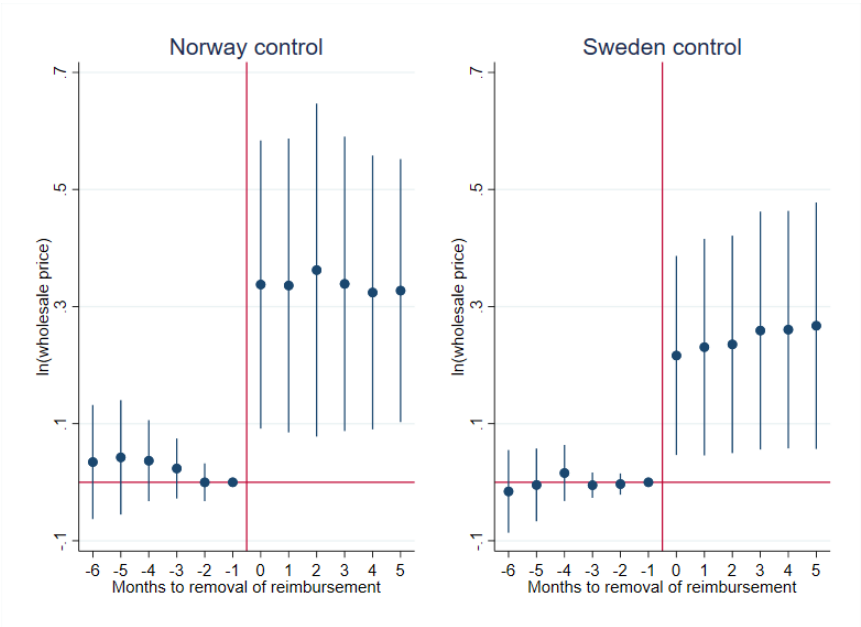

Figure A4: TWFE. Removals of reimbursement statuses in Finland. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat (2010m1-2017m6), FIMEA (2010m1-2017m7) and IQVIA MIDAS Quarterly sales (2010m2-2017m7).

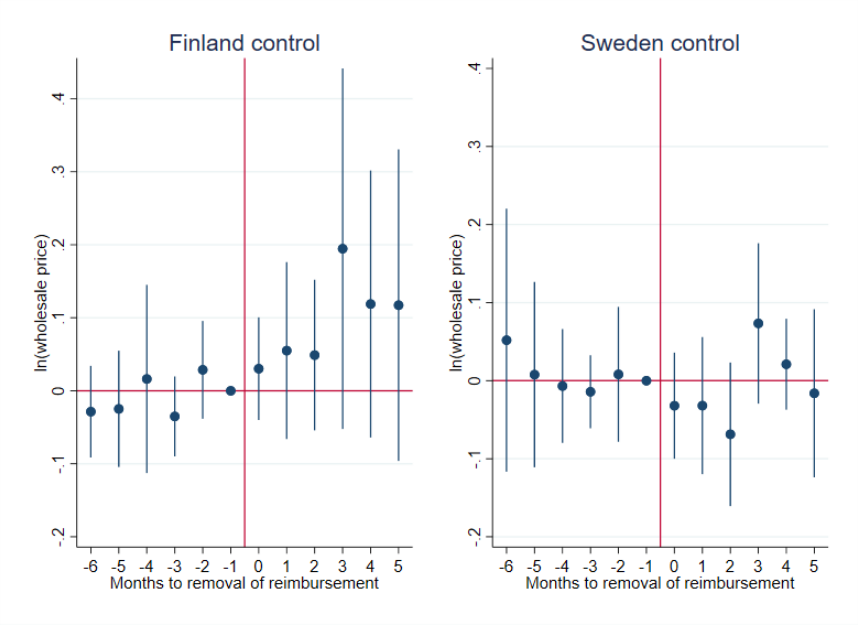

Figure A5: TWFE. Removals of reimbursement statuses in Norway. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat (2010m1-2017m4), FIMEA (2010m1-2017m4) and IQVIA MIDAS Quarterly sales (2010m2-2017m4).

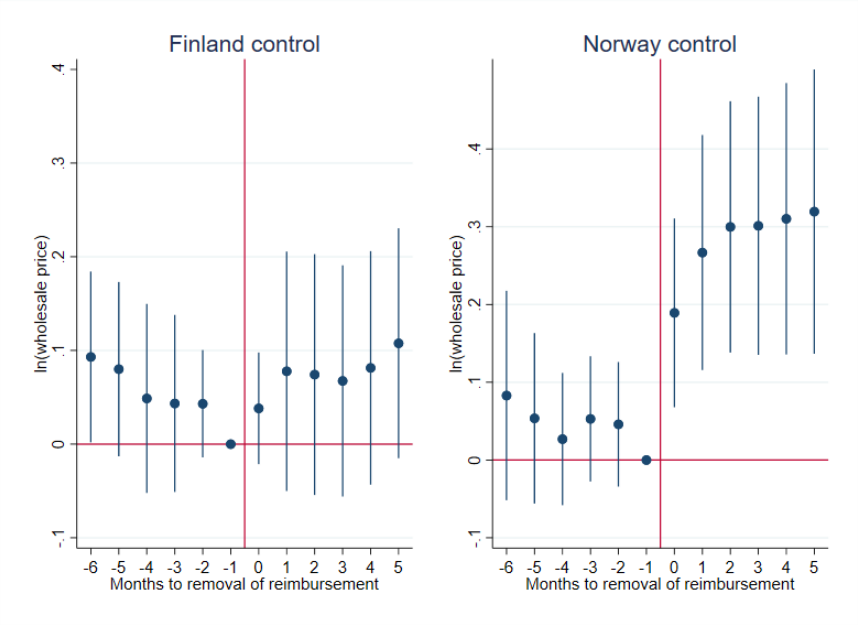

Figure A6: TWFE. Removals of reimbursement statuses in Sweden. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat (2010m1-2017m6), FIMEA (2010m11-2017m8) and IQVIA MIDAS Quarterly sales (2010m1-2017m8).

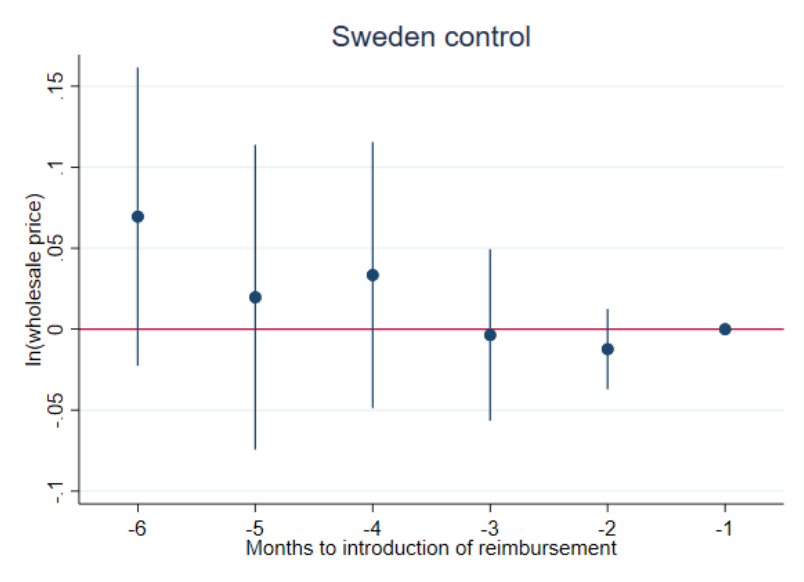

Figure A7: Pre-treatment TWFE. Introductions of reimbursement statuses in Finland. All competition control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m2.

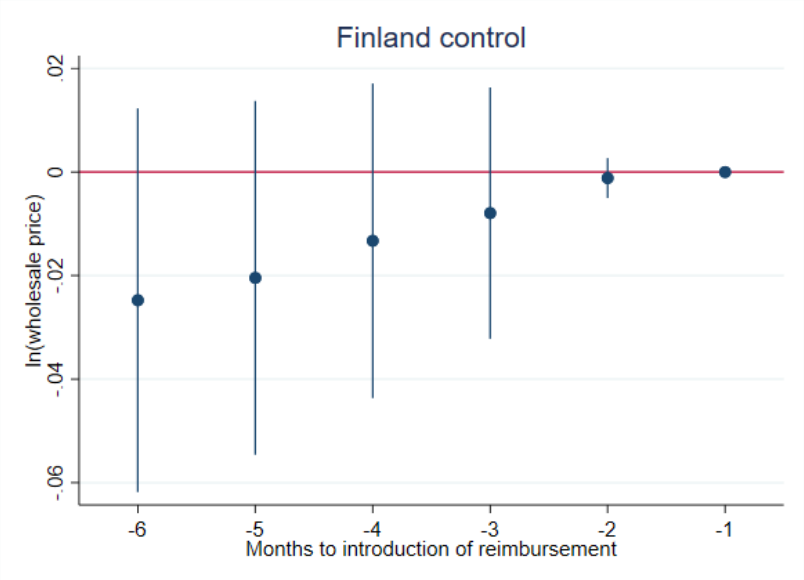

Figure A8: Pre-treatment TWFE. Introductions of reimbursement statuses in Norway. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

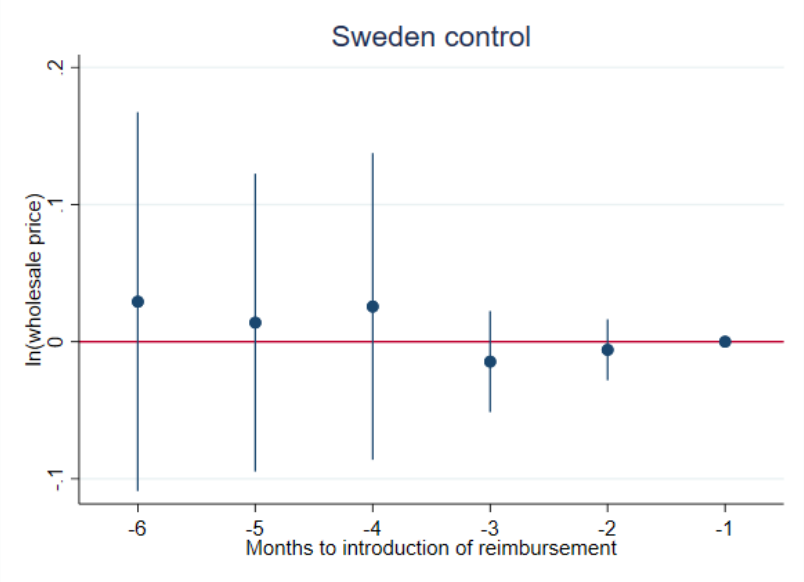

Figure A9: Pre-treatment TWFE. Introductions of reimbursement statuses in Norway. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m10.

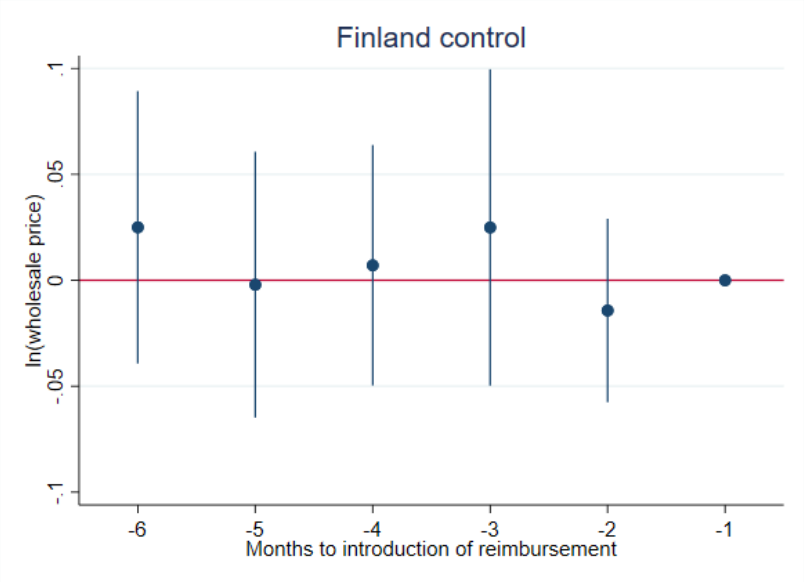

Figure A10: Pre-treatment TWFE. Introductions of reimbursement statuses in Sweden. All competition control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m4-2017m12.

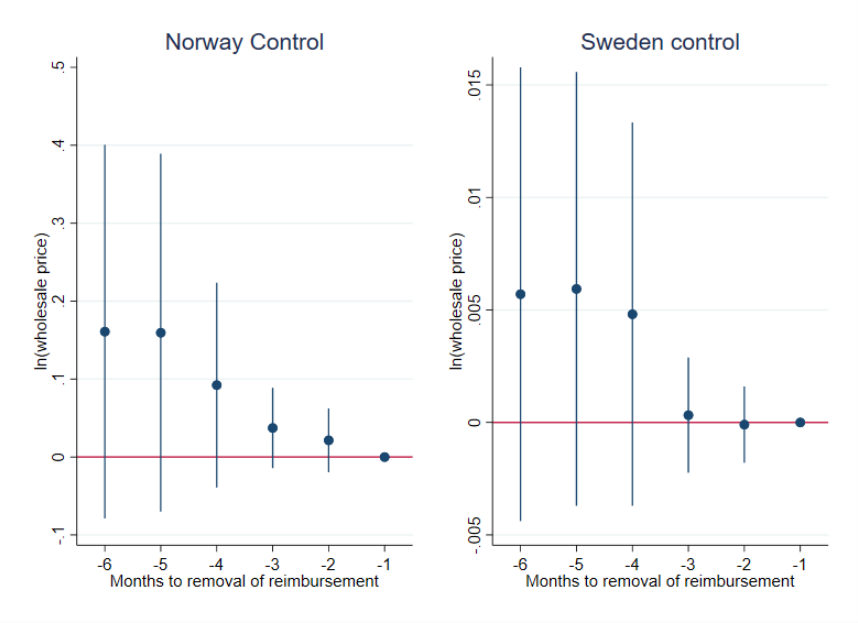

Figure A11: Pre-treatment TWFE. Removals of reimbursement statuses in Finland. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat (2010m1-2017m6), FIMEA (2010m1-2017m7) and IQVIA MIDAS Quarterly sales (2010m2-2017m7).

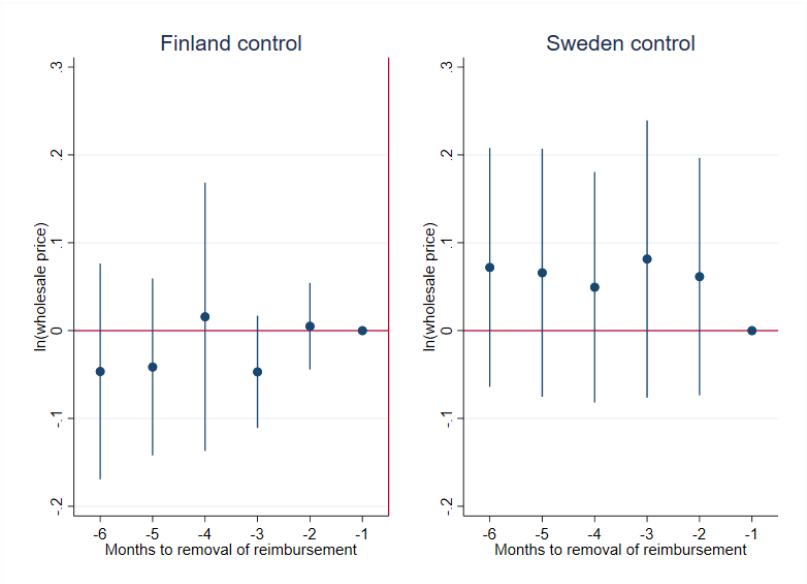

Figure A12: Pre-treatment TWFE. Removals of reimbursement statuses in Norway. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat (2010m1-2017m4), FIMEA (2010m1-2017m4) and IQVIA MIDAS Quarterly sales (2010m2-2017m4).

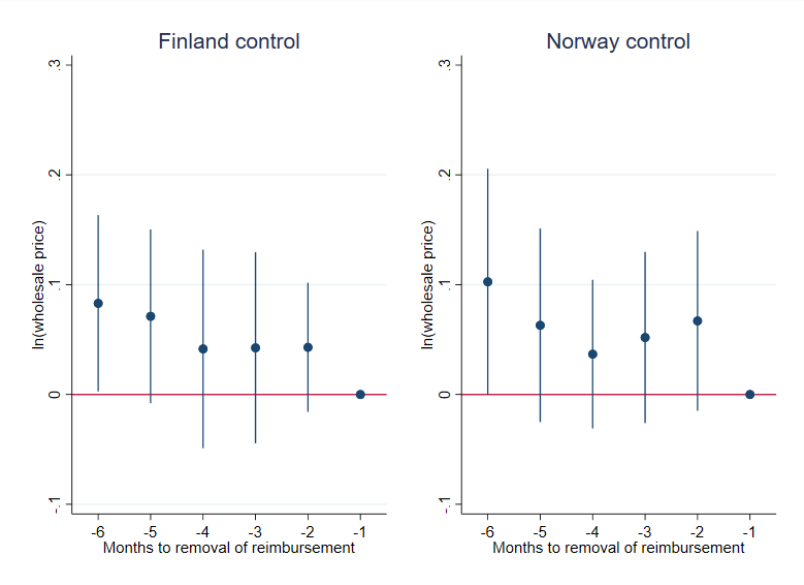

Figure A13: Pre-treatment TWFE. Removals of reimbursement statuses in Sweden. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat (2010m1-2017m6), FIMEA (2010m11-2017m8) and IQVIA MIDAS Quarterly sales (2010m1-2017m8).

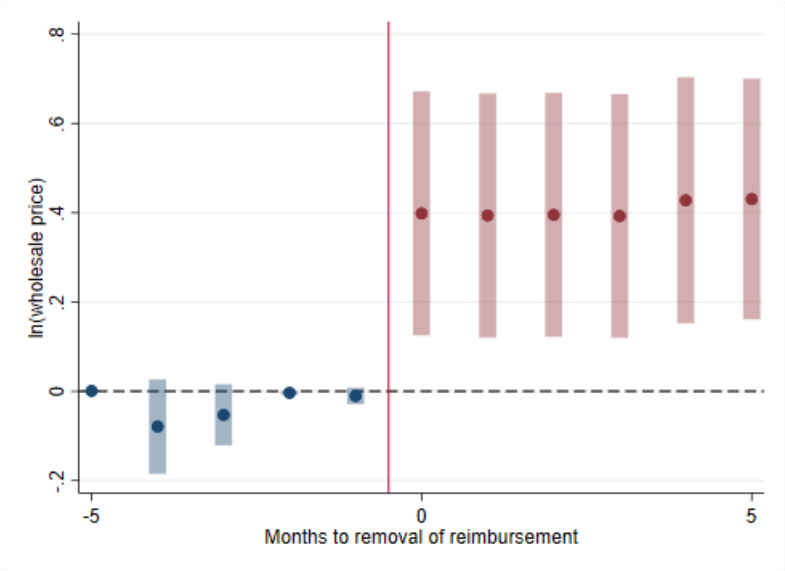

Figure A14: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Finland with Norway as the control group. Time variable relative to treatment. No control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

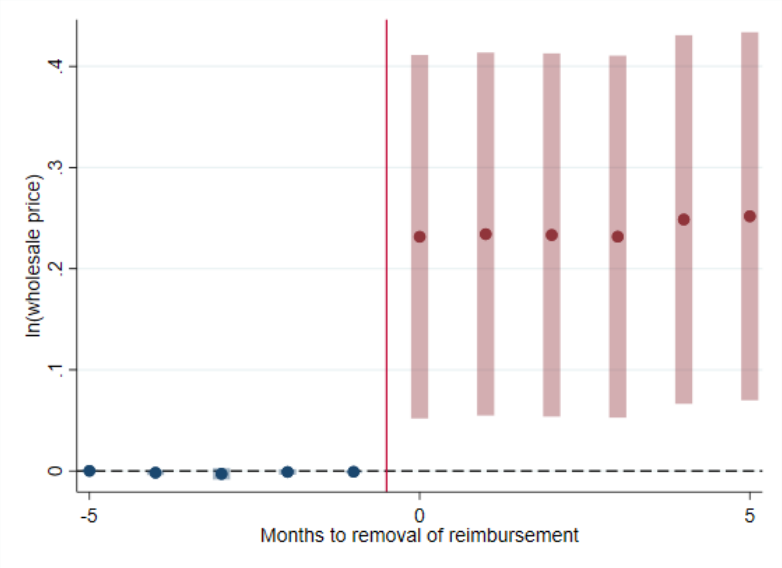

Figure A15: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Finland with Sweden as the control group. Time variable relative to treatment. No control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m7.

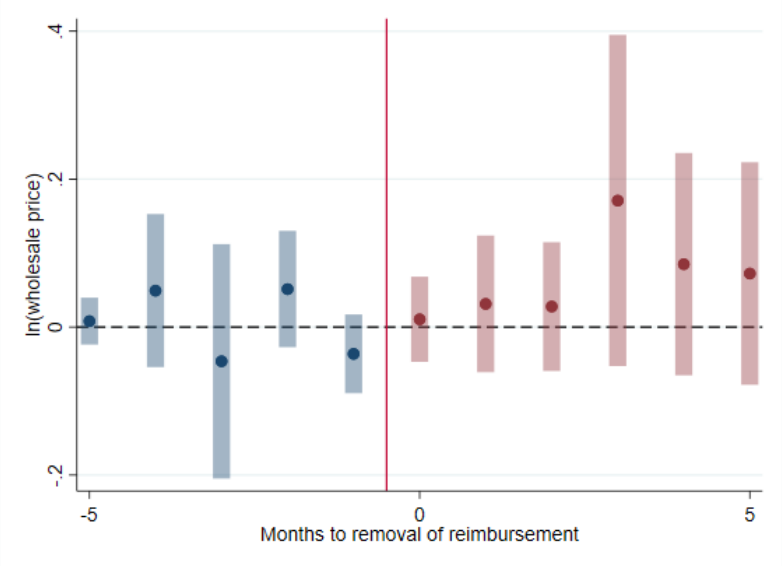

Figure A16: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Norway with Finland as the control group. Time variable relative to treatment. No control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m4.

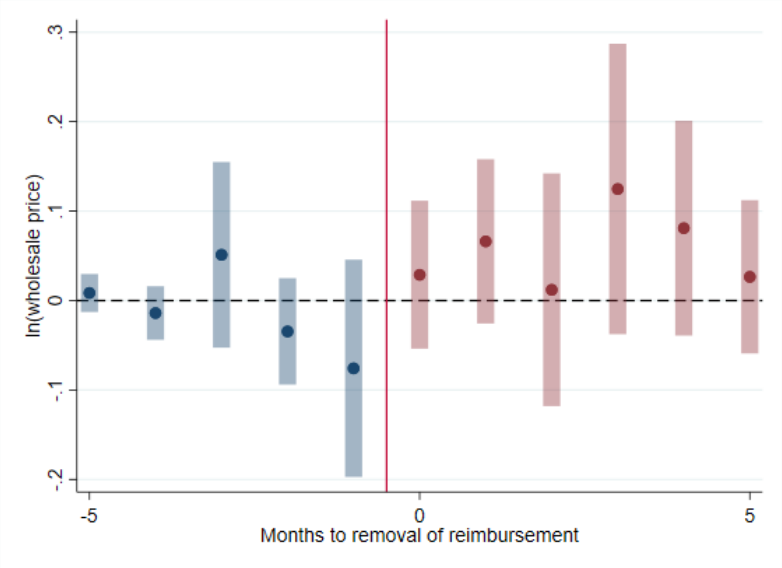

Figure A17: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Norway with Sweden as the control group. Time variable relative to treatment. No control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m2-2017m4.

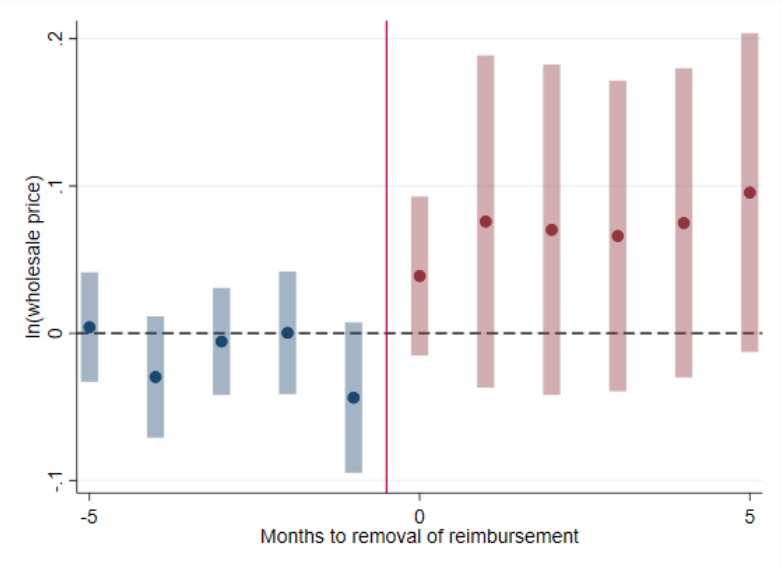

Figure A18: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Sweden with Finland as the control group. Time variable relative to treatment. No control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m11-2017m8.

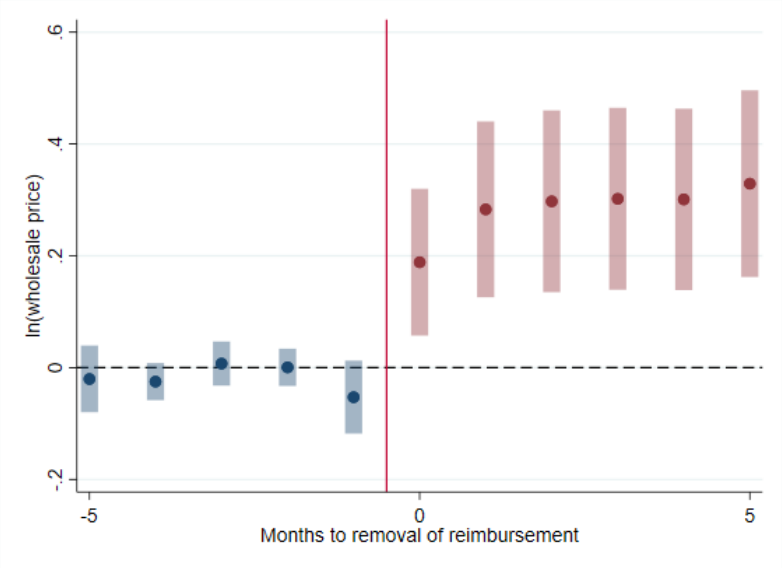

Figure A19: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Sweden with Norway as the control group. Time variable relative to treatment. No control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m6

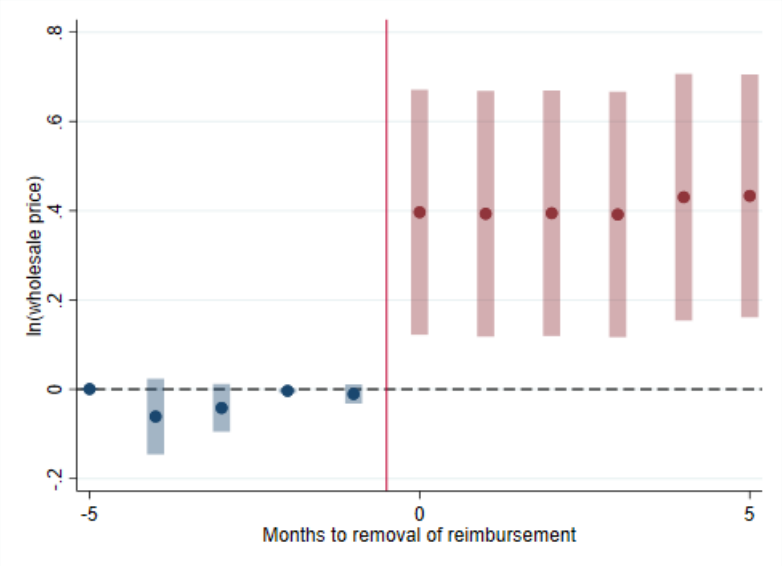

Figure A20: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Finland with Norway as the control group. Time variable relative to treatment. All competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m6.

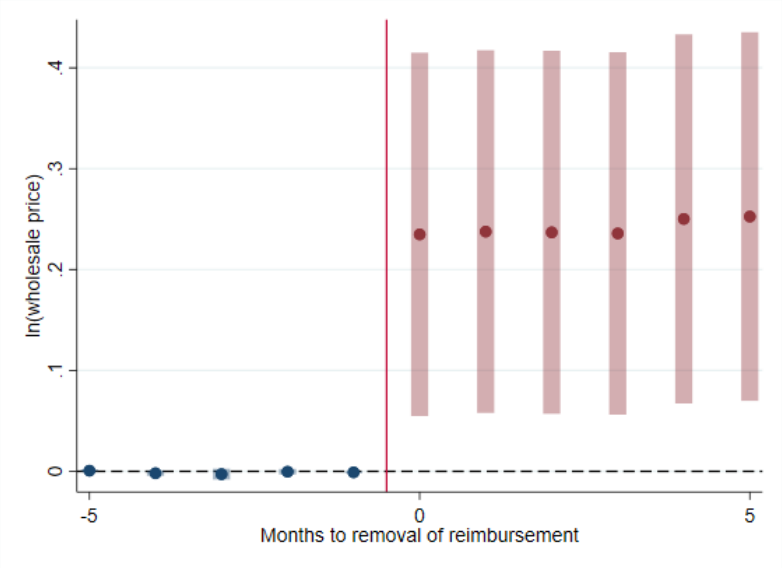

Figure A21: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Finland with Sweden as the control group. Time variable relative to treatment. All competition control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m2-2017m7.

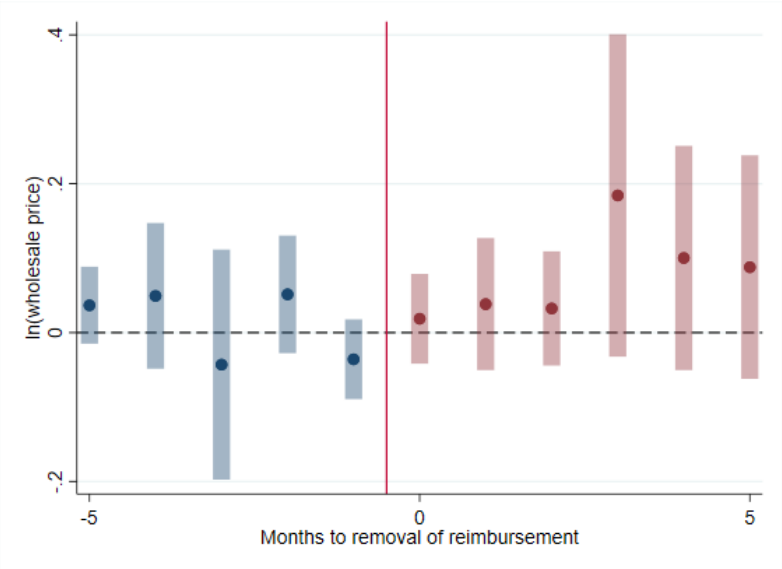

Figure A22: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Norway with Finland as the control group. Time variable relative to treatment. ATC 5 competition and generic competition dummy control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and FIMEA. 2010m1-2017m4.

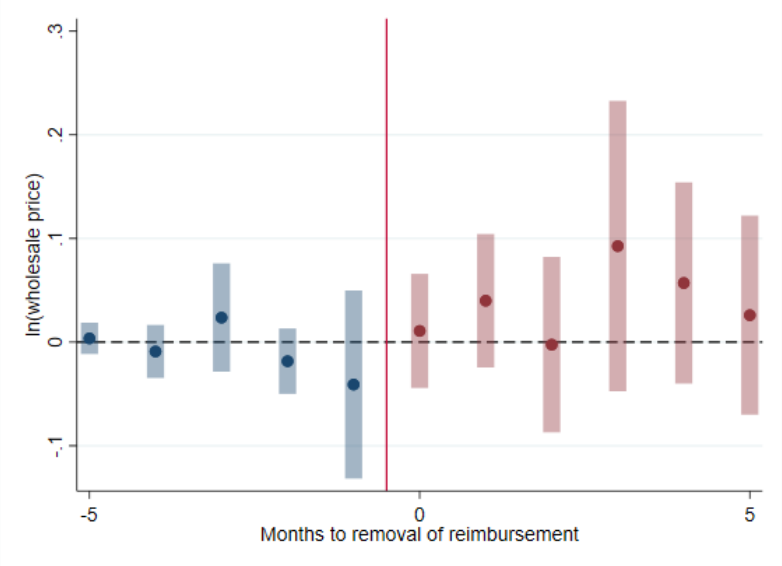

Figure A23: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Norway with Sweden as the control group. Time variable relative to treatment.. ATC 5 competition and generic competition dummy control variables. ATC 5 clustered standard errors. Outomce data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m2-2017m4.

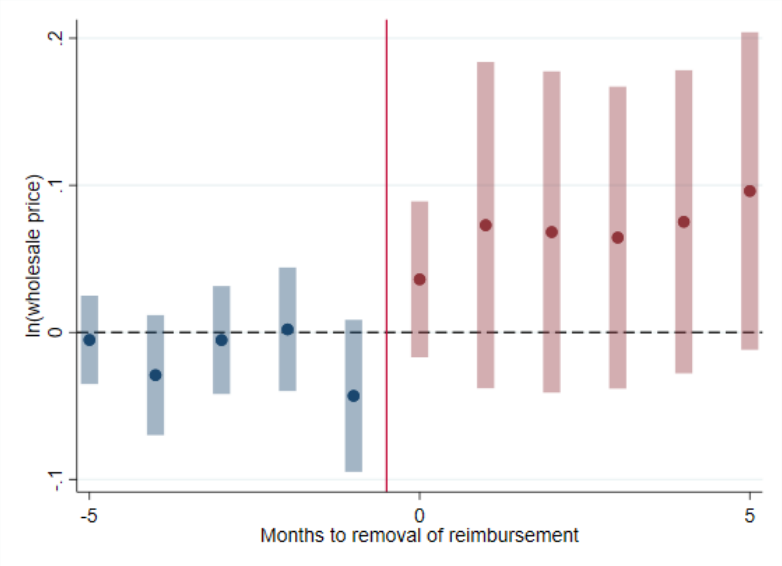

Figure A24: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Sweden with Finland as the control group. Time variable relative to treatment. All competition control variables. ATC 5 clustered standard errors. Outcome data source: FIMEA and IQVIA MIDAS Quarterly sales. 2010m11-2017m8.

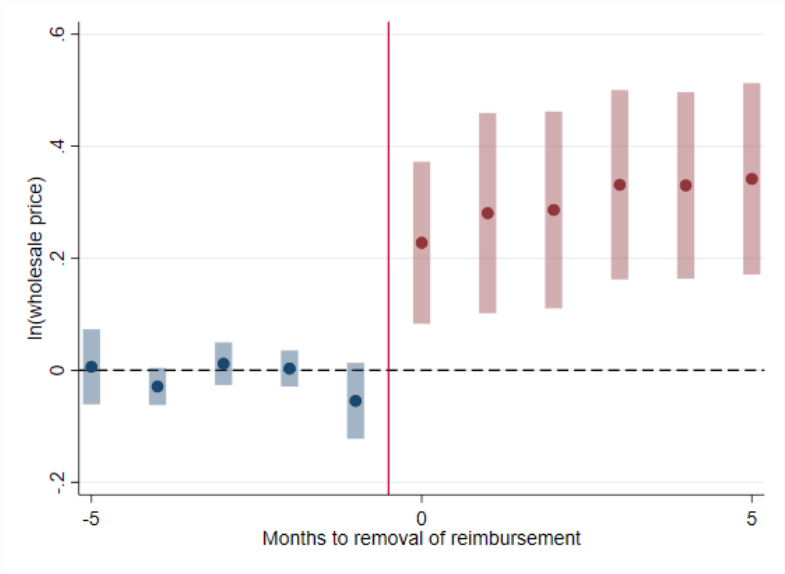

Figure A25: Callaway and Sant'Anna (2021) estimation. Removals of reimbursement statuses in Sweden with Norway as the control group. Time variable relative to treatment. ATC 5 competition control variables. ATC 5 clustered standard errors. Outcome data source: Farmastat and IQVIA MIDAS Quarterly sales. 2010m1-2017m6.