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Original Research

Geographic Pricing and Cross-Market Tariff Spillovers in a Differentiated Bertrand Duopoly

Chandra Kathuroju

Reedy High School, 3003 Stonebrook Pkwy, Frisco, Texas, 75034, United States of America
Corresponding author email: Chandra.Kathuroju@gmail.com

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Abstract

This paper studies how third-degree price discrimination impacts the Nash equilibrium of a duopolistic Bertrand model in differentiated markets. The model looks at two automobile producers, one based in the UK and the other based in the EU, competing in two different markets–Ireland and Britain market. The European Union producer faces a tariff only in the British market, while the United Kingdom producer faces no tariff in either of the markets. By calculating both firms' best-response functions, this study compares the equilibrium prices and quantities under geographic price discrimination and a uniform price system. The results show that price discrimination results in the tariff increasing both producers' equilibrium prices in Britain, while leaving prices in the Irish market unchanged. This leaves the cost shock isolated in the British market. Additionally, the tariff increases the British producer's equilibrium quantity demanded while reducing the EU producer's quantity demanded. However, under uniform pricing, the tariff results in a cross-market spillover, increasing equilibrium prices in Ireland, set by both producers, despite the absence of a tariff in that market.

Keywords: Third-Degree Price Discrimination; Geographic Pricing; Nash Equilibrium; Bertrand Duopoly; Product Differentiation; Asymmetric Tariffs; Cross-Market Spillovers

1. Introduction

When competing firms operate across multiple geographic markets, differences in trade policies can create asymmetric costs that influence their pricing decisions. For example, consider two automobile producers competing in Britain and Ireland. If one producer faces a tariff on its sales in Britain while the other does not, the tariff directly increases the cost of selling automobiles for one firm in one market, creating an incentive to raise prices.[1] However, because the producers compete with differentiated but substitutable products, the tariff may also influence the pricing decision of the competing producer. This raises an important economic puzzle: if a tariff is imposed in Britain, could it also affect the equilibrium prices paid by the consumer in Ireland, where no tariff exists? Furthermore, how would this asymmetric cost affect competition between the two firms, and to what extent could the producer that does not face the tariff benefit through changes in equilibrium prices and quantities?

[1] Mary Amiti, Stephen J. Redding, and David E. Weinstein, "The Impact of the 2018 Tariffs on Prices and Welfare," *Journal of Economic Perspectives* 33, no. 4 (November 2019): 187–210.

The answer may depend on whether firms are permitted to engage in third-degree price discrimination. This pricing strategy allows producers to charge different prices to identifiable groups of consumers, including consumers separated by geographic location. When geographic pricing is a viable option, firms can adjust prices independently across markets,[2] in response to different cost conditions. A uniform price, however, results in the same prices across all markets for a producer.

Following the current extensive research around Nash equilibrium under differentiated competition and price discrimination,[3] the primary objective of this paper is to examine how an asymmetric tariff changes equilibrium prices and quantities, and whether geographic price discrimination influences the movement of this cost shock across the two markets. Our research question, therefore, employs this blueprint: How does third-degree price discrimination impact Nash equilibrium in differentiated markets?

The paper studies a two-market Bertrand duopoly where one firm faces a tariff in one of the two markets. We adopt an example of a UK and EU automobile firm facing customers from the Irish market and the British market, deriving equilibrium outcomes under discriminatory and uniform pricing, and discussing the resulting cross-market spillovers and limitations.

2. Literature Review

2.1 Bertrand model with product differentiation

Existing literature has examined a slightly different version of this paper's differentiated Bertrand model. In one specific case, the Hotelling model was used, in which markets were covered, demand was linear, and findings showed the average price dropping and consumer welfare increasing when discriminatory pricing was replaced with uniform pricing in a covered market, all calculated with the output and pricing properties under price discrimination.[4] The findings set the foundational effects of a uniform price system central to this paper. However, our paper requires calculating these properties under a specified version of the Bertrand model under third-degree discrimination, rather than a uniform price. Another paper analyzes the effects of third-degree price discrimination through a duopolistic differentiated Bertrand model. The effects of third-degree price discrimination were examined through cross-price elasticity and industry-demand elasticity, which together determine a firm's own-price elasticity of demand. Greater cross-price elasticity in the weak market makes price discrimination less likely to increase total industry output, while greater industry-demand elasticity in the weak market makes an increase in total output more likely, all else equal.[5] The importance of competition is made explicit, and the prisoner's dilemma becomes an outcome when two firms either don't have best-response symmetry or face different strong markets. The traditional outcome only occurs when both firms in a duopoly face the same strong market.[6]

Other papers investigate international price discrimination in the European car market, with oligopoly market power being determined by product substitutability and demand elasticity.[7] This paper serves the purpose of constructing a differentiated Bertrand model to represent a similar scenario. The same empirical scenario would be significant for the framework of this paper, but the key weaknesses lie in the infeasibility of researching exact car prices across a number of nations.

Numerous papers tend to take it a step further by analyzing discrimination in a differentiated Bertrand model in comparison to a case study. A study on the French automobile market demonstrates the con-

[2]Yang Li, Brett R. Gordon, and Oded Netzer, "An Empirical Study of National vs. Local Pricing by Chain Stores under Competition," *Marketing Science* 37, no. 5 (September 2018): 812–37, https://doi.org/10.1287/mksc.2018.1100.

[3]Kenneth S. Corts, "Third-Degree Price Discrimination in Oligopoly: All-Out Competition and Strategic Commitment," *The RAND Journal of Economics* 29, no. 2 (1998): 306, https://doi.org/10.2307/2555890.

[4]Markus Dertwinkel-Kalt and Christian Wey, "Third-Degree Price Discrimination in Oligopoly When Markets Are Covered," *Journal of Industrial Economics* 71, no. 2 (June 2023): 464–90, https://doi.org/10.1111/joie.12325.

[5]Thomas Holmes, "The Effects of Third-Degree Price Discrimination in Oligopoly," *American Economic Review* 79, no. 1 (1989): 244–50.

[6]Corts, "Third-Degree Price Discrimination in Oligopoly."

[7]Frank Verboven, "International Price Discrimination in the European Car Market," *The RAND Journal of Economics* 27, no. 2 (1996): 240–68.

sumer welfare benefits of a uniform price, but gains are unevenly distributed among consumer groups: wealthier and internet-savvy consumers receive most of the surplus benefits.[8] This finding essentially demonstrates that consumer characteristics determine welfare effects. Further research papers continue to investigate empirical studies, with the use of a mathematical model to provide new insights into the study. 96 anonymous hospitals were under review when conducting the study of price discrimination of coronary stents, and a bilateral Nash equilibrium model was used to estimate how competition and bargaining power influenced the final price.[9] This model came to a similar conclusion to what we've seen in our previous literature of a uniform price.

2.2 Third-degree price discrimination

Many studies about the deviation from a uniform price to third-degree discrimination collectively reveal that this method requires segmenting consumers into distinct markets.[10] In practice, this is commonly done through different modes of data collection; American Airlines discriminates on a temporal basis, charging more to inelastic business consumers during office hours and less to elastic leisure travelers.[11] Additionally, when companies under intense rivalries face a competitor like Southwest, they give up their discriminatory discounts and set a lower uniform price.[12] Such a model closely aligns with standard Bertrand competition and the theory of price wars, as relevant to my paper.

2.3 Brexit decision

The discussion of Brexit is necessary for the real-world motivation for our model. The UK government's decision to leave the European Union in 2020 introduced uncertainties in international trade, specifically in the automobile industry. Before Brexit, automobile manufacturers largely benefited from the economic integration with the European Union, as it fostered greater investment and resource access. But the possibility of new trade barriers could increase production costs and competition for trade.[13] Following Brexit, the EU-UK Trade and Cooperation Agreement established tariff-free trade for goods meeting specific rules-of-origin requirements. Goods that fail to satisfy these requirements will face tariffs.[14] These regulations are significant for automobile manufacturers because international supply chains can influence whether vehicles qualify for trade free of tariffs.[15]

The distinction between the British and Irish markets is particularly relevant to this paper. Ireland remains a European Union member. Britain, however, isn't a part of the EU anymore, leading to complications in tariff-free trade.[16] The historical literature gives us a real-world motivation for examining asymmetric trade costs under differentiated Bertrand competition. We progress to the idea that, although Brexit didn't impose a universal tariff on an EU firm, the rules-of-origin condition suggests that policy rules can influence pricing decisions. The paper builds on this scenario by introducing a hypothetical tariff faced by the European Union producer in the British market.

[8] Xavier D'haultfoeuille et al., *"Price Discrimination and Online Sales in the Automobile Industry"* (2025), https://www.tse-fr.eu/sites/default/files/TSE/documents/doc/wp/2025/wp_tse_1654.pdf.

[9] Matthew Grennan, "Price Discrimination and Bargaining: Empirical Evidence from Medical Devices," *American Economic Review* 103, no. 1 (February 2013): 145–77, https://doi.org/10.1257/aer.103.1.145.

[10] Dirk Bergemann, Francisco Castro, and Gabriel Weintraub, *Uniform Pricing versus Third-Degree Price Discrimination*, Submission 244 (2019).

[11] Diego Escobari, Nicholas G. Rupp, and Joseph Meskey, "Dynamic Price Discrimination in Airlines," *SSRN Electronic Journal*, ahead of print, 2012, https://doi.org/10.2139/ssrn.2248124.

[12] Matthew S. Lewis, "Identifying Airline Price Discrimination and the Effect of Competition," *International Journal of Industrial Organization* 78 (June 2021): 102761, https://doi.org/10.1016/j.ijindorg.2021.102761.

[13] David Bailey and Lisa De Propris, "Brexit and the UK Automotive Industry," *National Institute Economic Review* 242, no. 1 (October 2017): R51–59, https://doi.org/10.1177/002795011724200114.

[14] European Commission, "The EU-UK Trade and Cooperation Agreement," European Commission, April 30, 2021, https://commission.europa.eu/strategy-and-policy/relations-united-kingdom/eu-uk-trade-and-cooperation-agreement_en.

[15] Abbas Panjwani, "Automotive Industry in the UK Debate," House of Commons Library, September 15, 2023, https://commonslibrary.parliament.uk/research-briefings/cdp-2023-0189/.

[16] Department of Foreign Affairs and Trade, "Brexit and Ireland," Gov.Ie, 2020, https://www.gov.ie/en/department-of-foreign-affairs/campaigns/brexit-and-ireland/.

2.4 Contribution

Existing research has examined third-degree price discrimination and its impacts on market outcomes. However, an additional thought concerns how the availability of price discrimination influences the cross-market spillover of a trade-related shock. Furthermore, much of our literature examines empirical evidence and establishes theoretical models. But we haven't covered much about this unique scenario: what happens to the Nash equilibrium in a duopoly when one firm faces a tariff in one market? Does price discrimination alter the equilibrium price, equilibrium quantities, and the optimal responses? My paper investigates these cross-border pricing spillovers through a differentiated Bertrand model.

3. Methodology

3.1 Model setup and inverse demand

Consider two automobile producers that compete in two geographically separate markets, Britain and Ireland. The producer based in the United Kingdom is referred to as producer U. The producer based in the European Union is referred to as Producer E. The firms' cars are differentiated but can be substitutable. Their inverse demand functions are given:

$$p_U = a - bq_U - dq_E$$

$$p_E = a - bq_E - dq_U$$

where a, b and d are positive parameters such that $b > d$. p_U is the price set by the UK producer; p_E is the price set by the EU producer. q_U Is the quantity of UK goods demanded; q_E is the quantity of EU goods demanded. a is the inverse-demand intercept. It tells us the maximum price consumers are willing to pay when both quantities in each equation are zero. Parameter b measures the magnitude of the quantity effect. For example, when producer U increases quantity, how much does its price drop? The d parameter tells us the cross-quantity effect: how much the competitor impacts the price when their quantity increases.

A one-unit increase in quantity will lower the price by b. A one-unit increase in the competitor's quantity will lower the price by d. The restriction $b > d$ means that the own-quantity effect is stronger than the cross-quantity effect. Therefore, this Bertrand model is differentiable due to the steeper own-product effect of b, while d captures the weaker competitor-product effect.

The products are substitutes because a greater quantity of one product reduces consumers' willingness to pay for the other. $b^2 - d^2 > 0$ implies that the direct-demand system below has a positive denominator, which guarantees the expected negative relationship between a firm's price and its quantity demanded.

3.2 Direct demand functions

Because this is a differentiated Bertrand model, both firms' choice variables should be price rather than quantity. Therefore, quantity should be the main function we plug into our objective function. We must rearrange the current equation into an inverse-demand system where we solve for q_U and q_E as functions of p_U and p_E. We first need to rearrange:

$$bq_U + dq_E = a - p_U$$

$$dq_U + bq_E = a - p_E$$

Rearranging the two equations for q_U and q_E gives the expanded forms.

$$q_U = \frac{(ab - ad - bp_U + dp_E)}{(b^2 - d^2)}$$

$$q_E = \frac{(ab - ad - bp_E + dp_U)}{(b^2 - d^2)}$$

$ab - da = a(b - d)$, so these equations can be simplified further into

$$q_U = \frac{[a(b-d) - bp_U + dp_E]}{(b^2 - d^2)}$$

$$q_E = \frac{[a(b-d) - bp_E + dp_U]}{(b^2 - d^2)}$$

For producer U,

$$\frac{\partial q_U}{\partial p_U} = \frac{-b}{(b^2 - d^2)} < 0$$

$$\frac{\partial q_U}{\partial p_E} = \frac{d}{(b^2 - d^2)} > 0$$

∂ signifies partial differentiation. $\frac{\partial q_U}{\partial p_U}$ means that we find the derivative of the UK quantity demand equation with respect to p_U. Partial differentiation allowed us to differentiate while setting the other choice variable, p_E, constant. This can further be applied to $\frac{\partial q_U}{\partial p_E}$. Derivatives were necessary to find the effect of a marginal price increase on the quantity.

The calculation suggests that if producer U increased its own price by an extra unit, the quantity demanded would decrease by $\frac{b}{(b^2-d^2)}$. And if producer E increases its price, the quantity demanded for UK goods would increase by $\frac{d}{(b^2-d^2)}$. The same result holds symmetrically for the quantity change of producer E.

Now, we look at each firm in each of the two markets. The four market-specific demand functions are shown below. Because Britain and Ireland are assumed to have identical preferences, the parameters will remain the same:

$$q_U^B = \frac{(ab - ad - bp_U^B + dp_E^B)}{(b^2 - d^2)}$$

$$q_E^B = \frac{(ab - ad - bp_E^B + dp_U^B)}{(b^2 - d^2)}$$

$$q_U^I = \frac{(ab - ad - bp_U^I + dp_E^I)}{(b^2 - d^2)}$$

$$q_E^I = \frac{(ab - ad - bp_E^I + dp_U^I)}{(b^2 - d^2)}$$

From here, we examine a few new notations. q_U^B and p_U^B represent quantity demanded and price set by the UK producer in the British market; q_E^B and p_E^B represent quantity demanded and price set by the EU producer in the British market; q_U^I and p_U^I represent quantity demanded and price set by the UK producer in the Irish market; q_E^I and p_E^I represent quantity demanded and price set by the EU producer in the Irish market. The superscripts indicate the geographic market, while the subscripts indicate the producer.

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3.3 Profit maximization with third-degree price discrimination

We first study the case where the firms are allowed to charge different prices to consumers from different markets(third-degree price discrimination).

When firms are allowed to charge different prices in Britain and Ireland, producer U's profit is

$$\Pi_U = (p_U^B - c)q_U^B + (p_U^I - c)q_U^I$$

Π_U represents the total profit of the UK producer. Knowing this, we added the profit from the British market and the profit from the Irish market. Producer U has the same constant marginal cost c in both markets and faces no tariff. Producer E similarly has the same constant marginal production cost c in both markets. However, Producer E faces a tariff only in the British market. So its total profit Π_E is

$$\Pi_E = (p_E^B - c - \tau)q_E^B + (p_E^I - c)q_E^I$$

Since we have a constant marginal cost c, the total production cost for U is $c(q_U^B)$ and $c(q_U^I)$. Therefore, the profit equation is simple. On the other hand, the tariff τ is also a constant per-unit cost on E's British sales, so our total cost would be $(c+\tau)(q_E^B)$. E's effective marginal cost is $(c+\tau)$ in Britain and c in Ireland.

3.4 First-order conditions for producer U

Because profit in Ireland does not depend on p_U^B, differentiating total profit with respect to p_U^B is equivalent to differentiating producer U's profit in Britain. In the British market, U chooses the optimal price p_U^B to maximize its total profit. To maximize, we find the derivative to get the instantaneous rate of change. Then, setting the derivative equal to zero helps us identify a possible maximum or minimum. Finally, we solve for the p_U^B and p_U^I to get our best-response function. By doing so, our equations show us the change in price that amounts to the highest profit(maximum). The second derivative is the extra step to finding whether the FOC yields a maximum or minimum. However, for the mathematical simplicity of this model, we automatically assume that there is only a maximum. So the second-order condition is not needed for further calculation.

$$\frac{\partial \Pi_U}{\partial p_U^B} = q_U^B + (p_U^B - c)(\frac{\partial q_U^B}{\partial p_U^B}) = 0$$

Since $\frac{\partial q_U^B}{\partial p_U^B} = \frac{-b}{(b^2-d^2)}$, substitution gives us

$$\frac{[a(b-d) - bp_U^B + dp_E^B - b(p_U^B - c)]}{(b^2-d^2)} = 0$$

Since the denominator is positive, the numerator should be equal to zero:

$$2bp_U^B = ab - ad + bc + dp_E^B = a(b-d) + bc + dp_E^B$$

We can do the same process for Ireland. Since we have the same parameters and variables, our equations are symmetrical. All we have to do is just replace the price notations:

$$2bp_U^I = ab - ad + bc + dp_E^I = a(b-d) + bc + dp_E^I$$

3.5 First-order conditions for producer E

In Ireland, E is similar to the UK producer because it has no tariffs. We must replace the notation again. So its best-response function is

$$2bp_E^I = ab - ad + bc + dp_U^I = a(b-d) + bc + dp_U^I$$

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In Britain, E's effective marginal cost is $(c+\tau)$. Here there's an extra calculation to do. The tariff falls under marginal cost, turning into $(c+\tau)$.

$$2bp_E^B = ab - ad + bc + b\tau + dp_U^B = a(b-d) + bc + b\tau + dp_U^B$$

3.6 Separation of the British and Irish pricing problems

The British first-order conditions consist of only British prices p_U^B and p_E^B, while the Irish first-order conditions contain only Irish prices p_U^I and p_E^I. There are no cross-market price terms. The original four-equation system can now, therefore, be separated into two independent two-equation systems based on their markets.

Economically, this makes sense because the two firms partake in third-degree price discrimination in each geographic market. The model doesn't contain cross-market demand. This relationship reflects game theory, where the producer based in the UK and the producer based in the EU must choose the optimal price for profit maximization based on the competitor in that same market.

4. Results

4.1 Irish-market equilibrium

Neither firm faces a tariff in Ireland; both have marginal cost c, and both face the same demand structure. As we discussed before, this means they are symmetric. Their first-order conditions are

$$2bp_U^I = ab - ad + bc + dp_E^I = a(b-d) + bc + dp_E^I$$
$$2bp_E^I = ab - ad + bc + dp_U^I = a(b-d) + bc + dp_U^I$$

Solving the two equations simultaneously gives the following expanded equilibrium-price expression for either firm:

$$p_U^{I*} = p_E^{I*} = \frac{[2ab^2 - abd - ad^2 + 2b^2c + bcd]}{(4b^2 - d^2)}$$

$*$ represents the equilibrium. The two producers have identical equilibrium prices in the Irish market. So p^{I*} is the overall equilibrium price in Ireland, representing both producers. Factoring $4b^2 - d^2 = (2b-d)(2b+d)$and the numerator by $(2b+d)$gets us to

$$p_U^{I*} = p_E^{I*} = p^{I*} = \frac{[a(b-d) + bc]}{(2b-d)}$$

Using the expanded price directly in either Irish demand function gives the original substitution form.

$$q_U^{I*} = q_E^{I*} = \frac{\{ab - ad + (-b+d)[\frac{(2ab^2 - abd - ad^2 + 2b^2c + bcd)}{(4b^2 - d^2)}]\}}{(b^2 - d^2)}$$

Using the equal-price condition first makes the same calculation easier:

$$q_U^{I*} = q_E^{I*} = \frac{[a(b-d) - (b-d)p^{I*}]}{(b^2 - d^2)}$$

After factoring $b^2 - d^2 = (b-d)(b+d)$ and substituting p^{I*}, the quantity simplifies to

$$q_U^{I*} = q_E^{I*} = \frac{b(a-c)}{(b+d)(2b-d)}$$

The firms charge the same price and sell the same quantity in Ireland because they have identical marginal costs, face identical demand parameters, and neither firm faces a tariff.

4.2 British-market equilibrium with the tariff

In Britain, U has marginal cost c, while E has effective marginal cost $(c+\tau)$. There is no longer symmetry. The first-order conditions are

$$2bp_U^B = ab - ad + bc + dp_E^B = a(b-d) + bc + dp_E^B$$

$$2bp_E^B = ab - ad + bc + b\tau + dp_U^B = a(b-d) + bc + b\tau + dp_U^B$$

Solving these conditions simultaneously gives us the expanded equilibrium-price expressions.

$$p_U^{B*} = \frac{[2ab^2 - abd - ad^2 + 2b^2c + bcd + bd\tau]}{(4b^2 - d^2)}$$

$$p_E^{B*} = \frac{[2ab^2 - abd - ad^2 + 2b^2c + bcd + 2b^2\tau]}{(4b^2 - d^2)}$$

Factoring the common non-tariff component gives the equivalent forms.

$$p_U^{B*} = \frac{\{(2b+d)[a(b-d) + bc] + bd\tau\}}{[(2b-d)(2b+d)]}$$

$$p_E^{B*} = \frac{\{(2b+d)[a(b-d) + bc] + 2b^2\tau\}}{[(2b-d)(2b+d)]}$$

Since the tariff terms are added instead of multiplied $(2b+d)$, the factor can't be cancelled. These expressions can actually be compared directly with the Irish equilibrium price:

$$p_U^{B*} = p^{I*} + \frac{bd\tau}{(4b^2 - d^2)}$$

$$p_E^{B*} = p^{I*} + \frac{2b^2\tau}{(4b^2 - d^2)}$$

Thus, both firms charge higher prices in Britain when $\tau > 0$, but E's price rises more, as it's the one that faces the tariff. Britain only responds to how E's price is set by the tariff.

Substituting the two British equilibrium prices into the British demand functions first gives the expanded forms.

$$q_U^{B*} = \frac{\{(2b-d)(2b+d)(ab-ad) + b^2cd + 3ab^2d - ad^3 + bcd^2 - 2ab^3 - 2b^3c + b^2d\tau\}}{\{(2b-d)(2b+d)(b^2-d^2)\}}$$

$$q_E^{B*} = \frac{\{(2b-d)(2b+d)(ab-ad) - 2ab^3 + 3ab^2d - 2b^3c + b^2cd - ad^3 + bcd^2 + bd^2\tau - 2b^3\tau\}}{\{(2b-d)(2b+d)(b^2-d^2)\}}$$

Using the no-tariff component and the tariff component gives a much more interpretable equivalent expression.

$$q_U^{B*} = q_U^{I*} + \frac{b^2d\tau}{[(4b^2 - d^2)(b^2 - d^2)]}$$

$$q_E^{B*} = q_E^{I*} - \frac{b(2b^2 - d^2)\tau}{[(4b^2 - d^2)(b^2 - d^2)]}$$

Therefore, the tariff increases the UK producer's equilibrium quantity and reduces the EU producer's equilibrium quantity in Britain. Economically, this makes sense because a higher competitor price gives the UK producer more quantity demanded, while also allowing them to raise their own price, but still remain below their competitor's price. The EU firm is at a disadvantage because it directly faces the tariff, resulting in a higher price. This allows the UK producer to raise both price and quantity in the British market.

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5. Comparative static

5.1 Effect of the tariff on price and quantity

Here, we can more precisely identify the tariff's actual impact on the Nash equilibrium in third-degree price discrimination. Differentiating the British equilibrium prices with respect to τ gives

$$\frac{\partial p_E^{B*}}{\partial \tau} = \frac{2b^2}{(4b^2 - d^2)} > 0$$

$$\frac{\partial p_U^{B*}}{\partial \tau} = \frac{bd}{(4b^2 - d^2)} > 0$$

A greater tariff raises the producer E's effective marginal cost, so it must raise its price in the British market. To be more precise, a one-unit increase in τ raises E's equilibrium British price by $\frac{2b^2}{(4b^2-d^2)}$ units. U doesn't pay the tariff, but its best-response function has a positive coefficient for E's price—when p_E^B rises, U's optimal P_U^B also rises. Therefore, U strategically responds to the price increase, even though it doesn't pay the tariff itself. And because $b > d > 0$, E's price is more strongly impacted than U's.

Differentiating the British equilibrium quantities gives us.

$$\frac{\partial q_U^{B*}}{\partial \tau} = \frac{b^2 d}{[(4b^2 - d^2)(b^2 - d^2)]} > 0$$

$$\frac{\partial q_E^{B*}}{\partial \tau} = \frac{-b(2b^2 - d^2)}{[(4b^2 - d^2)(b^2 - d^2)]} < 0$$

The tariff therefore shifts British demand toward the UK producer. As E's higher effective marginal cost pushes up its price, consumers substitute toward U, so U's equilibrium quantity and relative market share rise. E experiences the opposite effect: its higher price reduces its quantity demanded and relative market share. The absolute effect on E's quantity is larger than the positive effect on U's quantity. This is shown through $b(2b^2 - d^2) > b^2 d$.

5.2 Third-degree price discrimination across geographic markets

Different prices in different geographical locations are third-degree price discrimination because the producers are segmenting consumers into groups based on location. The tariff impacts the competition across these segments. It gives both firms an incentive to set different equilibrium prices if they are allowed to do so.

Although the underlying demand functions are identical, the tariff creates different cost conditions. For E, marginal cost is c in Ireland but $(c + \tau)$ in Britain, producing the price difference.

$$p_E^{B*} - p_E^{I*} = \frac{2b^2 \tau}{(4b^2 - d^2)} > 0$$

U also charges a higher British price even though it does not pay the tariff directly:

$$p_U^{B*} - p_U^{I*} = \frac{bd\tau}{(4b^2 - d^2)} > 0$$

Therefore, identical demand doesn't imply identical equilibrium prices when costs and competitive conditions differ across markets. Producer U can take advantage of producer E's price increase and raise its price as well, meaning it may gain more profit in comparison to when it didn't respond to a tariff, as shown in the Ireland market.

5.3 No third-degree price discrimination: common pricing

To examine how price discrimination affects the firms' pricing strategies, we study common pricing/uniform pricing.

Now suppose each producer must charge the same price in both markets:

$$p_U^B = p_U^I = p_U$$

$$p_E^B = p_E^I = p_E$$

Because the markets have identical demand functions and the same pair of prices is charged in both, each producer sells the same quantity in both markets.

The major change from the price-discrimination case is that each producer no longer chooses a separate British and Irish price. Their total profit is the cumulative sum of the profits in each of the markets. This means that a single price for the producers must be balanced between the British and Irish markets.

$$q_U^B = q_U^I = q_U$$

$$q_E^B = q_E^I = q_E$$

U's total profit becomes

$$\Pi_U = (p_U - c)q_U^B + (p_U - c)q_U^I = 2(p_U - c)q_U$$

E's total profit is

$$\Pi_E = (p_E - c - \tau)q_E^B + (p_E - c)q_E^I$$

Using $q_E^B = q_E^I = q_E$, this simplifies to

$$\Pi_E = 2(p_E - c - \frac{\tau}{2})q_E$$

This is why the EU producer's common-price profit-maximization problem can be interpreted as if it faced an average additional marginal cost of $\frac{\tau}{2}$. The tariff applies in only one of two otherwise identical markets, and common prices imply equal quantities across them, so the two markets receive equal weight in this profit expression.

5.4 First-order conditions and common-price equilibrium

Under common pricing, the direct demand functions are unchanged. In the expanded form used in the derivation,

$$q_U = \frac{(ab - ad - bp_U + dp_E)}{(b^2 - d^2)}$$

$$q_E = \frac{(ab - ad - bp_E + dp_U)}{(b^2 - d^2)}$$

Equivalently, factoring $ab - ad = a(b - d)$,

$$q_U = \frac{[a(b-d) - bp_U + dp_E]}{(b^2 - d^2)}$$

$$q_E = \frac{[a(b-d) - bp_E + dp_U]}{(b^2 - d^2)}$$

Differentiating U's total profit with respect to p_U is

$$2bp_U = ab - ad + bc + dp_E = a(b-d) + bc + dp_E$$

Differentiating E's total profit with respect to p_E gives us.

$$2bp_E = ab - ad + bc + (\frac{b\tau}{2}) + dp_U = a(b-d) + bc + (\frac{b\tau}{2}) + dp_U$$

Solving these two best-response equations simultaneously gives the expanded equilibrium-price expressions.

$$p_U^* = \frac{[2ab^2 - abd - ad^2 + 2b^2c + bcd + (\frac{bd\tau}{2})]}{(4b^2 - d^2)}$$

$$p_E^* = \frac{[2ab^2 - abd - ad^2 + 2b^2c + bcd + b^2\tau]}{(4b^2 - d^2)}$$

Factoring the common non-tariff component gives

$$p_U^* = \frac{\{(2b+d)[a(b-d) + bc] + (\frac{bd\tau}{2})\}}{[(2b-d)(2b+d)]}$$

$$p_E^* = \frac{\{(2b+d)[a(b-d) + bc] + b^2\tau\}}{[(2b-d)(2b+d)]}$$

Relative to the Irish equilibrium under market-specific pricing, the same results can be written more transparently as

$$p_U^* = p^{I*} + \frac{bd\tau}{[2(4b^2 - d^2)]}$$

$$p_E^* = p^{I*} + \frac{b^2\tau}{(4b^2 - d^2)}$$

Where p^{I*} is the Irish equilibrium price from the third-degree price discrimination case we have previously shown.

5.5 Effect of tariff on Irish consumers

The final comparison reflects how third-degree price discrimination in the automobile markets changes the cross-market effect of the British tariff. When price discrimination is allowed, the unique pricing allows the Irish equilibrium equations to contain no tariff term.

$$\frac{\partial p_U^{I*}}{\partial \tau} = 0$$

$$\frac{\partial p_E^{I*}}{\partial \tau} = 0$$

Therefore, the tariff can be isolated to the British market, so it does not affect the prices paid by Irish consumers in this model.

When firms must charge one common price across both countries, however, the British tariff enters the common-price equilibrium. Relative to the Irish prices under third-degree price discrimination, Irish consumers pay

$$p_U^* - p_U^{I*} = \frac{bd\tau}{[2(4b^2 - d^2)]} > 0$$

more for the UK producer's product, and

$$p_E^* - p_E^{I*} = \frac{b^2\tau}{(4b^2 - d^2)} > 0$$

more for the EU producer's product. The effect is stronger for E because it directly faces the tariff on its British sales, while U is affected only indirectly through strategic interaction from equilibrium.

The main, central result is that third-degree price discrimination can prevent an extra cost from spilling over into another market. This was mathematically and economically shown in our model through game theory. But when a regulation imposes a single, uniform pricing system, even part of the British tariff is transmitted to the Irish consumers due to the balancing out of prices across both markets, even though Ireland didn't actually impose a tariff. Likewise, the same happens for the Irish consumers purchasing from the UK firm, but the spillover is smaller since U reacts only indirectly.

6. Discussion and Limitations

6.1 Main theoretical result

The model generates a clear contrast between Market-specific and common pricing. In third-degree price discrimination, the automobile companies could adjust their British pricing in response to the tariff, leaving Irish prices unchanged. Without price discrimination, each firm must choose one price that balances and represents profitability across the British and Irish markets. Therefore, the British tariff enters the common price and results in a cross-market spillover that raises the price for Irish consumers as well. This situation provides a theoretical mechanism applied to a real-life scenario, in which restrictions on geographic price discrimination can affect consumers outside the market in which the original cost shock occurred.[17]

Another important finding concerns the strategic relationship between the two producers. Although producer E is the only firm directly impacted by the British tariff, producer U also adjusts its equilibrium price in response. This occurs because the firms sell differentiated but substitutable products, meaning that one pricing decision influences the demand faced by the competitor.[18] When producer E increases its British price to account for the tariff, producer U has an incentive to increase its own price for profit. However, the increase in producer U's price is smaller than that of producer E. As a result, Producer U experiences an increase in the equilibrium quantity demanded in Britain, while Producer E experiences a decrease. These findings demonstrate that a cost increase affecting one firm can influence the equilibrium decisions of its competitor, even if that competitor doesn't experience the additional cost.

In the differentiated Bertrand model, each producer maximizes profit given its competitor's price. Solving their best-response functions simultaneously yields the Nash equilibrium, where neither producer benefits from changing its price alone. Under third-degree price discrimination, firms choose prices separately in Britain and Ireland. Under uniform pricing, each firm chooses one price across both markets, producing higher Irish prices but lower British prices than under discrimination.

The comparison between the two pricing systems also highlights the importance of geographic market segmentation. Under third-degree price discrimination, firms can respond to different competitive and cost conditions in Britain and Ireland independently. This flexibility allows them to adjust their British prices without changing their equilibrium prices in Ireland. In contrast, uniform pricing prohibits this flexibility, and the tariff imposed on Britain becomes relevant to pricing decisions in Ireland. This shows that market-specific cost shocks can be spilled over to other markets if restrictions or regulations are placed on price discrimination. Irish consumers who were once under the protection of geographic pricing now face the price spikes, and British consumers who were once facing the higher prices from the concentrated tariffs now face a smaller effect.

[17] Robert C. Feenstra, "Symmetric Pass-Through of Tariffs and Exchange Rates under Imperfect Competition: An Empirical Test," *Journal of International Economics* 27, nos. 1–2 (August 1989): 25–45, https://doi.org/10.1016/0022-1996(89)90076-7.

[18] Jeremy I. Bulow, John D. Geanakoplos, and Paul D. Klemperer, "Multimarket Oligopoly: Strategic Substitutes and Complements," *Journal of Political Economy* 93, no. 3 (June 1985): 488–511, https://doi.org/10.1086/261312.

6.2 Limitations

Several limitations should be considered when interpreting these findings. First, the model assumes that Britain and Ireland have identical demand parameters, although consumers in different countries may have different preferences and purchasing behaviors. Second, both producers are assumed to have constant marginal production costs, with the tariff representing the only difference in costs between the two markets. In reality, transportation costs, taxes, and other geographic-specific expenses can influence the equilibrium prices.[19] Third, the model considered only two competing producers for simplicity in calculations, whereas the automobile industry contains numerous firms offering differentiated products.[20] Finally, the findings come from a theoretical model rather than empirical observations of automobile prices. Therefore, the results show how geographic price discrimination works in Nash equilibrium under the model's assumptions, but they don't predict automobile producers' exact pricing behavior in a real-world context.

7. Conclusion

This paper investigated how third-degree price discrimination impacts Nash equilibrium in differentiated markets through a theoretical Bertrand duopoly model. We analyze two automobile firms competing in two markets. By applying game theory and solving the producers' best-response equations simultaneously, the model determined the equilibrium prices and quantities under both geographic price discrimination and uniform pricing. Our results from the equations demonstrate that when third-degree price discrimination is permitted, the British tariff increases both producers' equilibrium prices in Britain, while leaving the Irish equilibrium price unchanged. But when firms are required to charge a uniform price across both markets, the tariff creates a cross-market spillover that increases prices in Ireland despite the absence of a tariff in that market. Additionally, the findings suggest that a tariff imposed on one producer can influence its competitors' optimal pricing decisions through strategic interaction in game theory.

Overall, this research demonstrates that third-degree price discrimination changed how firms respond to market-specific cost shocks and how these shocks impact Nash equilibrium across geographically separated markets. Although the model relies on simplified assumptions, it provides a theoretical foundation for understanding how restrictions on price discrimination, in this case, geographical pricing, can influence competition and pricing outcomes in differentiated markets.

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[19] Andrew Atkeson and Ariel Burstein, "Pricing-to-Market, Trade Costs, and International Relative Prices," *American Economic Review* 98, no. 5 (November 2008): 1998–2031, https://doi.org/10.1257/aer.98.5.1998.

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