Rewarding Incremental Innovation: Evidence from Pharmaceutical Line Extensions

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Abstract

The FDA grants a three-year market exclusivity period for reformulated versions of existing drugs, known as line extensions, upon their approval. This policy can incentivize manufacturers to delay the launch of improved drugs until the original formulation's patent nears expiration, depriving patients of earlier access to better treatments. I develop a dynamic model to analyze manufacturer pricing and launch timing strategies under various policies, assessing how removing delay incentives impacts overall welfare. I apply this model to the dementia drug market, focusing on Namenda, an original formulation, and its line extension, which was launched shortly before Namenda's patent expiration. My findings show that a "no exclusivity" policy, where line extensions receive no protection after the original patent expires, enhances consumer welfare, even though it introduces the risk that the line extension might not be developed due to reduced profitability. In contrast, providing the full three-year exclusivity, referred to as "full exclusivity", after the original patent expires ensures profitability for line extensions but leads to significantly higher drug costs for insurers with minimal gains for consumers. Extending beyond the Namenda case, simulations indicate that line extensions with only minor quality improvements are most at risk of not being developed under a no-exclusivity policy, which limits consumer welfare losses under that policy, if those minor innovations do not come to market.

Keywords: Pharmaceutical Pricing, Drug Rebates, Dynamic Pricing, Product Entry

JEL Codes: I18, I30, L10, L50, C41, C57

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1 Introduction

Pharmaceutical companies have long been scrutinized for their high drug prices and the strategies they use to preserve these prices. One such tactic is the development of line extensions (LE), which are reformulated versions of a drug's original formulation (OF). Between 2011 and 2021, 64% of drug applications submitted to the FDA were for products that were simply new formulations of existing drugs, suggesting that line extensions are a major focus for drug manufacturers (Hannick, 2022).[1] In addition, major drug manufacturers have indicated that line extensions have become a key aspect of their innovation strategies, with larger portions of their R&D budgets being dedicated to developing these extensions(Senate Finance Committee, 2022).

The current policy awards branded pharmaceutical companies a three-year market exclusivity period protecting them from competition, beginning upon the line extension's approval and launch. When planning when to launch, manufacturers face a trade-off between the risk of cannibalizing sales of their original formulation and the potential duration of the "additional exclusivity" period. The additional exclusivity period is the period between the original formulation's patent expiry and the end of the line extension's exclusivity period. Since the three-year exclusivity begins upon launch, if the manufacturer launches the line extension within the final three years of the original formulation's patent expiry, they will earn an additional exclusivity period, as the line extension's exclusivity ends after the original formulation's patent expires.[2,3] Launching earlier gives manufacturers more time to transition patients from the original formulation to the line extension and possibly expand the market. However, an earlier launch also creates a larger overlap between the OF and LE, increasing sales cannibalization and shortening the additional exclusivity period, during which manufacturers would continue to earn profits from the line extension. Manufacturers make their launch decisions on their expectations of whether the LE will primarily expand

[1] Litigation outcomes over the past decade have restricted manufacturers' ability to use alternative strategies for extending product lines, contributing to their increased reliance on line extensions.

[2] The length of the additional exclusivity period is determined once the line extension is launched. This period can effectively be thought as additional periods of patent protection across a product line (OF and LE), where the manufacturer can profit from a protected branded drug.

[3] If the three-year exclusivity ends before the original formulation's patent expiration, there is no additional exclusivity period.

the market or cannibalize sales of the original formulation.

Concerns exist that the current exclusivity policy may incentivize manufacturers to delay introducing line extensions closer to the original formulation's patent expiry date.[4] This is particularly true for manufacturers focused on minimizing sales cannibalization, as they may delay LE launches to maximize profits. Drug manufacturers argue these reformulated drugs benefit consumers and that the awarded exclusivity allows them to recoup development costs. However, manufacturers have also been criticized for the limited improvements these line extensions offer, as they are typically incremental levels of innovation, which may be more likely to cannibalize sales and be delayed. By delaying launches, manufacturers increase profits, while consumers face delayed access to improved products and insurers incur higher branded drug expenditures due to the delayed uptake of the generic version of the original formulation. These outcomes stem from the delay incentive the current policy provides. To address this, I examine alternative policies that modify or remove the exclusivity period, separating exclusivity from launch timing. Under an alternative policy, however, manufacturers' strategic decisions on timing and pricing would also change, making it essential to model these incentives accurately to evaluate welfare.

To address these issues, I develop and estimate a dynamic model of manufacturer pricing and launch timing decisions. This model captures the role of insurers by demonstrating how the manufacturer's pricing decisions influence insurers, who then determine the co-pays patients face. Each period, manufacturers decide whether to launch the line extension and set product prices. These prices then influence how insurers set co-pays using an objective function approach. Patients make their drug choices based on the co-pays they face, and this process repeats each period until none of the manufacturer's products remain protected. I apply the model to the dementia drug market, where the original formulation, Namenda, had a line extension, Namenda XR, which was introduced about two years before Namenda's patents were set to expire.

I estimate demand in a first stage, accounting for history dependence, as patients often make repeated choices. Using these demand parameters, I then solve the dynamic model to obtain the manufacturer's strategic decisions on launch timing and pricing. The man-

[4]https://www.crfb.org/papers/limiting-evergreening-name-brand-prescription-drugs

ufacturer seeks to maximize the sum of future discounted profits, considering how history dependence influences patient choices each period, how pricing affects the co-pays patients face, and how launch timing affects their profit window. The manufacturer's pricing decisions also influence the insurer's formulary arrangement, which maps products to specific co-pays. I estimate how an insurer weighs consumer surplus and drug expenditures in selecting a formulary arrangement, using an objective function to capture the insurer's value of each arrangement. Under this approach, formulary arrangements that offer greater value to insurers occur more frequently, and manufacturers anticipate these insurer decisions when setting their drug prices. Additionally, I estimate the development cost of launching the line extension to evaluate its profitability under alternative policies.

I evaluate the welfare implications of two alternative policies: granting exclusivity for three years after the original formulation's patent expires (referred to as "full exclusivity") and offering no exclusivity for the LE after the original formulation's patent expires (termed "no exclusivity"). In the case of Namenda, I find that full exclusivity increases manufacturer profits by 3% and drug expenditures by 5%, while reducing consumer welfare by 1% over a period of eight years. Although this policy provides earlier access to LEs, the responses from manufacturers and insurers lead to higher patient co-pays, which limits welfare gains from increased access. Furthermore, under the full exclusivity policy, the generic version of the LE (generic LE) cannot enter the market until the entire exclusivity period has ended. This policy delays the introduction of the generic LE, contributing to overall consumer welfare loss. In contrast, under the no exclusivity scenario, the LE is launched earlier, which is again associated with higher co-pays for patients, but there is a risk that the LE may no longer be profitable and thus might not be launched at all. However, if the LE did still launch, the generic LE would enter the market earlier, as soon as the original formulation's patents expire. Despite the potential welfare loss from consumers not receiving the LE and the generic LE, or facing higher cost-sharing due to earlier launches, the potential benefits of an earlier generic LE dominate, resulting in a 0.5% increase in consumer welfare from the no exclusivity policy. Additionally, under this policy, manufacturer profits would decrease by 1% due to the increased likelihood of the LE not being launched and the shorter horizon for earning profits, while insurer drug expenditures remain effectively unchanged.

To broaden the analysis beyond the dementia market, I use simulations to identify which types of line extensions are more likely to delay their launch within the final three years of the original formulation's patent protection. The line extensions that are currently being strategically delayed would be affected by alternative policies, as the incentive for strategic delays would be eliminated. I vary key demand parameters in the simulations and find that line extensions are most likely to be delayed when they are highly substitutable with the original formulation or have very similar quality.[5] These line extensions are more likely to cannibalize sales from the original formulation rather than expand the market; hence, manufacturers have a limited incentive to launch them early. The no exclusivity policy has the potential to increase consumer welfare the most, but this ultimately depends on the welfare losses associated with line extensions not being developed if they are no longer profitable under that policy. I find that line extensions most likely to be not developed are those with minimal quality improvements or those that are extremely similar to the original formulation. This suggests that the potential loss to consumer welfare from reduced product variety due to the no exclusivity policy, resulting from line extensions that are no longer developed, would be minimal.

1.1 Related Literature

Many firms may develop improvements to their product lines and must carefully evaluate when to introduce them and how to price them, given the market environment where they not only face competition from other firms, but also need to account for their existing product lines. My paper primarily relates to the strategies of drug manufacturers, whose products have finite periods of protection, and they develop new products to take their place. My work also aims to extend the broader literature on the economic consequences of strategies around product introduction that firms engage in, as it is important to assess their welfare impacts.

Previous work on quantifying welfare effects in this literature focuses on the effects of delaying products through drug settlements and "pay for delay" agreements, concluding

[5]For example, I vary a product dummy multiplier for the line extension, to capture it's quality or vary the nesting parameter.

that while settlements are not welfare improving, they could be offset by innovation from future drugs (Helland and Seabury, 2016; Branstetter, Chatterjee, and Higgins, 2016). As court cases have limited some other strategies manufacturers previously engaged in to delay products, line extensions remain a viable option that could lead to drug delays. My paper further explores how firms use delay tactics, assessing their welfare implications and consequences for innovation. Additionally, G. Ellison and S. F. Ellison (2011) and Bokhari and Yan (2020), have suggested that line extensions or product proliferation may be strategies that firms may try to employ to deter entry or uptake of generics. My work considers the welfare implications of how alternate policies around line extensions can deter generic uptake.

This work contributes closely to the literature on welfare implications of line extensions. Shapiro (2016) examines how earlier market entry of line extensions would affect consumer welfare. There is also a recent literature on timing incentives that the current policy has on firms. Fowler (2019) finds that firms may have an incentive to delay the launch of their line extension, depriving consumers of an improved drug sooner. Yin (2023) shows how current line extension exclusivity may not be welfare improving while considering strategic manufacturer pricing decisions. My work closely aligns to the analysis of these papers, but extends the analysis of the current literature by additionally considering the manufacturers strategic launch decision and how it interacts with their pricing decisions. This allows my work to better assess welfare implications by discussing the likelihood of line extensions being lost under counterfactual policies.

Additionally, this work builds on the literature that models the influence insurers have on the prices set by drug manufacturers. Incorporating the insurer is typically a complex process, but recent work (Feng and Maini, 2021) provides a simpler, tractable solution to address the impact of insurers on drug pricing. My work follows a similar approach and builds upon theirs by accounting for how the insurer influences pricing, which impacts other decisions the manufacturer makes. This work examines the complex interactions among various actors in the pharmaceutical supply chain, providing a more comprehensive welfare evaluation of policy.

History dependence is a known phenomenon in the pharmaceutical setting, as patients

repeatedly make the same drug choices. As a result, the demand system I use is closely related to previous work on demand systems with switching costs. Feng (2022) and Dubé, Hitsch, and Rossi (2009), both show the importance of history dependence when studying prices in a dynamic setting. My work incorporates this phenomenon and further contributes to the literature by providing more evidence of its importance in pharmaceuticals, as manufacturers need to consider how history dependence impacts the uptake of line extensions, to maximize profits in a finite horizon.

2 Institutional Details

The success of the generic drug market in the United States was bolstered by the passing of the Hatch-Waxman Act, which helped put pressure on branded manufacturers through competition from generic manufacturers. The intention behind this act was to incentivize generic entrants to challenge patents, which potentially could lead to generic entry at an earlier date, limiting the branded manufacturer's market power and leading to welfare improvements through earlier, lower prices for consumers. Overall the act has been successful in generic entry over the past few decades (Hemphill and Sampat, 2012), as the number of generics available has drastically increased during that timeframe. However, the structure of the Hatch-Waxman Act has led to certain practices by branded manufacturers to preserve their patent life and the concern around these practices has been increasing the last two decades (Frondorf and Feldman, 2016).

Pay for delay was a common strategy that manufacturers engaged in and Jacobo-Rubio, Turner, and Williams (2020) show the value of the stakes of litigation around pay for delay, for the branded and generic firms, and show why a settlement is worthwhile for both parties. The sheer number of settlements related to pay for delay led to increased scrutiny which was hallmarked by the Actavis Supreme Court Case in 2013. The landmark case resulted in a verdict that settlements in which cash payments were exchanged could be subject to additional anti-trust scrutiny. The FTC has found that the number of cash-based settlements seemed to dwindle after the case, suggesting firms may not find the practice as enticing (FTC, 2017), and pay for delay is no longer a viable option for manufacturers. As a result,

manufacturers have shifted to other strategies that can help them maximize the total profits they can get from a product line.

Line extensions have become an increasingly common option manufacturers are taking to extend their product lines (Hannick, 2022). When considering a line extension, the branded manufacturer seeks to marginally improve their drug over their original product, which grants them up to 3 extra years of exclusivity. When these line extensions are developed and the originator drug loses its exclusivity, they are protected from the pharmacy substitution that occurs between branded and equivalent generics. Substitution laws allow branded drugs to be replaced with equivalent generics at pharmacies. This means patients with prescriptions for branded drugs that have an equivalent generic available, will be given the generic version instead.[6] However, as the line extension is a reformulation of the original branded drug, the generic for the original drug is not considered an equivalent alternative to the line extension. Hence, prescriptions for line extensions will not be replaced with the generic version of the original drug.

The process of launching a line extension is typically a shorter process relative to the process of getting approved for the original formulation. Firms have a good understanding of the length of the approval process needed and have more control over the timing of launching a line extension to market (Fowler, 2019). Line extensions affect insurers as the generic substitution clause typically leads to a reduction in drug expenditures, but as line extensions limit the substitution, insurers may be responsible for increased drug costs, when line extensions are present. Generic makers are ultimately able to make a generic of the line-extended version, but only after this additional exclusivity period is over. The additional exclusivity period is meant to provide a reward to branded drug makers for improving their original drug; however, there has been some debate as to whether they may be abusing it. For example, a case where branded manufacturers may be viewed as abusing the level of marginal improvement in a line extension is seen with Aricept.[7] It should be stated that not all manufacturers are doing this as some have rather large improvements such as changing

[6]Note, it is possible for the patient to still get the branded drug if the prescription is "Dispense as Written", but this is not common.

[7]Aricept's dosage was changed from 20 to 23mg, but the branded manufacturer was able to successfully argue this improvement and was essentially guaranteed 3 more years of branded sales prior to their original 20mg pill facing competition by generics.

the route of administration of a product. Abuse of the marginal improvement along with the notion of delaying line extensions, has led to scrutiny over both the necessity and the control of this exclusivity period granted to manufacturers.

The timing details of exclusivity from the current policy have some nuances, which lead to potential incentives to delay for drug manufacturers. When the manufacturer launches their original formulation, they have a patent for a finite period of exclusivity remaining on it before it faces generic entry. Upon the launch of the line extension, the firm gets an exclusivity period of 12 quarters on their LE. If this exclusivity period for the LE ends after the original formulation's protections end, the periods in between the OF expiring and the LE exclusivity ending will be the additional exclusivity period the firm has on their LE. During this period, generics are available for the OF, but substitution laws will not allow prescriptions for the LE to be swapped for the generic, only those for the OF will be swapped. Therefore, the firm with a LE with additional exclusivity will continue to earn revenues in that period, for patients who are taking the LE, even as they primarily lose the other patients on the OF to the generic. In the case where the exclusivity period ends before the OF protections expire, the LE will still be protected by the exclusivity awarded to the OF, until the OF expires. However, once the OF expires, the LE's exclusivity will expire too and both products will face generic entry.[8] The additional exclusivity period of the new product provides the additional exclusivity only when the firm launches the product within the last 3 years of the original product's life-cycle.

The ability to extend the total amount of years a product line gets is attractive to the manufacturer. As a result, manufacturers may deliberately time their release close to the end of the originator's life cycle, which is the concern stemming from the current policy. Policies that decouple the exclusivity period from line extension approval, such as removing the exclusivity period, or fixing it at a set period after the originator loses exclusivity can mitigate the delay incentive firms have when timing their line extension launch. Whether these alternate policies improve welfare or not, after considering manufacturer responses to alternate policies, will be the question this paper aims to address.

[8]See appendix for a diagrammatic description of this timeline

3 Data Overview

I utilize three main sets of data. I summarize each dataset respectively at a high level and how each will used in the empirical strategy for both the demand and supply side.[9] I then describe the main drug market I focus on in this analysis, along with specific descriptives in that market.

3.1 SSR Health

SSR Health has quarterly revenue data, after 2007, for the majority of major pharmaceutical products and using the list of line extensions can identify which ones have revenue for the distinct products. This data has information on how revenues evolved and can provide the average price manufacturers received, as revenue and quantities are provided per period, primarily at the molecule level, for for certain products at the product level. I find line extension and original product pairs which have product level net price data in SSR Health and I treat those prices as prices after rebates. These prices are close approximations of what the manufacturer offered the insurer for formulary placement and what the manufacturer earns for selling it's products. They are also the prices used to estimate the supply-side side of the model.

3.2 FDA Orange Book and Line Extension Data

I construct a dataset of the approved line extensions from 1985-2016, following the steps from (**Fowler 2019**).[10] This dataset has information on original formulation and line extension pairs, when each product in the pair was brought to market, relevant patent information/extensions for the original product, as well as information on the parent companies. To be considered a line extension, the product must share an active ingredient with an original product, belong to the same parent company as the original product, and have one of the appropriate line extension types, in the FDA documentation. The most important details is

[9] I leave detailed information about the data and data construction to the appendix.

[10] I thank Dr. Annabelle Fowler for her help with providing clarifying details for this data construction process. My ending dataset is extremely similar to hers although there are slight differences. This could be due to the FDA updating the data between our respective data downloads.

when a firm brought the line extension to market, relative to their original product facing expiry. As manufacturers may have additional or secondary patents, the patent information provides some additional detail on when the manufacturer anticipates generic entry for their original product. I treat the launch time observed in the data as their optimal launch time for the line extension, as manufacturers are profit maximizers.

Trends in Drug Development

Line extensions serve as a patent-extension strategy and have made recent headlines about delaying new medications to consumers (Robbins and Stolberg, 2023). Since 1985, there has been a decline in original formulations (OF) that were approved by the FDA each year. Looking at the average trend, the FDA approved only about 20 original formulations in the 2010s compared to roughly 30 in the 1980s.

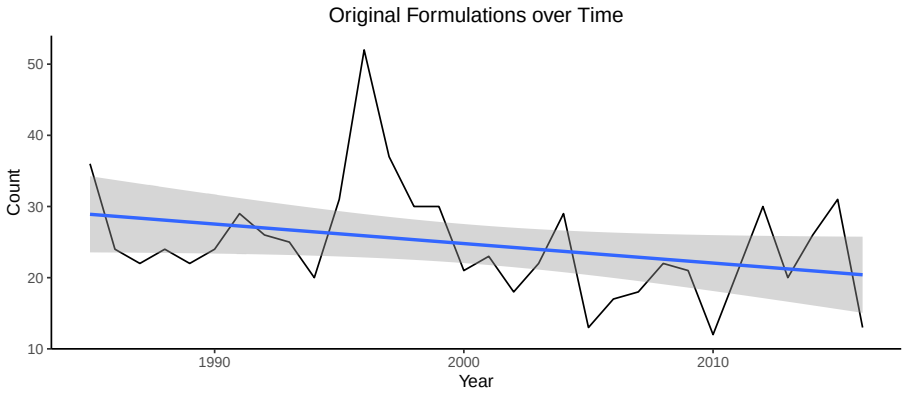


Figure 1

While it may be the case that new drug discovery has been more difficult, it is important to keep note of this downwards trend. The trend in line extensions approved each year tells a different story.

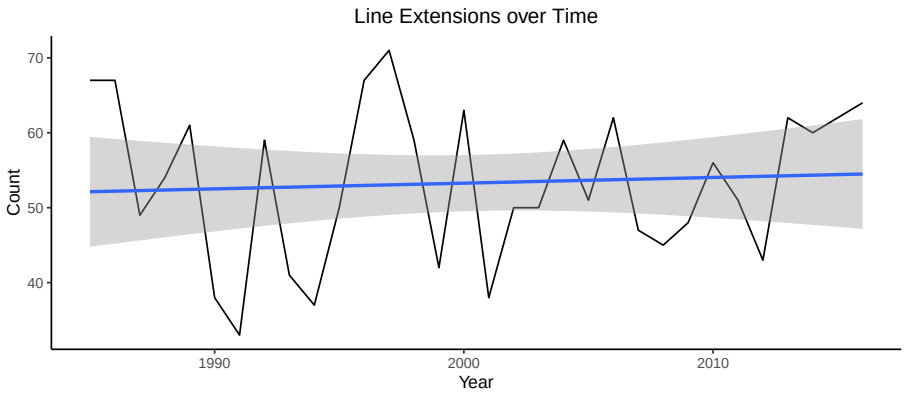


Figure 2

The average trend in line extensions has been steady, although slightly increasing over time. Line extensions have relatively become a larger presence in the pharmaceutical market, especially in recent years. When considering the massive R&D pharmaceutical manufacturers conduct, these trends suggest additional reasons to focus on line extensions in future research, as it is an increasingly common strategy manufacturers are doing. In summary, developing a better understanding of the welfare implications around line extensions and their policies is critical.

Line Extension Launch Timing

Manufacturers know that their line extension exclusivity begins when they choose to launch the line extension. Using the FDA dataset, I compare how early line extensions launch relative to the original product expiring.[11] It is the line extensions that launch within the final 3 years an OF is protected that are the line extensions that will be most impacted by policy changes around exclusivity. It is important to note that not all line extensions launch within this period, but a substantial portion ($\approx 35\%$) do, suggesting that a delay strategy may be a common taken by manufacturers.[12] There are also some cases where LE launch occurs after OF expiry. While those launches are possible, it would be difficult for

[11] Figure in Appendix

[12] Due to data limitations, this is an approximation, but likely under-counting the proportion of LEs that delay. This is primarily due to a conservative approximation of the total protective period for the original product from the data construction, given the data. See appendix for details.

the manufacturer to successfully gain market shares with strong generic competition.[13]

In addition, line extensions may be eligible for a drug substance patent. That patent begins once filed. As a result, those line extensions would not have the same delay incentives, as that patent protection dominates the exclusivity awarded to the line extension. I compare line extensions with and without those patents and find that those without the drug substance patents are launched on average 1.25 years closer to the original product's protection expiring.[14] This makes sense, as without the patent, the manufacturer only gets the 3 years of exclusivity, which begins upon launch. As a result, manufacturers aim to make the most out of their exclusivity, by considering how cannibalizing or market expanding their product may be, when making their launch decision. Line extensions without drug substance patents would be impacted by policy changes around the exclusivity period, which is why they are the line extensions this paper focuses on.

3.3 MarketScan - Private Insurer Claims

On the demand side, the primary data source will be MarketScan, which covers private health insurance claims for 250 large employers across the United States. The data covers the years of 2000-2022 and has all claims with individual level identifiers, so individuals can be tracked across years. I primarily use prescription drug claims, which have information on date of service, the product chosen, days supplied, strength, and the payment breakdown of patients (Deductible, copay, coins, etc). For each patient, I can see their history of drug choices for the market of interest. I primarily focus on the dementia market and look at the years between 2012 and 2017. In the dementia market, individuals choose between Namenda, Namenda XR, "Other Dementia" (generics with other active ingredients) or the generic for Namenda (Memantine), but the specific choice set varies over time, as there is both product entry and exit. I construct a data panel of yearly choices for patients using data from Marketscan. I consider the product with the most days supplied in a year to be the patient's choice.[15] From the 1% sample of claims, there are roughly 20,000 choice events. I consider

[13]This results from the conservative date of OF expiry from the data, which leads to over-counting launches after OF expiry, so I will rule those cases out in the model.

[14]See appendix for figure, and once again the same caveat of noisy dates for OF expiry remains.

[15]Additional details about constructing choices and yearly co-pays are available in A4 in the appendix

any individual that has a claim for a moderate to severe dosing of a prescription dementia drug in the market.[16] The patients in my data are all from plans tied to employment, so the composition of patients may not be nationally representative. [17]

The co-pays from the claims data are plan specific. In order to create a menu of co-pays patients face, I assume all patients face a representative insurer. I find the normalized 30 days supplied co-pay value per year for each product as the amount patients pay. I then take the median value of the normalized co-pays across all patients in a year and consider this to be the yearly co-pay for that product. As co-pays are plan specific, taking the median across all plans in a year will add some error on the prices.[18,19] Additional details on pricing and choice decisions are discussed in the appendix.

3.4 Descriptives - Namenda

Namenda is the main drug I focus on during the empirical model, which is a product in the dementia market. The key branded drugs in the market are Namenda and Namenda XR, which are both produced by Allergan. The other drugs are generic versions of former branded drugs with different ingredients, which include Donepezil, Galantamine and Rivastigmine, which I group together as Other Dementia.

How Namenda XR impacted the market

Namenda was the main branded product in the dementia market in the early 2010s and was set to expire and face generic competition near the end of 2015-Q2. Allergan introduces a line extension, Namenda XR, in 2013-Q2 about 2 years prior to Namenda facing generic entry. After generic Namenda enters, Allergan effectively would lose patients who were still

[16] If a patient no longer has any claims in a whole year for other prescription drugs, I remove them from the market.

[17] While I do focus on the dementia market, the patients are either dependents of individuals who are the plan sponsor or are employed individuals. Calibrating demand parameters to MEPS may allow estimates to be more nationally representative, but I leave this for forthcoming work.

[18] The normalized co-pays for each product within a year are fairly consistent, which suggests this error is mild.

[19] Alternatively one could impute missing co-pays for products that a patient did not choose. Both strategies require some level of imputed prices, so I opt for the simpler route to keep the model tractable.

taking Namenda to the generic.[20] However, patients who switched to Namenda XR would not be directly affected by generic substitution laws, which is why line extensions are attractive to the manufacturer as they can mitigate that market share loss. I plot market shares for the main drugs in the dementia market below.[21]

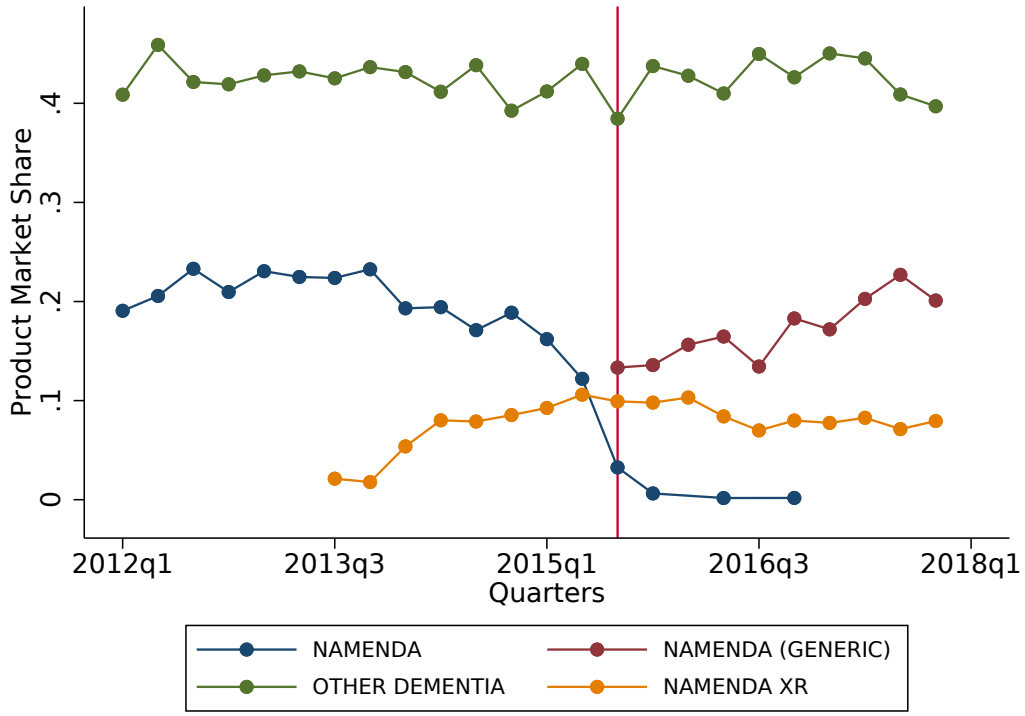


Figure 3: Market Shares of Dementia Market in 2012-2017

From the figure above, the shares of Namenda are constant around the low 20 percent mark until the introduction of Namenda XR. It is quite clear to see cannibalization occur amongst Allergan's products, as the shares of Namenda decline, while Namenda XR starts to gain in the market. It is noteworthy to also point out that the shares of the other dementia group are relatively unaffected by the introduction of Namenda XR. The outside option here is not choosing a prescription drug. The vertical red line marks the expiry of

[20]Manufacturers are aware that they lose large portions of their market shares H. Grabowski et al. (2021) when generic entry occurs.

[21]I plot quarterly market shares here, but focus on yearly market shares for the main analysis, as manufacturer pricing decisions occur at the yearly level. Choices are constructed in a similar manner, but just at the quarterly level. The figures are quite similar, but the quarterly figure is easier to interpret

the original product Namenda expiring and the generic for Namenda arriving in the market. The market shares for Namenda quickly drop to near zero after generic entry, as the generics gain shares. The market share for Namenda XR remains relatively constant around the 10% mark. This is an example of why firms find line extensions attractive, as the line extension effectively allowed Allergan to hold onto roughly 50% of their original share, well above what branded firms are usually able to hold onto (H. Grabowski et al., 2021). Additionally Allergan continued to hold that market share in the face of generic entry of Namenda over time, until the generics for Namenda XR were approved in the following year. In the figure above, the generic version of Namenda XR was approved in 2016, after the 3 year exclusivity period ran out, and a small dip can be seen at that point in the market shares for Namenda XR. However, in this case, the generic was delayed for 2 years, for external reasons, which is why there is only a small drop in the market share for Namenda XR around the end of 2016. Again the market shares for the Other Dementia product was relatively unaffected here as well. It is also seen that after the original expired and the generic for Namenda takes its place, the market share for the outside option decreases, as a larger share of patients are now choosing to take prescription drugs, as on average they are relatively cheaper after additional generics arrive.

An important thing to consider when discussing the value of a line extension, which manufacturers often argue for, is that it can also increase the manufacturer's total market share, by drawing from other products or the outside option, as the drug now offers an improved version. If the line extension is sufficiently innovative, or is able to reach a group of consumers that previously was not able to take the original drug, it is possible that the line extension can have an expanding effect for the firm's market share and their profits. Looking at the graph again, but this time combining the total market shares for Namenda and Namenda XR, the "expansion" effect of the line extension can be viewed, by summing Namenda and Namenda XR's shares.

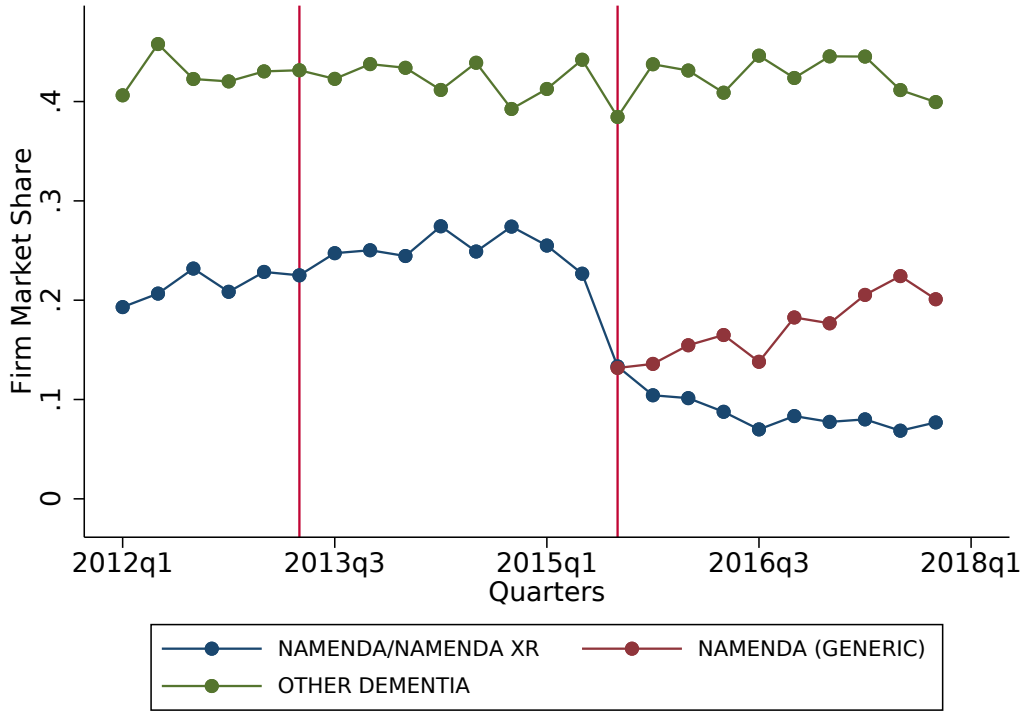


Figure 4: Manufacturer shares in Dementia Market in 2012-2017

The area between the two vertical red lines is when both products were in the market. There is a slight upwards trend during that period, but it is also important to note that there was a slight upwards trend in the pre-period as well. While the total market share has slightly increased in this period with the introduction of the line extension, the magnitude is quite small, so in this case it does not appear that Namenda XR was really market expanding. Additionally, there was little to no change to the market shares of the Other Dementia product in this period. From the figures, it appears that Namenda XR was relatively minor in it's market expansion and primarily cannibalized the sales of Namenda, suggesting that the incremental innovation of Namenda XR may not be considered very meaningful.

History Dependence - Patients make repeated choices

History dependence is a common phenomenon in pharmaceuticals Feng (2022) and I provide some evidence suggesting this may also be the case in prescription drug market for dementia. Looking at individuals who take a dementia product, before Namenda XR was

released, I construct choice transitions of individuals, based on their current drug choice, conditional on having chosen a drug in the last period.

		Next Chosen Drug	
		Namenda	Other
Previously Chosen Drug	Namenda	**0.747**	0.253
	Other	0.223	**0.777**

I again group multiple smaller dementia drugs (Donepezil, Rivistagmine, and Galantamine), which are all generics together in the "Other" category. Individuals have roughly a 75% chance to take the same drug the next time they make a drug choice as they currently chose. These probabilities are constructed simply from the observations in data and there may be a variety of factors like co-pays and advertising strategies changing, but the table simply shows the raw probabilities. I view this table as possible supporting evidence of the phenomenon of history dependence, where individuals are likely to repeat their drug choices, which is why I additionally model for it. It is clear that the previous choice may have a great impact on the next drug choice, especially paired with the fact that a market share for a product never exceeds 50% in this market.

4 Model

Under the current policy, the exclusivity period for line extensions begins at launch. Delaying the line extension limits sales cannibalization of the OF product and increases the additional exclusivity period, but gives the manufacturer less time to move patients to the line extension. Delays also affect consumer welfare and could impact insurer drug expenditures. I present a model that captures these trade-offs to provide a complete welfare evaluation of alternative policies.

The model captures the interactions among three agents. A monopolistic drug manufacturer, a representative insurer, and consumers.[22] My model follows Feng and Maini (2021),

[22]In this setting, the representative insurer is grouped with the PBM (Pharmacy Benefit Manger), for simplicity.

but I extend their approach by allowing for the manufacturer to additionally make a launch decision on when to introduce the line extension. The model is a discrete time, single agent finite horizon problem. The setting is finite horizon, where each period is t, as the drug manufacturer stops making decisions once its products run out of exclusivity. Each period the manufacturer makes pricing and launch decisions. To capture the interaction of the drug manufacturer and insurer, the manufacturer's price decision influences the formulary the insurer chooses, which determines the co-pays patients face. Co-pays are determined by the formulary arrangement, which consists of a small number of tiers with specific co-pays, that the insurer assigns. For each formulary arrangement f, there is a set of product co-pays that patients will face, denoted c^f_{jt}, for each product j in period t, which will affect drug choices. Patients make their drug choices based on the products available and their co-pays each period.

4.1 History dependent demand

I model the consumer's problem as a discrete demand system, where previous choices matter. Each period, a consumer makes a single drug choice from the choice set they face in that period or chooses the outside option (no drug). A consumer's utility is affected by their previous choice, denoted k, where $k \in 1, 2, ..., J_{t-1}$, where J_{t-1} is the number of products available in the previous period, $t-1$. $k = 0$ indicates that the consumer had previously chosen the outside option or makes a choice for the first time. Consumer i's utility, with previous choice k that picks product j, when facing formulary f, in period t is:

$$u_{ijt}(k; \eta^D, f) = \delta_j + \alpha c^f_{jt} + \gamma \mathbb{I}\{k = j \neq 0\} + \nu_{ig} + (1-\sigma)\varepsilon_{ijt} \tag{1}$$

δ_j are product dummies and c^f_{jt} is the co-pay for product j in period t, based on the formulary arrangement f. The co-pay is the amount the patient pays for the drug.[23] The γ is a coefficient to capture the history dependence from the previous drug choice by consumer i.[24]

[23] I assume consumers are not forward looking in this model and the only "dynamic" component of the demand system is the impact of the previous choice. It is an empirical challenge to include forward looking behavior for consumers and on the supply side, so I assume myopic consumers.

[24] I assume that history dependence is not drug-pair specific and that all drugs have the same level of history dependence. I plan to explore other pair-wise variations in the appendix.

To allow for more flexible substitution patterns, I also incorporate a nesting structure, where g denotes the nests, to allow for more flexible substitution patterns. I consider different sets of nests at the main ingredient level, branded vs non-branded, and inside vs outside. For notational convenience, let $\eta^D = \{\delta, \alpha, \gamma, \sigma\}$ be the vector of demand characteristics. The last two terms are a T1EV error component, which allows for logit choice probabilities.

Due to the error structure, consumer i's probability of choosing product j in period t, facing formulary arrangement f and their previous choice of k is given by:

$$\mathcal{P}^f_{ijt}(k;\eta^D) = \frac{\exp\left(\frac{\delta_{jt} + \alpha c^f_{jt} + \gamma \mathbb{I}\{k = j \neq 0\}}{1-\sigma_g}\right)}{\sum_j^g \exp\left(\frac{\delta_{jt} + \alpha c^f_{jt} + \gamma \mathbb{I}\{k = j \neq 0\}}{1-\sigma_g}\right)} \frac{\exp(D^f_g)}{\sum_g^G \exp(D^f_g)} \tag{2}$$

The coefficient σ captures the correlation in the error terms for products within a nest and can vary by nest. The first fraction is the probability of choosing product j, conditional on choosing the nest g that product j belongs to. The second fraction denotes the probability of choosing nest g, where D^f_g is the inclusive value that captures the value of choosing nest g, for a patient facing formulary arrangement f. D^f_g is given by:[25]

$$D^f_g = log\left[\sum_j^g \exp\left(\frac{\delta_{jt} + \alpha c^f_{jt} + \gamma \mathbb{I}\{k = j \neq 0\}}{1-\sigma}\right)\right] \tag{3}$$

It is helpful to define two terms here for clarity in the following sections: previous period market shares and an expression for consumer welfare. I denote $S_{k,t-1}$ to be the share of individuals who were taking product k, last period (t-1). $S_{k,t-1}$ makes up elements of the vector S_{t-1}, which captures the previous period's market shares. Given formulary arrangement f, the resulting market shares, from the consumer choice probabilities for each product j is:[26]

[25] If $\sigma = 0$, the demand system reduces to the standard logit, as ϵ_{ijt} is T1EV as well and the choice probabilities collapse to just the first term of equation 2, where all products are in one nest

[26] This equation only holds if there are no other individual specific components that affect choice probabilities, i.e. random coefficients, apart from previous choice.

$$S_{jt}^{f}(c_{jt}^{f}, S_{t-1}; \eta^{D}) = \sum_{k=0} S_{k,t-1} \mathcal{P}_{ijt}^{f}(k; \eta^{D}) \tag{4}$$

Given the structure of the demand system and the impact of previous choices on utility, if consumers face formulary arrangement f, this leads to the following expression for consumer surplus:

$$CS(c_{jt}^{f}, S_{t-1}; \eta^{D}) = \sum_{k} \sum_{g} S_{k,t-1} D_{g}^{f} \tag{5}$$

I do not model the intensive margin in the demand system to keep the model tractable on the supply side.[27] Lastly, I assume there is no unobserved heterogeneity for patients, as this would greatly enlarge the state space. This assumption could mean that manufacturers incorrectly assign some of choice persistence to history dependence.[28]

4.2 Insurer's Problem

I take a reduced form approach to determine the co-pays patients face to capture the influence of a representative insurer, by considering factors that insurers care about.[29] Pricing is a key tool the manufacturer can use to encourage patients to switch products, but insurers can impact the prices patients face as well. Insurers and drug manufacturers typically negotiate over formulary placement which impacts the co-pays patients face. While one could model this as a bargaining process, I follow Feng and Maini (2021), and model the price and formulary setting as a bid placed by the manufacturer. The bid is the price insurers would pay for the drug, which affects the probability of the formulary arrangement chosen by the

[27] It is true that patients can differ in the number of days supplied they get when filling a prescription. Different fills of days supplied can impact how often consumers visit the doctor to make choices. I do consider this a mild assumption, as the majority of patients typically do choose the same days supplied when filling a prescription.

[28] Following an argument from Pareschi and Lopez (2024), the model still approximates the dynamic implications in the market well, as manufacturers do offer lower prices for new products and increase them over time. This manufacturer response suggests that manufacturers do perceive some presence of "history-dependence".

[29] Data limitations are a primary reason for not further modeling the insurer. Additionally adding another level of strategic interaction is quite difficult and would make the model less tractable, so I consider it outside the scope of this paper and will be left to be considered in future work.

insurer. A formulary arrangement can be interpreted a mapping from products to co-pays.[30] The insurer gets a value, Γ_f, for each formulary arrangement f. The manufacturer submits a price bid P_{jt}, for each product it has on the market. In the context of line extensions, this can be a bid for just the OF, just the LE, or a vector of bids when the OF and LE are on the market together. Given the manufacturer's price bids, Γ_f is:

$$\Gamma_f(P_t, S_{t-1}; \phi) = CS(c^f_{jt}, S_{t-1}; \eta^D) - \phi_d \sum_j ((P_{jt} - c^f_{jt}) S^f_{jt}(c^f_{jt}, S_{t-1}; \eta^D)) \\ - \phi_e \sum_j (I_{c^f_{jt}=\infty}(S_{j,t-1})) + \epsilon_f \quad (6)$$

The first component captures the dollars of consumer surplus generated based on formulary choices and co-pays. The second component is the cost of remaining drug expenditures for the insurer. The third term is the share of consumers who were taking a drug that now find it excluded from the formulary and are now unable to purchase the drug. Essentially, this is an additional penalty the insurer faces for excluding certain drugs from the formulary, which scales by the share of consumers impacted. The ϵ_f is a formulary arrangement specific error term that is T1EV. Following the error structure, the probability a particular formulary $f \in \mathcal{F}$ is assigned is given by:

$$\Omega_f(P_t, S_{t-1}; \phi) = \frac{e^{\Gamma_f(P_t, S_{t-1}; \phi)}}{\sum_{f \in \mathcal{F}} e^{\Gamma_f((P_t, S_{t-1}; \phi)}} \quad (7)$$

$\mathcal{F}$ is the total number of formulary arrangements that are possible.[31] This probability distribution can be interpreted as the probability that consumers will face each formulary, where each occurs with some probability. Formularies that are more valuable to the insurer will occur more often.

I assume that the previous choice of consumer i has no effect on the likelihood that they face a particular formulary. This means consumers who chose different products last period will face the same probability distribution over formulary arrangements.[32] This is

[30] See appendix for, an example of different formulary arrangements

[31] The number of possible formulary arrangements depends on the number of products available in the market. As mentioned in the data section, each branded product can fall into three possible tiers. It increases when both OF and LE are on the market. For example, OF being in preferred tier and LE being non-preferred tier is different than OF being on non-preferred while LE is preferred.

[32] For clarity, if the probability of drug A falling in the preferred tier is 40%, both a consumer who

a consequence of having a representative insurer.[33] I do not model insurance choice for consumers, as that is outside the scope of this paper.

4.3 Manufacturer's problem

The drug manufacturer is a profit maximizer that starts with their original formulation on the market and knows that product is protected until period T. The manufacturer considers how to optimally price their products conditional on launching or not and then makes their launch decision accordingly. The manufacturer is the single active agent, as they take all competitors prices as given. While this is a simplification, I argue that in the prescription market I focus on, there is typically one dominant branded drug manufacturer player, where the competitors are primarily smaller generics of older existing products. These generic makers don't make pricing decisions with regards to formulary placement, as their drugs are placed on the generic tier, and can't use prices to change that placement. This simplification greatly reduces the computational burden and keeps the model tractable.[34]

State space & Transitions

The payoff relevant variables for the manufacturer are the previous period's market shares, the current period, and whether or not the line extension has been launched. Manufacturers are aware that consumer utility is affected by previous choices, so previous period's market shares impact their decisions. The current period is relevant to determine the manufacturer's terminal period. Line extensions are granted an exclusivity period of E periods upon launch.[35] If the line extension is launched in period t and $t+E > T$, the line extension's exclusivity runs past T and the manufacturer will now profit until $t+E$. If the line extension gets launched in period t, the updated terminal period, T^*, is defined as $T^* = max\{T, t+E\}$, as the launch only occurs once and is permanent. The final state variable is whether the line

previously chose drug A and a consumer who chose drug B would would face that formulary with drug A in the preferred tier with a 40% probability.

[33] In reality, different insurers offer different formularies and patients choose the plans with formularies they prefer based on their previous drug choices. Having a representative insurer shuts down that channel.

[34] The model can be extended to allow for competition between branded manufacturers, but I do not explore this in this paper.

[35] Under current policy this is 3 years of exclusivity

extension has launched. If the line extension has not launched ($L = 0$), the manufacturer still makes a launch decision at the start of the period, but once launched, the manufacturer only sets prices each period.

Manufacturer flow profits

Each period, the manufacturer gets flow profits, based on their product portfolio choices, prices and demand. The price the manufacturer sets is what they offer to the insurer, which can influence the co-pays patients face for products, subsequently affecting demand. The previous period's market shares, S_{t-1}, will impact how market shares evolve, as manufacturers are aware how previous choices affect a consumer's utility. As consumers face each formulary arrangement, f, with probability Ω_f, this leads to an expected share of each product j, accounting for all formulary arrangements, denoted by:

$$S_{jt}(P_{jt}, S_{t-1}) = \sum_{f}^{\mathcal{F}} S_{jt}^{f}(c_{jt}^{f}, S_{t-1}; \eta^{D})\Omega_f(P_{jt}, S_{t-1}) \tag{8}$$

This weighted sum across all previous product shares and formulary possibilities leads to an expected market share, given manufacturer product and pricing decisions. If the size of the market is denoted M, which is assumed to be fixed throughout time, then demand for product j in period t is:

$$D_{jt} = MS_{jt}(P_{jt}, S_{t-1}; \eta^{D}) \tag{9}$$

As a result, in each period, the manufacturer earns

$$\pi(P_t, S_{t-1}, L) = \sum_{j} P_{jt}D_{jt} \tag{10}$$

Recall that P_{jt} is either a singleton or a vector of prices for each product j the firm offers. I also assume there are no marginal costs the manufacturer faces.[36,37]

[36]Given the data constraints, it is difficult to separate rebate discounts and marginal costs from the net prices offered to insurers by manufacturers. This is a common assumption in the pharmaceutical literature

[37]Additionally Yin (2023) has shown that marginal costs for prescription drugs are very small compared to the prices charged, so I consider this a mild assumption.

Manufacturer Dynamics

At the start of the problem, when the manufacturer has not launched the line extension, their problem is characterized by the following equations:

$$V^*(S_{t-1}, t, L = 0) = \max_{P_t} \pi(P_t, S_{t-1}, L = 0) + \beta V(S_t, t + 1, L^*) \tag{11}$$

$$V^*(S_{t-1}, t, L = 1) = \max_{P_t} \pi(P_t, S_{t-1}, L = 1) + \beta V(S_t, t+1, L = 1) - R + (\epsilon_{t,L=1} - \epsilon_{t,L=0}) \tag{12}$$

Equations 11 and 12 characterize the value the manufacturer gets from launching (L=1) or not launching (L=0) in the current period. Conditional on launching or not, the manufacturer sets prices optimally to maximize flow profits and their discounted future values. The manufacturer incurs a fixed, one time launch cost of R, during the period of launch. The manufacturer also receives T1EV shocks, specific to their periodic launch decision ($\epsilon_{t,L\in\{0,1\}}$), and the difference between the shocks can be interpreted as a stochastic shock on the launch cost.

After considering how to optimally price their products and realizing the launch shocks, the manufacturer makes their launch decision based on the following equations:

$$V(S_t, t + 1, L^*) = log(e^{V^*(S_t, t+1, L=0)} + e^{V^*(S_t, t+1, L=1)}) \tag{13}$$

$$V(S_{t-1}, t) = \max_{L\in 0,1} \{V^*(S_{t-1}, t, L = 0), V^*(S_{t-1}, t, L = 1)\} \tag{14}$$

If the manufacturer does not launch, they retain the option to make a launch decision again in the following period. Equation 13 denotes their continuation value from not launching, due to the structure of the launch decision errors. Only manufacturers who have not launched have the option to launch next period, while manufacturers who have launched do not, which leads to different expressions for continuation values in equations 11 and 12. Finally, equation 14 captures the manufacturer's launch decision, after all shocks have been realized.

The errors from the launch shocks leads to a probability of launch per period for the manufacturer, as long as they have not launched. This probability is given by:

$$\mathcal{P}_L(S_{t-1}, t) = \frac{e^{V^*(S_{t-1},t,L=1)}}{e^{V^*(S_{t-1},t,L=0)} + e^{V^*(S_{t-1},t,L=1)}} \tag{15}$$

If the manufacturer does launch the line extension, they only make pricing decisions to maximize their sum of periodic discounted profits, for the rest of their problem. Hence, the continuation value after launching, in equation 12, is defined by the following expression:

$$V(S_{t-1}, t, L = 1) = \max_{P_t} \sum_{t}^{T^*} \beta^{t-1} \pi(P_t, S_{t-1}, L = 1) \tag{16}$$

5 Empirical Model

I estimate demand in a first stage and then using the demand estimates, I solve and estimate the "supply side" model, to recover parameters from the insurer's problem and a fixed development cost for manufacturers. I discuss the process and identification details of each stage of the estimation process below.

5.1 Demand Estimation

Using patient choices and the constructed logit choice probabilities, the demand parameters are estimated by maximizing the likelihood that patients chose their observed choices. This is equivalent to maximizing:

$$\Delta = \max_{\eta^D} \sum_{t} \sum_{i} \sum_{j} log(\mathcal{P}^f_{ijt}(k; \eta^D)) I(y_{it} = j) \tag{17}$$

Here $I(y_{it} = j)$, is an indicator function, where y_{it} is consumer i's choice in period t and is equal to 1 if they chose product j. Standard errors are calculated using the observed information matrix from the likelihood routine.

5.2 Identification - Demand

Identification for the price coefficient comes from variation in product co-pays across yearly markets. Differences in the products that makeup each nest, as products enter and

exit the market, allows for identification of nesting parameter, when a nesting structure is utilized. To identify the history dependence term, I leverage differences in choice probabilities of individuals who previously did and did not take a repeated drug choice, to estimate the additional value of a repeat choice. Finally, product dummies can then be identified from differences in the choice probabilities relative to the outside option in each market.

I do not instrument for the co-pays patients face. There are two directions of bias that may influence co-pays. Patients may have selected into plans with lower co-pays for the drugs they prefer. Alternatively, there could be a link between higher quality products and co-pays, which would suggest higher co-pays for those products. Which direction is stronger is unclear, so the direction of this bias is ambiguous.[38] However, in the estimation I show that I still find elasticities in a similar range to the literature, where demand is estimated with co-pays. I don't distinguish unobserved heterogeneity from history dependence. If unobserved heterogeneity fully accounted for patient behavior, this would eliminate dynamic incentives for firms (i.e investing and harvesting their consumer base). In the pricing data, manufacturers do offer lower prices initially for the line extension, suggesting that they are pricing dynamically to encourage adoption.[39] This suggests that manufacturers do think history dependence plays a role when patients make their decisions.[40]

5.3 Supply Side - Estimation

I solve the dynamic problem for the manufacturer by recovering their value function from launching or not launching at each possible state in the problem. Using the initial market share as the initial shares for an initial state, I solve for the optimal prices, conditional on launch decisions and the parameters of the supply side, for all states of the game. I set the discount rate to be .88, following the work done by (DiMasi, H. G. Grabowski, and R. W. Hansen, 2016). The supply side parameters I estimate are parameters for the

[38] I could use variation in the number of generic manufacturers, which impacts the copay value for the generic tier. This could help correct for bias from higher quality drugs and higher co-pays. However, as I don't have a strategy to account for the plan selection bias towards co-pays, I don't utilize it.

[39] A similar argument is made in Pareschi and Lopez (2024)

[40] In forthcoming versions, for robustness I will instrument for previous choices, as my strategy may incorrectly attribute unobserved heterogeneity to history dependence. Details on this strategy are included in the appendix.

insurer process and the manufacturer's fixed costs using the generalized method of moments approach (GMM) from (L. P. Hansen, 1982). For prices, I estimate 4 moments: the mean of the OF's price when just the OF is on the market, the respective means of the OF and LE when both on the market, and the mean of the LE's price when it is just the LE on the market. For each of the pricing moments, the moment is the difference of means of the observed prices in the data and the model predicted prices. For launch timing, I additionally estimate two moments. The first is the difference of the model predicted probability of launch in each period (Equation 14) and the observed launch probability.[41] For the second launch moment, I calculate the difference between hazard functions, using model predicted and observed launch probabilities, which details the cumulative probability that the line extension has launched by a certain period.[42] In total, I have 6 moments to estimate 2 parameters from the insurer's problem and a parameter for the manufacturer's fixed cost.

Let $g_P(\phi)$ be the pricing moments and let $g_L(\phi)$ be the launch timing moments, then the stack of moments becomes:

$$g(\phi) = \begin{bmatrix} g_P(\phi) \\ g_L(\phi) \end{bmatrix} \tag{18}$$

I estimate the parameters using a 2-step GMM procedure to minimize the expression:

$$\min_{\phi} q(\phi) \equiv g(\phi)' W g(\phi) \tag{19}$$

Here $W = I$ in the first step and then I calculate the variance covariance matrix of moment errors, denoted Λ. I then run the optimization routine again in a second step, with the $W = \Lambda^{-1}$, as the optimal weighting matrix to estimate ϕ. I calculate standard errors by constructing the standard asymptotic variance of the parameter estimates after the second step in the GMM procedure.

[41] I assume the probability of launch is 1 in the period I observe the launch and 0 in periods prior.

[42] For the hazard function, I assume the probability of launching in periods after an observed launch is 1. This assumes that the manufacturer would still be able to cover their costs of launching at a later period, through the additional exclusivity period they get. This is a milder assumption for launches that happen near OF expiry, as it does in the case of Namenda.

5.4 Identification - Supply

The ϕ parameters, belonging to the insurer process are identified using variation in the components (i.e. consumer welfare, drug expenditure) of their control function (Γ) at different states in the problem. The insurer parameters can be interpreted as weights on the relative components that provide value to each formulary arrangement. Variation in the manufacturer's observed prices, as the state variables change, helps recover the insurer process parameters, which approximately captures the outcome of the bargaining process. The fixed cost of line extension development is recovered given the differences in manufacturer revenues, for different launch times. The weights the insurer places on drug expenditures also aids in the identification of the fixed cost, as it impacts how profitable launches would be at different points in time. Effectively the fixed cost is high enough to discourage certain launch times, but not high enough to prohibit a launch.[43,44]

6 Estimation

6.1 Demand Estimates

Demand estimates for the products in the dementia market are shown below. The different model specifications vary by inclusion of history dependent terms and nesting structures.

[43] In forthcoming versions, this analysis will be done for additional drugs, so I can recover a set of bounds for the fixed cost, allowing me to approximate a distribution for the development cost.

[44] Additionally, the fixed cost will be revisited if a forthcoming counterfactual simulations, where I extend the analysis to simulate launch decisions of multiple firms and aim to match the likelihood that line extensions are not launched, based on the data of the universe of line extension launches.

	(1)	(2)	(3)	(4)	(5)	(6)
Model Spec.	No Hist	Hist Dep 1	Hist Dep 2	Inside Nest	Ing Nest	Brand Nest
Memantine	0.324**	0.415***	0.405**	0.619***	0.335**	0.106
	(0.116)	(0.124)	(0.123)	(0.136)	(0.105)	(0.104)
Namenda	2.005***	1.711***	1.690***	1.498***	1.247***	1.184***
	(0.287)	(0.321)	(0.317)	(0.243)	(0.270)	(0.255)
Namenda XR	1.287***	1.269**	1.189**	1.232***	1.012**	0.914**
	(0.388)	(0.438)	(0.435)	(0.345)	(0.370)	(0.343)
Other	1.155***	0.946***	0.939***	0.926***	0.675***	0.652***
	(0.0777)	(0.0812)	(0.0805)	(0.0836)	(0.0717)	(0.0690)
Co-pay	-0.005***	-0.0046***	-0.0045***	-0.0033***	-0.0036***	-0.0035***
	(0.0008)	(0.001)	(0.001)	(0.0007)	(0.0008)	(0.0008)
Hist Dep.		1.379***	1.387***	1.102***	1.451***	1.532***
		(0.0461)	(0.0470)	(0.110)	(0.0523)	(0.0487)
OF to LE			0.318*	0.342**	0.674***	1.082***
			(0.160)	(0.115)	(0.116)	(0.121)
Nest Similarity				0.649***	0.630***	0.515***
				(0.0684)	(0.0440)	(0.0589)
N	20442	20442	20442	20442	20442	20442

Standard errors in parentheses

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

Table 1: Demand estimates across various model specifications varying by nesting structure and different levels of history dependence.

Specification 1 does not include any nests or history dependence. The first 4 coefficients are product dummies, where Namenda is the OF product, Namenda XR is the LE, Memantine is the generic version of Namenda, and Other refers to the Other Dementia group. All products belong to their own nest and previous choices have no effect on utility. Specifications 2 and 3 add history dependence to the model, by including the previous choice

and both the previous choice and a different source of history dependence, for individuals who previously took the original product that now take the line extension. Both of these coefficients are positive, highlighting how patients typically repeat their drug choices and that individuals who were on the original product, are also likely to take the line extension. This original to line extension boost could be interpreted as an additional boost to utility from upgrading to the newer version. The last 3 specifications include both history dependence terms and also incorporate a nesting structure. Specification 4 includes a nest for all products (inside option) and a degenerate nest for the outside option. Specification 5 includes a nest for all memantine products, which is the primary ingredient of Namenda, Namenda XR and the generic for Namenda. Specification 6 includes a nest for branded products (OF and LE) and degenerate nests for everything else. In the nested specifications, there is significant correlation within the products of each of the nests, especially the inside and ingredient nests, indicating that products in the dementia market and ones that share the same ingredient are quite substitutable. Both of the history dependence terms remain positive and relevant, suggesting that history dependence still plays a significant role in patient choices, in addition to the nesting structure. The history dependence term consistently is larger than the OF to LE term, when both are included. This suggests that there is still a substantial hurdle for the manufacturer to overcome to encourage patients on the OF to switch to the LE. Finally, across all specifications, the line extension and original product's coefficients are quite similar, which may suggest that this line extension is not viewed to be a substantially different product, in terms of value. Moving forward, I use model specification 5, as the demand parameters when I estimate the supply side of the model. I choose this specification as I consider it to be the most appropriate for the manufacturer's concern of sales cannibalization, as the line extension is extremely similar to the original product and the eventual generic for the original product.

Demand Elasticities

Patients prefer lower prices and have different demand elasticities for branded and non-branded products. For the branded products, when using the specification 5, the calculated demand elasticities (absolute value) fall between $[.70, 2.11]$ for Namenda and fall between

[2.68, 3.32] for Namenda XR. The range comes from elasticities calculated at various price and market share combinations across the years the product is on the market. The min and max of those elasticities are reported.The non-branded products have substantially less elastic demand where for Memantine, it falls between between [.20, .43] and for the Other Dementia products, it falls between [.20, .23]. When using co-pays, the literature often finds patients facing inelastic demand, so with regards to the non-branded drugs, my estimates are in line with ranges of other elasticity estimates found in Einav, Finkelstein, and Polyakova (2018). However, I do find that the branded drugs do face elastic demand, which aligns with demand elasticity estimates for line extensions found in Yin (2023). Without the nesting specification of the branded nests, the demand is still relatively elastic, but the branded drug elasticities ranges fall to [.88, 1.38] for Namenda and [1.60, 1.95] for Namenda XR.

6.2 Supply Estimates

Using the current demand side parameters from model specification 5, I can solve the firm's dynamic game to determine when they will launch the line extension and how they will price their products each period. I take the formulary design, as given from the data, as modeling how formularies are designed is outside the scope of the paper.[45] I use the product dummies, the price coefficient, the nesting parameter, and the history dependence term as the key demand parameters that influence the manufacturer's decisions. This estimation strategy is similar to the one used by (Feng and Maini, 2021), but has been modified to additionally model for the manufacturer's launch decision. Minimizing moments of the objective function, yields the following estimates on the supply side.

[45] Additional details of this are discussed in the appendix.

Parameter	**Estimates**
Insurer	
Drug Expenditure (ϕ_d)	.174
	(.032)
Exclusion Penalty (ϕ_e)	-1.61
	(0.92)
Manufacturer	
Launch Cost (R)	217.56
	(310.56)

I estimate two parameters for the insurer and one for the manufacturer. The insurer parameters can be interpreted as the approximation of outcome of the bargaining process between the insurer and the drug manufacturer.[46] The magnitudes of these parameters are not the focus of this work, but are effectively components that the drug manufacturer is aware of and must consider when making their optimal decisions. Parameters can be interpreted relative to dollars of consumer welfare. For every additional dollar of drug expenditure the manufacturer faces for a formulary, it's value of that formulary drops by .174 dollars of consumer welfare. The insurer also has a slight distaste for exclusion, as for each additional 1% of consumers that face a product exclusion, the formulary value decreases by .016 dollars of consumer welfare.

For the manufacturer, I recover an estimate for the line extension development cost.[47] This cost can be interpreted as a lump sum of the development and advertising costs of launching the line extension. The value of the fixed cost is $\approx 40\%$ of the average annual product line revenue for the manufacturer.[48] In the case of Namenda, this translates to

[46]Standard errors have not been corrected for error from the demand estimates. Forthcoming versions will reflect the correction

[47]As I am estimating this parameter for one drug, I do face limited statistical power, which contributes to larger standard errors, especially for the launch cost. This is something I plan to address in forthcoming versions.

[48]For a normalized market size of $M = 1$, the $\approx 40\%$ value comes from comparing the fixed cost parameter estimate to the resulting average annual revenues the model generates

roughly 520 million dollars.[49] While this is slightly on the higher side, when compared to literature estimates for the cost of developing a line extension However, in my setting this cost is inclusive of additional advertising or rollout costs, so after factoring that, I consider this to be a reasonable range. If counterfactual policies reduce manufacturer revenues, then it is possible that the manufacturer cannot cover the fixed cost of developing the drug and it may not be released. This is important, as there are welfare consequences resulting from the product not making it to market.

7 Counterfactuals

The manufacturer makes its pricing and launch decisions, in light of the insurer's problem and the fixed cost of launching the line extension. Using the estimated parameters on the supply side, I now turn to evaluating two counterfacutals, detailed below. I evaluate how these counterfactuals would have impacted Allergan and their decisions around Namenda and Namenda XR and the subsequent welfare implications.

7.1 Counterfactuals - Namenda

Fixed Exclusivity

Under the fixed exclusivity counterfactual, the manufacturer is promised an exclusivity period for the line extension that will last until 3 years after the original product expires. The manufacturer is given this period, for any launch time prior to the original product expiring.[50] This means the manufacturer does not have to delay the launch of the line extension, to unlock a larger exclusivity period after the original expires. As a result, the manufacturer should be incentivized to release the line extension earlier. The table shows the present discounted value over an 8 year time frame, from the start of the problem, of the expected profits, drug expenditures and consumer welfare for a unit measure of consumers.[51,52] The

[49] Calculation based on annual Namenda revenues around 1.3 billion

[50] To be clear, if the original product was to expire at the end of 2030. If the line extension is launched anytime prior to 2030, it will be protected until the end of 2033.

[51] By unit measure, I have set the market share to be 1.

[52] The same yearly discount factor of .88 is applied to manufacturers, insurers and consumers.

values are expectations, as each period there is a probability of the line extension being launched and a corresponding welfare measure for each launch time. The possibility a line extension is not launched and those welfare implications are accounted for as well.

Net Present Value	**Baseline**	**Fixed Exclusivity**
Expected Revenues	2851.32	2935.92
Expected Insurer Expenditures	2519.64	2636.88
Expected Consumer Welfare	2717.76	2695.20
CS: Pre OF Expiry	2253.84	2254.92
CS: Post OF Expiry	463.92	440.16

With fixed exclusivity, the probability the line extension is launched at the start of the problem, increases significantly to 95%, relative to 43% from the baseline or current policy. However, despite the line extension being likely to arrive earlier, consumer welfare is slightly lower in expectation. There are multiple components that lead to changes in consumer welfare, so I will explain each in detail. I start by splitting the consumer welfare into two segments, Pre-OF Expiry and Post-OF Expiry. The Pre-OF expiry captures the periods prior to the OF product facing expiry and the Post-OF expiry captures periods afterwards.

Due to the nature of the probabilistic insurer process, responding to manufacturer strategic decisions, consumers end up facing costlier formularies for products when the launch occurs earlier, relative to later launches. When both products are available earlier, consumers pay more for the products, compared to if just the OF is on the market and the LE is launched later, which contributes to lower consumer welfare.

Consumers do get additional welfare from a higher likelihood of getting the line extension sooner, which gives them an additional choice earlier; however, the loss of welfare from the higher co-pays from earlier launches, which are more likely now, mostly undoes those welfare gains. This leads to consumer welfare in the Pre-OF Expiry period being slightly lower.

A consequence of the fixed exclusivity policy is that it delays the generic for the line extension to a later date, relative to the baseline. Under fixed exclusivity, the line extension's generic will not arrive until the full exclusivity period has run out. As a result this leads to

a drop in consumer welfare in the Post-OF Expiry period. The generic for the line extension is substantially cheaper for patients and provides the most value in terms of net-utility, so further delaying this is costly to consumer welfare. Putting the welfare effects from these periods together leads to consumer welfare falling in expectation under the fixed exclusivity policy relative to the baseline. Lastly, as the manufacturer now gets additional guaranteed periods to earn profits, their expected profits do increase and as insurers make up most of the payments to drug manufacturers, expected drug spending increases as well. While intuition may suggest that an earlier launch should improve consumer welfare, it is clear that accounting for the manufacturer's pricing response and subsequent cost-sharing impact plays a large role in the outcome of consumer welfare, where for this case, it ends up falling.

No Exclusivity

Under the no exclusivity case, the drug manufacturer simply gets no exclusivity for the line extension and it faces generics for both the line extension and the original when the OF's protection expires, as long as the line extension is launched.[53] If the line extension is not launched, then there will just be a generic for the OF that arrives once the OF expires. Very few countries offer any exclusivity to line extensions, so this policy is effectively what is followed by the rest of the world. Under this policy, it is possible that manufacturer profits could be lower, for manufacturers that did have late launches. If there is a cost of developing the line extension, it is possible that some line extensions may no longer be profitable, so considering consequences of the line extension not being developed is important.

Net Present Value	**Baseline**	**No Exclusivity**
Expected Revenues	2851.32	2827.08
Expected Insurer Expenditures	2519.64	2521.80
Expected Consumer Welfare	2717.76	2724.72
CS: Pre OF Expiry	2253.84	2252.88
CS: Post OF Expiry	463.92	471.84

[53]To be clear, if the original product was to expire at the end of 2030. If the line extension is launched anytime prior to 2030, it will be protected only until the end of 2030.

As a result of the no exclusivity policy, the probability the line extension is launched at the start of the game increases to 67%, relative to 43% from the baseline. However, given the estimated cost for the line extension, the probability it is never launched increases to 30%, compared to just 8% in the current policy. The increase in the probability of the line extension not being launched lowers the manufacturer's expected revenues, albeit very slightly. The decrease in revenue is primarily driven by the shorter horizon of profits for the manufacturer. As manufacturer revenues are closely related to insurer drug expenditures, those are also slightly lower as well; however, they don't fall as much as manufacturer revenues do. This is because in the baseline, the manufacturer offered lower prices in later periods for late launches, as the horizon of the game could be extended. As extending the horizon is no longer possible, the manufacturer now offers higher prices in those periods, which leads to insurer expenditures not decreasing as much as revenues do.

Consumer welfare is nearly equivalent to the baseline policy, in expectation. Once again, it is helpful to split consumer welfare into the pre and post components. In the pre component, consumers again face relatively higher cost-sharing formularies when the line extension is launched earlier, compared to when LE launches occur in later periods, which undoes the welfare gains of getting the line extension earlier, as products cost more. This leads to the expected consumer welfare in the "Pre-OF" Expiry period being higher in the baseline, but just slightly. When looking at the "Post-OF" Expiry period, consumer welfare actually increases under the no exclusivity case. Under the no exclusivity policy, the generic for the LE will arrive earlier, if the line extension does launch, compared to the baseline. As the generic for the line extension is cheap, it provides more net-utility to consumers then they would face in the baseline for the line extension and the expected co-pay associated. This leads to welfare gains in the post period from consumers getting the generic line extension earlier in this policy. If the line extension does not launch, there will not be a generic for the LE. As that likelihood is higher in the no exclusivity policy, this dampens the consumer welfare gains after OF expiry, as there is increased risk that the generic LE never arrives. In total, across the pre and post periods, this leads to consumer welfare increasing in expectation.

In the case of Namenda, it appears that the current policy did not increase the manufacturer's revenues or expenditures greatly, while minimally affecting consumer welfare due to

delay. While this may go against intuition, it is important to remember that manufacturer's strategic prices may be different under each policy. Intuitively one would expect an earlier launch would increase consumer welfare, all else equal. However, if different manufacturer prices and launch decisions can change the likelihood of formularies patients face, it is possible that welfare gains may be mitigated or lost due to higher co-pays that patients face, despite getting an additional choice. Hence, as seen above, accounting for strategic firm responses to policy is key for policy evaluation. The role the insurer plays is also important when responding to the manufacturer's strategic decisions, so work that further explores a detailed model or alternate insurer considerations is worthwhile for a more robust policy evaluation. One caveat with these results is that I assume there is no insurer plan response. For example, under the fixed exclusivity policy, the insurer incurs higher drug expenditures. If insurers adjust premiums to recover the costs of these increased expenditures, this would come at the expense of consumer welfare.[54]

It is also important to remember that these counterfactual results are representative for this particular drug. For drugs that provide different levels of consumer welfare or have different levels of improvements for line extensions, policy results may be different. Hence, extending the analysis to additional drugs is worthwhile for a more complete policy evaluation.[55]

8 Comparative Simulations

To begin to broaden the policy implications outside of the dementia market, I use simulations to highlight which types of line extensions are most likely to delay. It is the line extensions which are delayed by manufacturers under the current policy, which would be most impacted by the counterfactual policies I considered for the dementia market. Key demand parameters, such as the relative premium of line extension's product dummy over the original, nesting parameter or level of history-dependence affecting repeated choices, play a role in impacting when a manufacturer brings their line extension to market. These pa-

[54]Modeling this is outside the scope of the paper, but an important spillover to consider related to welfare
[55]I aim to address further this in forthcoming work.

rameters impact factors that affect the rate of adoption, such as cannibalization and market expansion, which the manufacturer must consider. For this exercise, I use my estimates for ϕ to account for how the insurer's process impacts product co-pays for patients. In each subsection, using a baseline set of parameters, I show how varying one key demand parameter at a time impacts the manufacturer's launch incentives and likelihood the line extension is ever launched.[56]

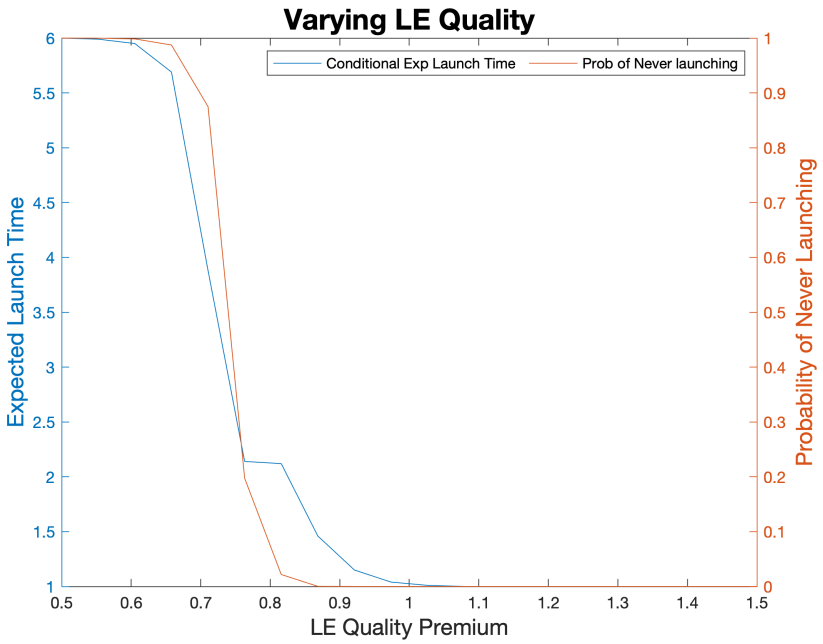
8.1 LE quality

I vary the line extension premium, which is a multiplier on the original formulation's product dummy. A higher multiplier implies that the line extension is a larger improvement over the original product. A multiplier equal to 1 indicates the product is equivalent in terms of utils to the original, while a lower multiplier suggests the product is lower quality. As I vary the line extension premium term, I plot the expected launch time of the manufacturer, conditional on launching, using the model launch probabilities from the estimated model.[57] I also plot the probability the line extension is never launched as well.[58]

[56] I use parameters from model specification 5 as the baseline

[57] For each period, there is a probability of launching. Using the period and the corresponding launch probability, I construct the expected launch time, conditional on launching

[58] Initial market shares did not significantly impact these trends, but a figure that compares differences is shown in the appendix.

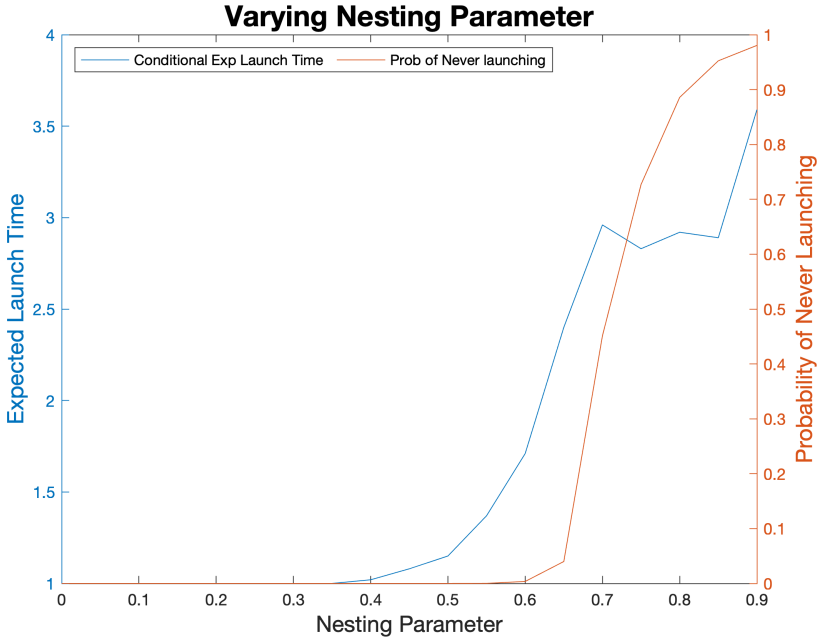


A lower expected launch time means the firm launches towards the start of the game, with 1 being in the first period. In general, when manufacturer's have lower line extension qualities, they have an incentive to delay their launches. This makes sense intuitively as their products will likely not expand the market and simply cannibalize sales, so the manufacturer stands to gain more by maximizing their additional exclusivity period, as the additional profits from an earlier launch will be limited with a product similar in quality to their existing one. Additionally, line extensions that are lower quality will face stronger competition from the generics of the OF, which greatly reduces their profitability. When the fixed cost of development is paired with the potential for lower profits, these line extensions will have a higher likelihood of never being developed.

8.2 Nesting parameter

I vary the nesting parameter on the nest of products that share an active ingredient. When the OF and LE are on the market they both belong to one nest and the eventual generic for the OF will take the OF's place in that nest when it arrives. All other products are in degenerate nests. As the nesting parameter approaches 1, this suggests that the products within the nest are more substitutable. As I vary the nesting parameter, I again plot the manufacturer's expected launch time, conditional on launching, and the probability

of never launching, using the model launch probabilities from the estimated model.



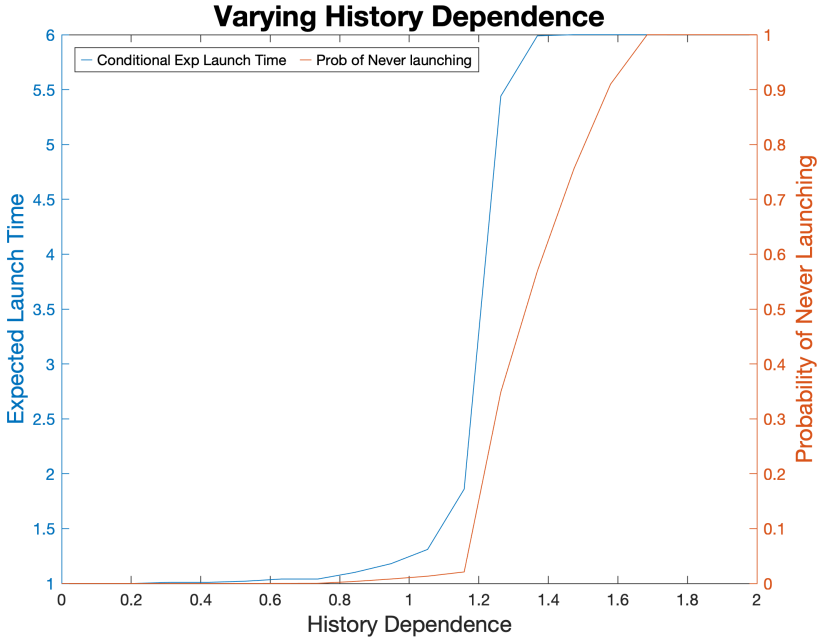
As the nesting parameter increases towards 1, the original formulation and line extension are viewed as more substitutable products and the manufacturer ends up delaying the launch of their product. If the OF and LE are very substitutable, the simulation suggests that the launch of the LE will not likely be market expanding. This is because individuals who take the line extension are less likely to come from an alternate product or the outside option and more likely to come from the OF. Highly similar products will primarily lead to sales cannibalization, so manufacturers have an incentive to delay their launch to minimize the impact of this. When the nesting parameter decreases towards 0, the opposite occurs, where the OF and LE are now less substitutable. This leads to the manufacturer launching earlier, as their concerns about sales cannibalization are limited as the line extension will be more market expanding.

Additionally, when the line extension is more substitutable with the OF and likely to be primarily sales cannibalizing, the likelihood the line extension never launches also increases. LEs that are highly substitutable with the OF, will also be more substitutable with the generic for the OF, which will limit the profits manufacturers can earn post generic entry for the OF. Given the cost of introducing the line extension, if the LE doesn't have the potential to increase profits through market expansion, it may be likelier to never be launched. On

the other-hand, LEs that are more market expanding have a low likelihood of not being developed.

8.3 History Dependence

I vary the level of history dependence, which is the utility boost of a repeated choice, for all products. Higher history dependence suggests that patients relatively like to make repeated drug choices compared to switching to an alternate choice. The presence of history dependence can have an impact on product entry, as new products may find it difficult to gain market shares, given that established consumer's don't like to switch to alternates. However, an earlier launch, provides the manufacturer more time to establish a market base and benefit from history dependence. As I vary the history dependence term, I again plot the manufacturer's expected launch time, conditional on launching, and the probability of never launching, using the model launch probabilities from the estimated model.



As the history dependence term increases, manufacturer's tend to introduce the line extensions later. This is primarily due to the fact that many patients will be forced to switch when the original product expires, so the manufacturer is able to benefit from introducing the line extension closer to a period where patients will be switching anyways. Additionally, given

how the insurer impacts drug pricing, it may be unfavorable for the manufacturer to offer prices that can encourage switches to the line extension, if history dependence is high. There does appear to be a sudden change in the expected launch time as the history dependence term gets close to the value of the OF.[59] As the history dependence term is below the value of the OF, the manufacturer launches earlier; however, once it gets very near, the line extensions begin to be released later. Once it crosses that value, line extensions are launched as late as possible. Additionally, for a sufficiently high level of history dependence, it may not be feasible to get patients to switch, leading to the likelihood of the line extension not being developed to be quite high, which is not the case for low levels of history dependence.

9 Conclusion

In this paper, I estimate and solve a model for the manufacturer's launch and pricing decisions, by considering the trade-offs the manufacturer faces when introducing the line extension. I then use this model to evaluate welfare under counterfactual policies designed to alleviate the manufacturer's delay incentives for launching a line extension. While previous literature on line extensions has considered the welfare implications of line extensions or separately considered the manufacturer's timing decision, this is the first work to consider how the manufacturer's response, with the presence of an insurer, affects welfare. Incorporating the manufacturer's response is critical to evaluate alternate policies, as neglecting the manufacturer response may lead to misevaluating the policies impact.

With this dynamic model, I show how a manufacturer would respond to counterfactual alternative policies around the exclusivity period. In the case of Namenda, I find that offering full exclusivity would increase drug expenditures and manufacturer revenues, but harms consumer welfare despite a higher likelihood of an earlier line extension launch. The expected welfare losses are driven by the generic for the line extension being delayed. Under the no exclusivity policy for Namenda, I find that consumer welfare increases, while manufacturer revenues and drug expenditures change at a negligible level. Here consumer welfare gains are driven by an earlier line extension and the generic for the line extension arriving earlier as

[59]The value for the OF is the product dummy on the OF product

well. However, no exclusivity does increase the risk of the line extension not being developed, which limits the increase to consumer welfare, although it remains positive in total.

To extend the scope of the work outside of Namenda, I utilize comparative statics to showcase which line extensions are most likely to be impacted by the alternate policies and evaluate the resulting welfare consequences. The comparative statics indicate that line extensions, which are lower quality improvements, have a greater incentive to delay their launches. Line extensions that delayed their launches to the final 3 years are most impacted by these policies. The comparative statics show that under the "no exclusivity" policy, the line extensions that are likeliest to be lost are those that are the least innovative or market expanding. These are line extensions that are extremely similar to the existing OF product, so losses to welfare from the increased likelihood of those line extensions not being developed would be minimal. As the downside to the no exclusivity policy is limited by this, incorporating the no exclusivity policy would improve consumer welfare in expectation, as consumers would increasingly benefit from getting line extensions and their generics sooner.

These simulations are a great initial step in broadening my application to other markets, but I plan to pursue this direction further. In forthcoming versions, I aim to extend the counterfactual analysis by estimating a distribution that of key demand primitives. This distribution approximates the key demand parameters of line extensions observed in the data, which influence the proportion of line extensions that are delayed. I plan to evaluate welfare under the alternative policies, using this approximated distribution, to represent broaden the policy implications to the "universe" of line extensions.

As policy makers continue to consider actions that may limit drug spending, this work suggests that focusing on line extensions may be beneficial. Recent reports indicate manufacturers are increasingly becoming involved in line extensions, so focusing on a growing area should be critical for policy makers (Hannick, 2022). Hence, a stronger understanding of how alternate policies could impact line extensions is vital, especially given the magnitude of spending in the pharmaceutical market.

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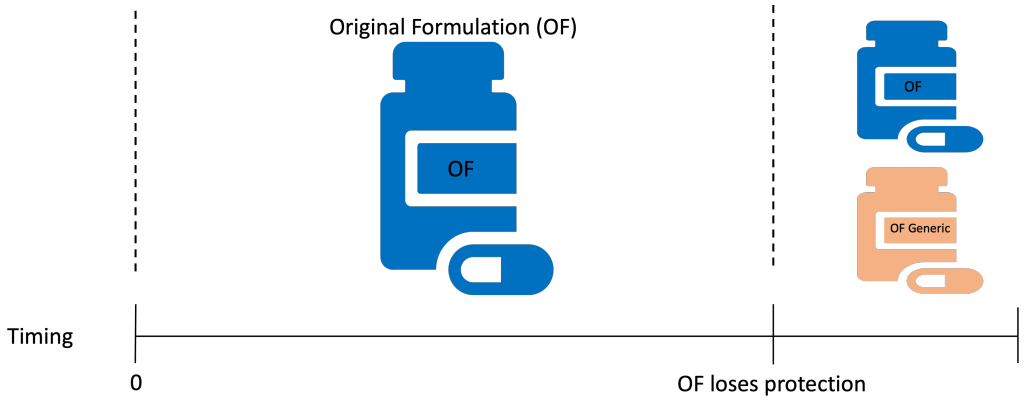
Appendix

A1 Line Extension Timing Diagram

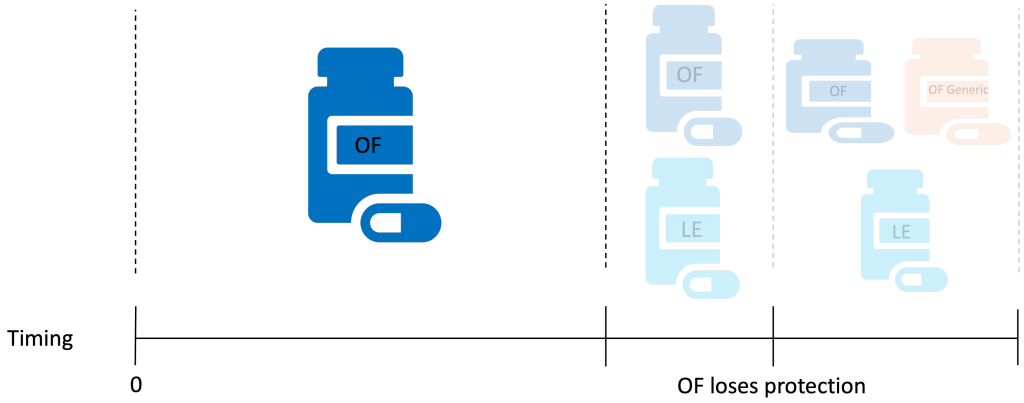
The following diagrams can be illustrative in understanding why timing is so important when considering pharmaceutical line extensions.

A1.1 No Line Extension



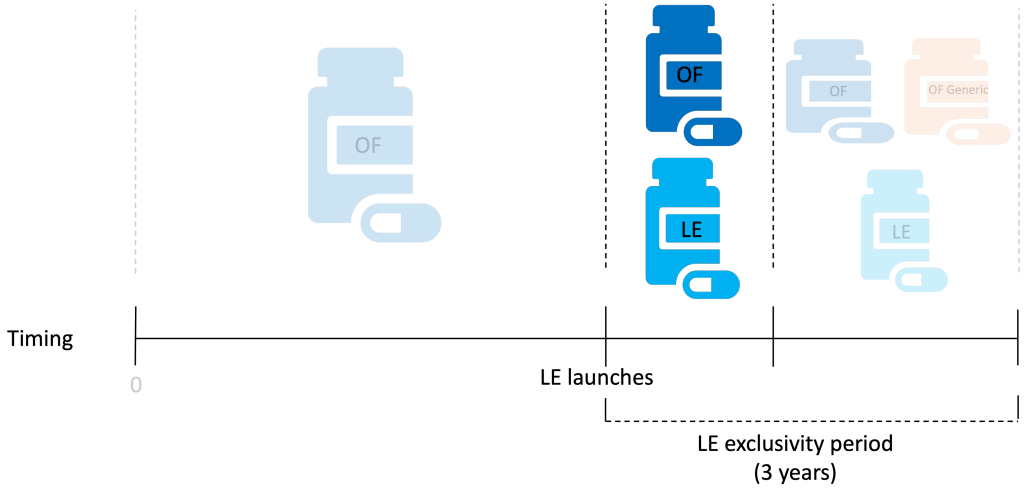
This is an example of a traditional case a branded firm faces in the absence of a line extension launch. The branded firm enjoys its protected exclusivity until a certain date where it loses that protection. Then it faces generic entry and loses substantial market shares and profits from that drug.

A1.2 Line Extension - Stage 1



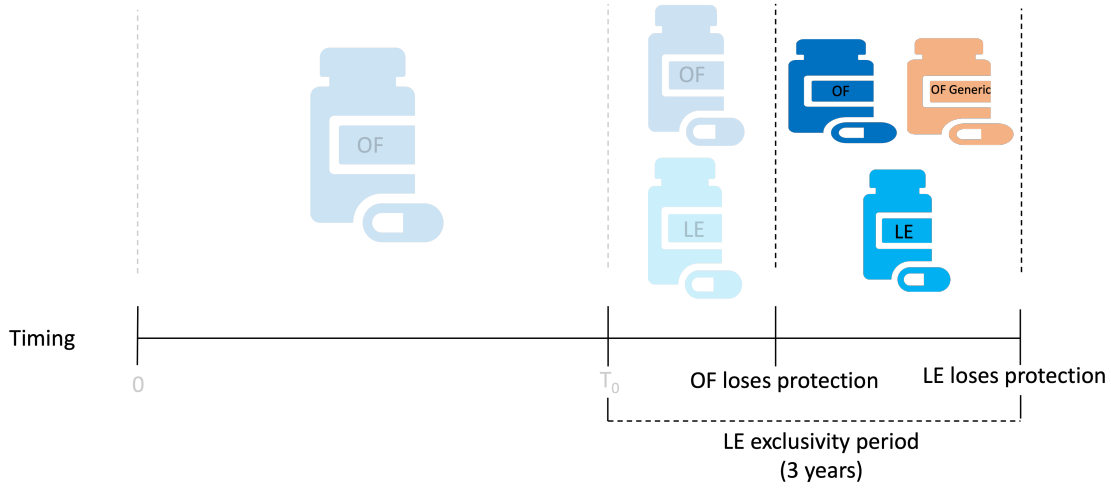
Things start pretty similar in the case where a firm is deciding to launch a line extension. At first the branded firm still has just its original product on the market, while it is still protected. The firm remains in this setting until they launch the line extension.

A1.3 Line Extension - Stage 2



Once the line extension is launched, it's 3 year exclusivity window begins. I am only focusing on line extensions that don't have drug substance patents, as their exclusivity start points are different. Once the line extension is launched, the branded firm now has 2 products on the market, until the original formulation loses its protection. During this period the branded firm's goal is to transition patients from the original formulation to the line extension before the generics for the original formulation arrive.

A1.4 Line Extension - Stage 3



Once the original formulation loses protections, the generics for the original formulation arrive. This leads to a substantial drop in market shares for the original formulation, as there is a cheaper equivalent generic available and the presence of automatic substitution laws. If a prescription is written for the original formulation and a generic exists, unless it is explicitly written as "Dispense As Written", which is not common, it will get substituted out for the cheaper generic to generate drug savings. It is precisely for this reason that the firm aimed to convert patients to the line extension before the start of this period. Patients on the line extension are not affected by the automatic substituion laws, as the generic for the original formulation is not an equivalent substitute for the line extension. In other words, if the firm converted a patient to a line extension, they won't lose them to the generics and will profit from them during this period. This period ends when the line extensions exclusivity period ends, which started at the beginning of stage 2 and at that point the firm will face generic entry for the line extension. This stage can be thought of as the "additional" exclusivity period the firm gets from their line extension.

A2 Descriptives on LE launches

The densities of how early the LE is launched relative to the OF is shown below. Positive numbers indicate that the line extension launches prior to the original product expiring.

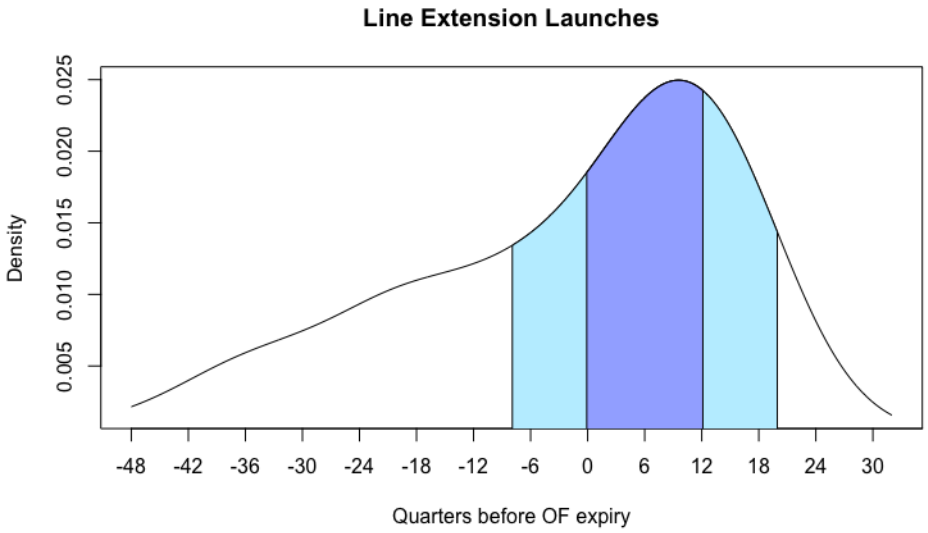


Figure A1: Distribution of LE launch timing

It should be noted, that the exact period the original product expires is not often in the data, as firms may face generic challenges earlier or may have secondary patents. Following the steps from Fowler (2019) to construct the data, the date for the original product expiring is a very conservative measure and as a result there are numerous manufacturers that appear to launch line extensions after the original product has expired in the figure. The FDA Orangebook data helps address some of these concerns, but not all, so date of the original product expiring in the graphs likely falls far earlier than the actual date the original product expires. The date is the earlier possible period of the original product expiring and likely to be much earlier (2-3 years) prior to the original product actually facing a generic challenge, so the figure is at best an approximation[60].

The darker blue region of the figure highlights the density of line extension launches that occur within 3 years of the Original Formulation's (OF) expiry. These are the line extensions

[60]In forthcoming versions, I plan to utilize additional data on generics and claims data to reduce uncertainty on how early line extensions are launched relative to the original product.

that will still have exclusivity after the OF product expires, which are the line extensions that will be impacted by the alternate policies this paper explores. Again, as the exact OF expiry date is a bit noisy, the lighter blue region captures the additional density of launches that occur 2 years before and after the period within 3 years of OF expiry. The true number of line extensions that earn the additional exclusivity period, with a late launch, likely falls in some range of the shaded blue regions. It is clear that not all line extensions delay their launches, as the manufacturer may anticipate the line extension being more market expanding than cannibalizing. However, it is also apparent that there is a large mass of line extensions that are launched in the window prior to the expiry of the original product, indicating that a delay strategy may be a common option taken by manufacturers. Finally, it is unlikely that there is such a large mass for launches after the OF expires. While those launches are possible, it would be difficult for the manufacturer to successfully gain market shares with strong generic competition[61].

Certain line extensions are granted drug substance patents, which begin once filed. As a result, they would not have the same delay incentives, as that patent protection dominates the exclusivity. I plot densities of line extensions with and without those patents below [62].

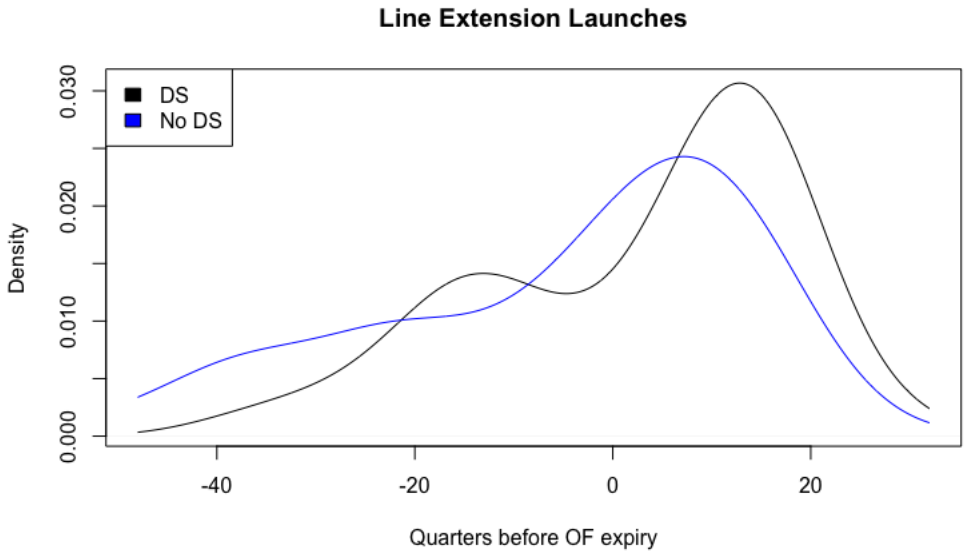


Figure A2: Launch times between products with and without drug substance patents

[61]This results from the conservative date of OF expiry

[62]Once again, the same caveat of noisy dates for OF expiry remains.

Line extensions that do not have drug substances are more likely to be launched closer to the original product expiring, which can be seen as they have more weight towards the left hand side of the figure. This makes sense, as without the patent, the manufacturer only gets the 3 years of exclusivity, which begins upon launch. As a result, manufacturers aim to make the most out of their exclusivity, by considering how cannibalizing or market expanding their product may be. Line extensions without drug substance patents would be impacted by policy changes around the exclusivity period, which is why they are the line extensions this paper focuses on.

A3 Future Work

It is important to discuss future directions of work, to build upon areas that this paper does not address. Consumer arrival could play a role in the manufacturer's decisions on when to introduce their products. If patients don't make frequent trips to the doctor, this may affect when a manufacturer may introduce a line extension, as a prescription switch is unlikely to happen outside of a doctor's visit. The manufacturer also has the ability to advertise the line extension, which also could facilitate consumers switching, in addition to changing prices. As I do not have data on advertising, this is not included in my model, but it certainly is at play and would be a valuable consideration.

Other research avenues are accounting for the presence of secondary patents and the uncertainty they may bring. One source of uncertainty relates to the exact date the manufacturer will lose protection for their original product. I take this as given, but in reality, firms may face a paragraph IV challenge and face generic entry earlier than expected. I assume firms know when they will face generic entry and it is likely that even with challenges they still have a strong idea, but in the case they were surprised by a lawsuit, this could affect their decision of when to launch the line extension, if they even can. My intuition is that the possibility of losing an original product earlier, would simply encourage firms to launch their line extensions earlier. The other uncertainty is around the strength of secondary patents that may extend the exclusivity period for the LE past the original 3 years. Once the 3 years are up, if a firm has a secondary patent that protects the LE for

a few additional years, generics for the LE will not be able to enter until that patent gets thrown out in court or expires. Having the possibility of a longer exclusivity period, could also affect timing decisions. Again, my intuition is that these manufacturer's would be more willing to launch the line extension earlier, as a secondary patent is very similar to a fixed exclusivity policy, as the secondary patent's date is the key date that matters for generic LE to enter. The amount to which they would do it earlier would depend on patent strength and length. I plan to consider these dimensions in future work, as it would be valuable to consider all of these extensions, to further consider how manufacturer's would respond, as all welfare measures are driven by their actions.

I abstract from competition amongst branded manufacturers in my setting, but could extend the model to allow for this. Branded manufacturers not only compete on formulary placement through the prices they offer to insurers, but they may also compete with product entry, whether that be a new original product or a line extension. My intuition suggests that competition would lead to earlier launches, as drug manufacturers would find it easier to move patients to the line extension, if the market was less competitive. Additionally, the possibility of a rival developing a new original blockbuster drug, should encourage earlier launches, as there is now additional risks to delay. However, manufacturers are respectively still on their own finite horizons, i.e each has their own periods where their products lose protection, so I would only anticipate a smaller shift to earlier launches, as they still will be aiming to limit cannibalization.

The insurer is a key player in this setting and its impact is primarily captures through a reduced form approach. It is very possible that insurers may strategically respond to how they design formularies in light of an alternate policy change. For example, insurers may be cautious to have their patients move from the OF to the LE. Patients that remain on the OF are likely to switch to the cheaper generic, which limits insurer expenditures. As a result, there may be a dynamic component that insurers care about, which would impact the manufacturer's strategic decisions. Insurers also may develop tier restrictions or therapeutic exclusion restrictions, both of which could also impact how the manufacturer responds.[63] Lastly, if insurers anticipate drug expenditures increasing, the co-pay values

[63]If the insurer considers OF and LE products to be therapeutically equivalent, they may only choose to

may increase as well, to mitigate those expenditures, which will influence patient demand. Further developing the insurer's problem to include alternate specifications of components the insurer cares about and/or alternate error specifications such as ordered probit are all worthwhile areas for future work.

A4 Computational Details - Demand

I detail the steps I take to estimate the demand system below. For each line extension pair, I define the market as a year. The choices that patients can make are the different drugs that can be taken for the specific use case. For example, in the dementia market after 2012, the main players were Namenda, Namenda XR, Memantine, Donepezil and numerous other smaller generic options. For drugs that have small market shares ($< 1\%$), I group them together to form an "other" category, called Other Dementia, to simplify the demand estimation. It is often the case that the line extension drug pair is the main branded drug.

A4.1 Prices

For patient co-pays, I find the normalized 30 days supplied co-pay value per year for each product as the amount patients pay. To get this, I modify the co-pay paid by days supplied of the prescription to reflect what a 30 day fill co-pay would be. I use claims where patients only paid the co-pay to get a cleaner sense of what the tiered drug cost was for the consumer. This allows me to only focus on product co-pays and not payments towards an insurance plan's deductible. For a subset of the data, there is plan specific information, which could allow for the analysis to be done at the plan level, but the availability is infrequent in this time range, so I am unable to utilize it[64]. The end result is one co-pay value per product per year, which effectively means all patients belong to one insurer[65]

cover one, which will influence how the manufacturer bids.

[64] When comparing the median copay to the plan specific co-pays, the amounts are reasonably similar.

[65] An alternative approach would be to allow individual prices, but would require prices to be inputted for products that an individual never chose, to get a sense of what prices of individual alternatives would be.

A4.2 Patient Choices

Each year, which is my definition of a market, an individual makes a drug choice. I consider the choice of an individual to be their modal drug choice, by days supplied in a year. Additionally, as this is done at the yearly level, I impose a cutoff of at least 60 days supplied in a year. If the individual's modal drug choice is for less than 60 days of a year, I classify them as taking the outside option[66].

Individuals are different in their quantity decisions, specifically in days supplied during prescription.[67] For individuals that get a prescription with multiple refills, I attribute the full quantity across the refills to the year of the original prescription. Then, the drug with the most days supplied is that individuals choice[68]. I construct a stock variable for the remaining drugs in a year by days supplied of previous prescriptions. If individuals have enough stock to finish the year and they don't make a choice in that year, I treat them as making a repeated choice for that year. In other words, if an individual chooses Namenda XR in 2014 and has a remaining stock of Namenda XR that extends into 2015, if they don't choose another drug with more days supplied than the remaining Namenda XR, I consider them to be making the choice of Namenda XR again, in 2015. If they don't have enough stock and don't make a choice, I treat them as choosing the outside option.Hence, individuals are actively making a choice if they are starting a prescription in a year or choosing not to select a drug, when their stock has ran out. Additionally, it's not clear who the decision maker is, so the choice is a collective decision between the patient and provider[69].

A4.3 Formulary Design

I take the formulary structure as given from the data and only allow for 3 tiers for branded drugs in the formulary: Preferred, Non-preferred and exclusion. Using the normalized copay amounts, I plot histograms of the co-pays over time and see that there are 2 clear peaks. I

[66] This leads to an outside option of $\approx 20\%$

[67] For example, individuals may get prescriptions for monthly fills, quarterly fills or half-year fills.

[68] This allows for a patient to experiment with a small fill of one prescription. If a patient tries a drug very briefly, then reverts back to their original choice, then I treat this as the patient sticking to their original choice

[69] This is a common problem faced by the literature for the consumer side, so I follow the standard approach.

view these peaks as representative of tier amounts across the population of individuals and these amounts become the preferred and non-preferred tier amounts I use in estimation [70]. I allow for a separate generic tier, only for generic products, and determine the amount by doing the same for generic products and see that the histogram shows one clear peak. I take the median co-pays of each of the tiers in each market and assign that as the copay for that tier per markets. The median co-pay values per tier do increase over time, but by small amount over the whole timeframe.[71]. To limit computational burden, I use the median co-pays of each tier for the model, which results in one co-pay value per tier for the model. Modeling the copay assigned to the tier and the amount of tiers offered, is outside the scope of this paper, so I simply take those values as given from the data. The third tier of exclusion, simply means the insurer does not cover the drug, which means patients are unable to get the drug. This is a simplifying assumption I make to keep the model's estimation tractable [72] I am left with a formulary with 3 tiers and a generic tier, with a co-pay amount for each tier. A consequence of this is that it creates a monopoly insurer, so all individuals in a market would face the same set of formularies. While in reality different insurers may have different co-pays or different tiers, this will not be the case in this setting. In this setting, the co-pay values will be the ones the patient faces based on the tier that results from the probabilistic insurer process over the same set of formularies.

A5 Computational Details - Supply

I provide a detailed summary of the computational details used to estimate the dynamic problem for the supply side.

[70]The preferred tier is the lower co-pay amount

[71]To be specific, co-pay values roughly increase on average by ≈5 dollars over the entire timeframe

[72]In reality patients can pay for the drug, even if it's excluded, but it is very unlikely that they do as the drug is extremely expensive relative to the covered drugs. Hence, allowing for patients to purchase excluded drugs should not affect my results substantially, as the share of consumers who would purchase still is effectively zero

A5.1 Discretized State Space

To limit computational burden, I discretize the state space for my problem. One of the key state variables in my setting is the previous period's market share vector. In my setting this is a triplet: market share for original product, market share for line extension and market share for the "other dementia" product. When the original product expires, the first value becomes the market share of the generic for the original product. Market shares can range from 0 to 1, but I create a grid of values/bins to assign market shares to. As market shares for a particular product are typically low, I primarily include a finer level of detail amongst lower market shares. Market share values go from [0,.5] in .05 intervals, and then .6, .7, and .9. This means that in the problem, market share state space vector will only include market shares with one of those values. I use a nearest neighbor algorithm to find the closest market share vector in the grid that matches the one that occurs in the model.[73]The nearest neighbor matching is done to determine what the next state variable would be, for the continuation payoffs. This greatly reduces the state space into a more manageable discretized version of a continuous variable.

A5.2 Discretized Action Space

I also incorporate a discretized action space, which for the firm would be the net price they choose for their product. The range of the prices goes from 140-300, by increments of 5. I chose the range by finding the min and max observed prices from the data and adding a buffer of 20% the mean price for a product line. When firms have 2 products on the market, they are choosing a pair of prices from the discrete grid (matrix), while when they just have one price, they are choosing from a discrete vector.

A5.3 Flow Profits and Policy Function

The discretization of the action space (prices) allows me to calculate the flow revenues upfront. I first calculate the flow revenues from having just the original, both products and

[73]For example, if the market share vector in a period is [.44, .21, .29], it would be matched to [.45, .2, .3], based on the market share grid values detailed above.

just the line extension for the manufacturer. I also calculate the resulting market shares from each of the actions the manufacturer could choose and map them to the discretized state space. So before considering any dynamics, for each state and action combination, I find flow revenues and next period's market shares. Once those have been recovered, I can solve the dynamic problem, by just using those saved flow revenues and next state variables. The next state variable tells me what value to use for the discounted continuation payoff and the flow revenues have already been calculated. So for each state, taking the max across the action space choices, over the sum of the flow revenues and discounted continuation payoff, will result in the optimal price for the firm, which is the policy function. This reduces the optimal flow profits to be a "static problem" upfront and avoids solving for the optimal price, using an optimizer each period, which would greatly slow the computation down, but does introduce some error; however, if the action space is relatively fine, those concerns are limited.

A6 Computation Routine - Overview

The demand parameters are estimated separately and are treated as inputs for the supply side estimation. The computation steps are listed, along with greater detail in important steps.

1. Start with an initial guess of ϕ
2. Calculate flow profits and next period's state for all state and action combinations
    - This is a one time calculation and the values from this are used for the dynamic game
3. Solve the dynamic game
    - For each launch time, denoted τ: Use the previously calculated flow payoffs and future state for each state and action combination, from the static problem, to recover policy and value functions using backwards induction.

  - Note the manufacturer uses the appropriate static game based on the products it is offering in that period, based on the launch timing

- Construct option values of not launching each period, as manufacturer's can choose to not launch.
  - For each launch time, denoted τ: Calculate flow profits of not launching and resulting future state.
- Re-solve the game using backwards induction for each launch time with option value as the continuation value, which is the inclusive of the values of launching and not launching in the next period, based on the next state from the static game. This results in policy and value functions of manufacturers for all launch decisions.

4. Estimate the parameters

- Starting at the first period and the initial condition for the previous period's market shares, find the model predicted price path, using the policy function.
  - These prices are used to construct the 4 price moments, which are conditional means based on which products are available.
- Using equation 15, construct the conditional launch probabilities for each of the possible launch times, based on the value functions at those states. These probabilities will be used to create 2 launch probability moments.
- Construct the objective function G, summing the difference in squares between data and model prices and data and model launch probabilities.
- Using the pattern-search routine, iterate through candidates of ϕ and M until G is minimized.
  - Parameters are estimated via two-step GMM. The first evaluation had the weighting matrix as the identity matrix.
  - Using the resulting parameters from the first evaluation, construct the optimal weighting matrix, then re-run estimation routine again to minimize G with the optimal weighting matrix to get a final of estimate ϕ.