# Supply and Demand Determinants of Heterogeneous VAT Pass-Through

Matthieu Bellon, Alexander Copestake*

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**Abstract**

We investigate the substantial variation in the extent to which a rise in value-added tax (VAT) is passed on to consumers. We first extend existing theory to characterize the roles of imperfect competition and product differentiation, then investigate these relationships empirically using a panel of 14 Eurozone countries between 1999 and 2013. We find that consumers pay a larger share of VAT increases when producers face more competitive upstream markets: the higher tax reduces final demand, but this lower demand does not in turn reduce input prices when upstream markets are competitive. Greater scope for quality differentiation also increases pass-through, by reducing the relative price elasticity of demand.

*Keywords:* VAT; Price effect; Pass through; Competition; Product Differentiation

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*Bellon: mbellon@imf.org; Copestake: acopestake@imf.org. The authors would like to thank Aleksandra Zdzienicka, Richard Baldwin, Dora Benedek, Masha Brussevich, Era Dabla-Norris, Michael Keen, Ruud de Mooij, Ferdinand Rauch, Philippe Wingender and Chris Woodruff for their advice, help and support, as well as various seminar participants for useful comments and discussions. They are deeply indebted to Dora Benedek, Michael Keen, Ruud de Mooij and Philippe Wingender for sharing their data. Joey Kilpatrick provided excellent research assistance. The views expressed in this paper are those of the authors and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

# 1 Introduction

Value added taxes raise about a fifth of total tax revenues both worldwide and among the members of the OECD (OECD 2018). Given the relative ease of modifying the rates, they are frequently at the center of policy debates during economic crises – whether for fiscal stimulus (as in the 2009 VAT reform in China) or for domestic revenue mobilization (as in Europe in the 2010s).[1] How the impact of a VAT change will be divided between firms and consumers is critical for policymakers aiming to target their support or to minimize the tax burden for one group relative to the other. Who bears the consequences of a VAT reform is governed by the key parameter of 'pass-through' – the elasticity of consumer prices with respect to the VAT rate (Weyl & Fabinger 2013, Adachi & Fabinger 2022).

There is a vast literature estimating the impact of VAT changes on prices. Yet, estimates of VAT pass-through to consumer prices can vary greatly across studies.[2] Building on Benedek, De Mooij, Keen & Wingender (2020, hereafter BDKW), who study heterogeneity across types of VAT reform, we empirically explore how pass-through is affected by differences in market structure.

To guide our empirical analysis, we extend existing theory to consider how the degree of competition affects pass-through. We build on the framework developed in Weyl & Fabinger (2013) and generalized in Adachi & Fabinger (2022). Compared to these papers, we use specific market structures and restrictions on some functional forms. However, these assumptions allow us to derive new results about the variations of pass-through with respect to the number of firms operating in a market. We additionally go beyond their framework to derive the pass-through and how it varies with demand characteristics in a setting with quality differentiation.

On the supply side, we first consider equally productive firms selling horizontally differentiated goods and competing on price under monopolistic competition. We then examine firms with heterogeneous marginal costs selling homogeneous product under Cournot competition. Finally, we consider a two-sector model where final good producers under perfect competition need inputs from firms that produce under imperfect competition (either monopolistic or Cournot competition). In all three cases, we find that the effect of competition intensity on pass-through depends on whether producers have increasing or decreasing marginal costs. In the intuitive case of increasing marginal costs, pass-through increases with competition because greater competition prevents producers from realizing and passing on savings from scaling down in response to a tax hike. We find that this result is robust under a variety of settings.

On the demand side, we investigate the role of quality differentiation. We generalize the 'quality

[1]More than 80 countries have undertaken VAT reforms so far during the Covid-19 pandemic, ranging from a temporary cut in Germany to stimulate consumer demand, to a tripling of the rate in Saudi Arabia to repair state revenues after the oil price crash (Asquith 2021).

[2]From, for instance, full pass-through (100%) of a cut in the Norwegian VAT on food (Gaarder 2018) to 9.7% for a cut in the French VAT on sit-down restaurants (Benzarti & Carloni 2017).

ladder' model in Khandelwal (2010) to allow for substitution or complementarity effects between consumer valuation of affordability and quality. We find that variation in pass-through depends on price-quality complementarity. For products with longer 'quality ladders', where differences in quality are starkest, we show that pass-through is larger when there is a high enough degree of price-quality complementarity. In this case, consumers faced with higher prices from higher taxes ask for objects of greater quality, resulting in even higher prices. With less complementarity, consumers prefer lower quality and a smaller price increase.

We investigate these relationships empirically using a panel of 14 Eurozone countries between 1999 and 2013. Following the methodology developed by BDKW, we regress country- and product-specific price changes on reforms of the associated value added tax, as well as various fixed effects and control variables. We enrich the specification by interacting the reforms with various measures of competition and scope for quality. With over 800 VAT changes, and by comparing products across countries and countries across products, we can quantify the effects of market structure on pass-through more accurately and more systematically than is possible with product-specific or economy-wide cross-country studies.

Consistent with our theory, we find that pro-competitive regulation in supplier markets has a substantial impact on pass-through. A one standard deviation rise in the competition-friendliness of regulation – roughly equal to the difference between Austria and relatively uncompetitive Italy in 2013 – increases pass-through by up to 66%. We benchmark this effect against other supply-side characteristics, and find that it is more significant and more important. This is also significant in a historical context: liberalizing reforms over the last thirty years have substantially increased the competition-friendliness of regulation in European product markets, so our findings imply that VAT cuts today will be passed on to consumers substantially more than in the past.

We also find that greater scope for quality differentiation increases pass-through. Our empirical results are consistent with our theoretical framework and suggest the existence of complementarity between preferences for quality and price. Intuitively, the wider the variation in quality, the greater consumers' desire to avoid a reduction in quality, so the larger the price rise they will accept in response to a tax hike. While the estimated size of the effect is less consistent across specifications, it is at least as large as that for upstream regulation.

Together our results imply that market structure should be an important consideration when reforming VAT. For a government seeking to mobilize revenue through raising VAT (e.g. Saudi Arabia in May 2020), a greater share of the burden of higher taxes will fall on consumers relative to firms for products with higher upstream competition or for products characterized by a wider quality range. For a government using a VAT cut to stimulate consumption (e.g. Germany in June 2020), or to support firm profits, the effects are the opposite. Firms will retain more of the VAT cut in higher markups, and consumers will experience smaller price reductions, the less competitive the upstream sector or the narrower the range of product quality.

Our results are robust to a range of considerations. Alongside various alternative specifications, we assess the impact of advanced announcement of reforms, drawing on announcement dates compiled by (Amaglobeli et al. 2018), and variation across the business cycle and between VAT increases versus decreases. We also control for competitiveness at the same level (rather than upstream) in various ways, and find no significant impact on our results.

**Literature:** A substantial literature exists estimating the effects of specific tax changes. Carbonnier (2007) considers the impact of decreasing VAT on cars and housing repairs in France; Benzarti & Carloni (2017) consider a VAT cut for French restaurants, Mariscal & Werner (2018) consider the impact of differences in VAT for Mexican border cities, and Gaarder (2018) considers a cut in the VAT on food in Norway. Bachmann et al. (2021) examine the recent temporary VAT cut in Germany. A few studies consider effects across multiple countries: while Benzarti et al. (2017) focus on changes in the VAT on hairdressing in Finland, they also consider all VAT changes across EU member states, and Andrade et al. (2015) consider the impact on French export prices of VAT changes in several destination markets. As with BDKW, who constructed the core dataset of European VAT rates used in this paper, we draw on a broad range of countries and consumption categories to enable tighter controls and produce more general results.

Other studies of upstream reform have found substantial downstream effects on firms. Arnold et al. (2016) construct a measure of services liberalization in India, and find a strong positive effect on the productivity of manufacturing firms intensive in the liberalizing services. Bertrand et al. (2007) find similar effects on French manufacturing firms of banking deregulation in the 1980s.[3] Turning to the empirical literature on product quality, we use the 'quality ladder' measure derived in Khandelwal (2010) because it can produce estimates for a broad class of consumption categories (at the cost of assumptions on the structure of demand). In contrast, papers using directly observed quality measures tend to be confined to a limited range of products (e.g. rugs, wine or coffee respectively in Atkin et al. 2017, Chen & Juvenal 2016, Macchiavello & Miquel-Florensa 2017), so cannot be used to study VAT reforms which affect a wide range of products simultaneously.

The rest of this paper proceeds as follows. The next section outlines the theoretical motivation, then Section 3 describes the data and outlines the empirical strategy. Section 4 presents the results, and Section 5 addresses their robustness. Section 6 concludes. The Appendix and Online Appendix provide detailed theoretical derivations and additional results and robustness checks.

[3]Our measure of upstream regulation, *Regimpact* from the OECD, has been widely used to study the impacts of regulation on productivity (Amable et al. 2007, Arnold et al. 2008, Bourlès et al. 2013, Cette et al. 2013, 2014, Havik et al. 2008, International Monetary Fund 2015, Yahmed & Dougherty 2012), on competitiveness (Braila et al. 2010), and on firms' input sourcing decisions (Di Ubaldo & Siedschlag 2018). To the best of our knowledge the indicator has not previously been used to investigate VAT pass-through.

# 2 Theoretical Motivation

We examine the role of market structure and consumer preferences in determining pass-through by considering five specific cases, building on the framework developed in Weyl & Fabinger (2013) and Adachi & Fabinger (2022). While all cases start with strong assumptions regarding functional forms, the end of the next subsection discusses results under more general settings.

Consider a good $i$ with consumer price $p_i$ and producer price $\widetilde{p}_i$ subject to ad valorem tax-exclusive rates $\tau_i$, meaning that $p_i = \widetilde{p}_i(1+\tau_i)$. As is standard, we define the degree of pass-through to the consumer as the proportionate response of the consumer price to an increase in the tax factor:

$$\gamma^i = \frac{\partial \ln p_i}{\partial \ln (1+\tau_i)} \tag{1}$$

We investigate the factors determining $\gamma^i$ in the following settings. All proofs are in Appendix A.

## 2.1 Imperfect competition in a downstream sector

We consider a single-good market in which there are $N$ producers. We infer the role of greater competition by studying the impact of having more producers. Every firm indexed by $n$ produces a quantity $q_n$ under the cost function

$$C_n(q_n) = a + c_n q_n + \frac{b}{2} q_n^2 \qquad \text{with } a > 0;\ c_n > 0; \tag{2}$$

where $b < 0$ corresponds to decreasing marginal costs and $b > 0$ corresponds to increasing marginal costs. We examine two different market structures in turn.

First, we consider the case of monopolistic competition where each firm produces a different variety of the good and competes on price. To allow for tractable aggregate results, we assume in this case that all firms are equally productive ($c_n = c$ for all $n$). Preferences over the different varieties follow the standard Dixit-Stigliz form and we assume that aggregate demand $Q = \left(\int_1^N q_n^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$ is isoelastic, implying that $q_n = \left(\frac{p_n}{P}\right)^{-\sigma} \frac{A}{P}$, with $A > 0$, the elasticity of substitution across varieties $\sigma > 1$ and $P$ the price index which takes the form $P = \left(\int_1^N p_n^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$.[4] Thus, each firm chooses its price $\widetilde{p}_n$ to maximize profits $\pi_n = \widetilde{p}_n q_n - C(q_n)$ subject to the demand for their variety. Because all firms are identical, the prices they choose are identical and we can drop the subscript $n$ for prices. We also show in the appendix that tax pass-through is the same whether it is computed at the individual or aggregate price level.

Second, we consider a more general case with heterogeneous firms that have different production

[4] As we show in the appendix, this demand function stems from a simple utility maximization problem.

costs. We use $q$ to denote the average quantity per firm and we find convenient to define the average marginal cost as $\bar{C}' \equiv \frac{1}{N}\sum_n C_n = \frac{1}{N}\sum_n c_n + bq$, which is a function of $q$. We assume that the mean of the cost distribution $\bar{c} = \frac{1}{N}\sum_n c_n$ is fixed and independent from $N$.

In this second case, there is no differentiation and firms are competing in quantities at a common price $\widetilde{p}$ under Cournot competition.[5] Total demand $Q = \sum_n q_n$ is assumed to be isoelastic and such that $p(Q) = A'Q^{-\beta}$, with parameter restrictions ensuring the existence, stability and uniqueness of the Cournot-Nash equilibrium.[6] Each firm $n$ chooses its output $q_n$ independently to maximize profits $\widetilde{p}_n(q_n)q_n - C_n(q_n)$.

**Proposition 1** *In the Monopolistic competition and Cournot competition cases, the pass-through and its derivative with respect to $N$ take the form*

$$\gamma = \frac{1}{1+\frac{\varepsilon_d}{\varepsilon_s}} \tag{3}$$

$$\frac{\partial\gamma}{\partial N}\frac{N}{\gamma} = q\varepsilon_s'\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q} \tag{4}$$

*where $\varepsilon_d$ is the elasticity of demand ($\varepsilon_d^{monopolistic} = \sigma$ and $\varepsilon_d^{cournot} = 1/\beta$), $\varepsilon_s$ is the inverse elasticity of the average marginal cost (i.e., the elasticity of supply, with $\varepsilon_s = (\bar{c}+bq)/(bq)$). In both cases, the average output per firm decreases with the number of firms $N$. Therefore, the pass-through increases wit $N$ only if and only if $b > 0$, when marginal costs are increasing.*

Proxying 'competitiveness' by the number of firms in the market, we thus show that the impact of competition on pass-through depends on the cost functions. For any cost function, lower demand resulting from higher taxes induces producer to scale back production ($\partial q/\partial N < 0$). With increasing marginal costs ($\varepsilon_s > 0$), a reduction in scale implies some savings on production costs which, in turn, allows for lower producer prices.[7] Greater competition dampens producer costs adjustment. When there are only few firms, they have stretched production capacities and a reduction in scale yields large savings. When many firms compete, they are small, and savings from scaling down are smaller and producers are less able to lower their prices in compensation for higher VAT. Therefore, greater competition with increasing marginal costs implies a greater pass-through.

Conversely, in the case of decreasing marginal costs, the reduction in demand induced by a higher VAT rate has a different effect on producers. Faced with higher marginal costs, producers choose to sell at higher producer prices and pass-through is greater than one ($\gamma > 1$ when $\varepsilon_s < 0$). Once again, greater competition dampens producer price adjustments. Thus, greater competition with decreasing marginal costs implies a lower pass-through.

[5]This case was previously described in Dierickx et al. (1988).
[6]See footnote 4.
[7]This can be seen because $\gamma < 1$ when $\varepsilon_s > 0$.

The derivations in the appendix show that **proposition 1** continues to hold even after we relax some assumptions. In the case of monopolistic competition, the results are valid for any cost function (linear or not). The derivative of the pass-through has the sign of $-\varepsilon_s'$. In other words, pass-through increases with $N$ when the slope of the marginal costs is positive and steep enough, and/or when marginal costs are convex enough.

For both cases, we also examine the variations of pass-through when the elasticity of demand varies with total output.[8] We show in appendix that the average output continues to decrease with the number of firms if and only if the elasticity of demand decreases or does not increases too rapidly with output.[9] Under this condition, we show that the pass-through behaves as described in **proposition 1** as long as the absolute value of the derivative of the elasticity of supply ($|\varepsilon_s'|$) is large enough. In other words, we can generalize the results in **proposition 1** for marginal costs increasing or decreasing fast enough.

We investigate in the empirical section whether the impact of competition on pass-through is consistent with increasing or decreasing marginal costs.

## 2.2 Imperfect competition in the upstream sector

We now examine the case of two sectors, with perfect competition in the downstream sector selling the final good and with Cournot or monopolistic competition in the upstream sector. Demand for the final good is characterized by $p_F(Q_F) = A'Q_F^{-\beta}$ and is the same as in the previous case with Cournot competition. Assuming perfect competition in the downstream sector allows us to consider a representative final good producer which maximizes profits $\widetilde{p}_F Q_F - p_I Q_I$ by choosing a quantity $Q_F$ to produce given the input cost function $Q_I = d(1-\rho)Q_F^{\frac{1}{1-\rho}}$ with $0 < \rho < 1$ and $d > 0$. Final good producers take the producer price $\widetilde{p}_F = \frac{p_F}{1+\tau}$ as given.

Solving the final good producer maximization problem to get input demand, we show in the appendix that the demand function in the upstream sector is also isoelastic and a function of the final good price: $p_I = \widetilde{p}_F d^{\rho-1}(1-\rho)^{\rho} Q_I^{-\rho}$.

For the sake of clarity, we assume that inputs $Q_I$ produced in the upstream sector are only consumed by final good producers and that inputs are not taxed (producer and consumer prices are then the same, meaning that $\widetilde{p}_I = p_I$). Each input producer $n$ maximizes profits $\widetilde{p}_I(Q_I)q_{I,n} - C_n(q_{I,n})$ subject to the isoelastic input demand function. As before, upstream firms internalize their impact on total production ($Q_I = \sum_n q_{I,n}$ in the case of Cournot competition and $Q_I = \left(\int_1^N q_{I,n}^{\frac{\sigma-1}{\sigma}} dn\right)^{\frac{\sigma}{\sigma-1}}$ in the case of monopolistic competition) and the cost function follows equation (2). Consequently,

[8] In our monopolistic competition setting, the elasticity of demand is the inverse of the concept of 'relative love for variety' introduced in Zhelobodko et al. (2012).

[9] The elasticity of demand decreases with output for all standard utility functions. This case corresponds to 'increasing love for variety'.

operations in the upstream sector are very similar to those described in the single sector cases in the previous section.

**Proposition 2** *In the 2-sector cases with Cournot or monopolistic competition in the upstream sector and perfect competition in the final good sector, pass-through in the final good sector and its derivative take the form*

$$\gamma_F = \frac{1}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}\right)} \tag{5}$$

$$\frac{\partial \gamma_F}{\partial N}\frac{N}{\gamma_F} = \varepsilon'_{sI}\frac{\partial q_I}{\partial N}\frac{\varepsilon_{dF}\varepsilon_f}{\tilde{\varepsilon}_s^2}\gamma_F N \tag{6}$$

*where* $\varepsilon_{dF} = 1/\beta$ *is the elasticity of demand for the final good,* $\varepsilon_{sI}$ *is the inverse elasticity of the average marginal cost (with* $\varepsilon_{sI} = (\bar{c}+bq)/(bq)$ *as before),* $\varepsilon_f = 1/(1-\rho)$ *is the elasticity of the cost function, and* $\varepsilon_{sF} = (\rho-1)/\rho$ *is the inverse elasticity of the final good producer's marginal cost. In both cases, the average output per input producer decreases with the number of firms* $N$*. Therefore, the pass-through increases wit* $N$ *only if and only if* $b > 0$*, when marginal costs are increasing.*

We obtain the same result as in the previous section. An increase in VAT lowers demand for the final good, and now also reduces demand for upstream inputs. In the case of increasing marginal costs ($b > 0$), a reduction in scale for input producers means lower cost, which are then passed through to input prices. Cheaper input costs allow for lower producer prices in the downstream sector. As in the previous case, greater competition dampens the variation in producer costs in response to VAT rate changes. With more firms competing, production capacities are not overly stretched, implying smaller savings from scaling down, and a lower reduction in producer prices. The results are the same as in the single sector case: pass-through increases (decreases) with competition when marginal costs are increasing (decreasing). We investigate in the empirical section whether the impact of competition in upstream sectors on pass-through is consistent with increasing or decreasing marginal costs.

## 2.3 Differences in scope for quality in the final good

We now examine a sector in which consumers make 'discrete choices', meaning that they choose at most one of the competing products. There are many varieties indexed by $n$ that differ along a horizontal and a vertical dimension as in Khandelwal (2010). Horizontal differentiation is assumed to randomly appeal more to some consumers than others and to be costless, implying that all varieties are consumed in equilibrium.[10] Following standard practice in the discrete choice literature, horizontal characteristics denoted $\xi_{nk}$ are assumed to be distributed i.i.d. type-I extreme value with

[10] Costless horizontal differentiation means that varieties differ on some characteristics, like color, that appeal more to some consumers than others while having no impact on production costs and no relation to prices.

mean zero.

By contrast, vertical differentiation, i.e. 'quality', is costly to produce but is regarded by all consumers as superior: holding prices fixed, all consumers would prefer higher quality objects. Each consumer $k$ knows her valuation of horizontal ($\xi_{nk}$) and vertical ($\lambda_n$) characteristics of every variety and chooses the variety $n$ that gives her the highest indirect utility.

$$V_{nk} = \delta_n + \xi_{nk}, \qquad \text{with } \delta_n \equiv \left(\theta\lambda_n^{\psi} - p_n^{\psi}\right)^{1/\psi} \qquad \text{and } \psi < 1 \tag{7}$$

where $\delta_n$ represents the mean consumer valuation of variety $n$. $\delta_n$ increases with quality and decreases with price.[11] The parameter $\psi$ controls the degree of substitution between price and quality, with higher $\psi$ indicating the two characteristics are more easily substituted – i.e. consumers are happy to sacrifice quality for a lower price – while a lower, possibly negative, $\psi$ indicates greater complementarity. In other words and as we show in the appendix, the marginal willingness to pay for quality increases with the quality-price ratio when $\psi$ is positive while it decreases with the quality-price ratio when $\psi$ is negative. Greater values of the parameter $\theta$ indicate a longer 'quality ladder', as defined in Khandelwal (2010), and imply that firms have incentives to produce higher quality.

Each firm $n$ produces a variety subject to a marginal cost function that is increasing with quality, $w + \frac{\lambda_n}{Z}$. Under the distributional assumption, the market share of variety $n$ is given by the familiar logit formula $m_n = \frac{e^{\delta_n}}{\sum_m e^{\delta_m}}$. We assume that the market is characterized by monopolistic competition with a sufficiently large number of firms so that no one firm can influence the market equilibrium prices and qualities. A firm $n$ maximizes profits by choosing the price and quality.

$$\max_{\widetilde{p}_n, \lambda_n} \left[\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right] \frac{e^{\delta_n}}{\sum_m e^{\delta_m}} \tag{8}$$

**Proposition 3** *In the case of discrete choices with monopolistic competition, pass-through takes the form*

$$\gamma = 1 + \frac{-\psi/(1-\psi)}{\theta^{\frac{1}{\psi-1}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{\psi-1}} - 1} - \frac{1}{1 - \theta^{\frac{1}{1-\psi}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} + w(1+\tau)\left(1 - \theta^{\frac{1}{1-\psi}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1}{\psi}}} \tag{9}$$

*Furthermore, the pass-through decreases with the length of the quality ladder $\theta$ when $0 < \psi < 1$, in the substitution case when the marginal willingness to pay for quality increases with the quality-price ratio. Conversely, pass-through increases with $\theta$ when $\psi$ is negative enough, for example when $\psi < -\frac{1}{w(1+\tau)}$*

Thus, the effect of quality on VAT pass-through depends on $\psi$, the degree of substitution-complementarity

[11] Equation (7) is a generalization of the specification in Khandelwal (2010) which would be obtained when $\psi \to 1$.

between consumer valuations of price and quality. In the substitution case when $\psi > 0$ (as in Khandelwal (2010)), for a given increase in consumer price resulting from a tax hike, consumers prefer a mitigation in the price increase at the expense of lower quality. Producers respond accordingly and pass-through is lower. The opposite is true in the complementarity case when $\psi < 0$ is negative enough: consumers prefer to tolerate a larger price increase and to be compensated with relatively higher quality. Those effects are magnified by the scope for quality, or 'quality ladder', $\theta$. Therefore, pass-through decreases with the quality ladder in the substitution case, while the opposite is true in the complementarity case. We investigate in the empirical section whether the effect of the scope for quality on pass-through is consistent with price-quality complementarity or substitution.

# 3 Data and Empirical Specification

Our primary data are monthly VAT rates across European countries and consumption categories constructed by BDKW using the European Commission publication *VAT Rates Applied in the Member States of the European Union* and additional publications by the International Bureau for Fiscal Documentation. The distribution and characteristics of VAT reforms across countries are summarized in Tables B.1 and B.2 in the Appendix.[12] All the countries studied are in the Eurozone, reducing distortions due to differing exchange rates or monetary policies.[13] Data on monthly prices are from Eurostat's Harmonized Index of Consumer Prices, categorized according to the 'Classification of Individual Consumption According to Purpose' (COICOP). We follow BDKW in limiting our sample to those categories for which prices are sufficiently market-driven – excluding, for example, rental accommodation, electricity and healthcare.

We measure the competition-friendliness of regulation in upstream non-manufacturing industries using the annual *Regimpact* indicator from the Organization for Economic Co-operation and Development (Conway & Nicoletti 2006, Égert & Wanner 2016, Koske et al. 2015). This uses predetermined country-specific input-output weights $w_{jk}$ to combine survey-based measures of anti-competitive regulation in several upstream non-manufacturing industries ($REGNMI_{jt}$), producing a measure

[12] There are no reclassifications or other rate changes among the small number of products at the zero rate in our sample, but we retain these observations to improve precision.

[13] For instance, the influence of common monetary policy changes on pass-through will be removed by time fixed effects in the regressions.

of the degree of regulation affecting final output sectors:[14]

$$Regimpact_{ikt} = \sum_{j=1}^{J} REGNMI_{jt} \cdot w_{jk} \tag{10}$$

where $k$ denotes the output sectors of interest and $j$ denotes upstream non-manufacturing sectors.[15] The distribution in product market regulation across consumption categories is shown in Figure B.1 in the Appendix. The trends in regulation are shown in Figure B.2 in the Appendix; in general regulation became much more pro-competitive over the period.

We use the scope for product differentiability derived in Khandelwal (2010). The scope for quality, or 'quality ladder', is backed out from price and quantity data. High market share conditional on price suggests that a product is high quality and long quality ladders correspond to products with a large dispersion in estimated quality. Khandelwal constructs his product-level measure using trade data on goods, which means 'quality ladder' estimates are only available for the subset of good industries and do not vary across countries.[16] This prevents us from using the full price and VAT dataset, and some controls, with this measure – so we also perform several robustness checks to verify that our results are not driven by the restrictions related to these data limitations. The distribution of quality scope across consumption categories is shown in Figure B.3 in the Appendix.

We use a variety of approaches to control for same-level market competitiveness. Our baseline specification uses a Herfindahl-Hirschman index, constructed using firm-level data from Orbis:

$$Concentration_{ikt} = \sum_{f} s^2_{fikt} \tag{11}$$

where $s$ is the market share of firm $f$ in country $i$, industry $k$ and month $t$.[17] One limitation of this approach, common to many studies using such data, is that it only takes into account sales by domestic firms. We thus supplement this control with a measure of openness to trade, using annual

[14] The lower the *Regimpact* score, the more competition-friendly the regulatory environment. For instance, one question on 'entry regulation' for the electricity industry sub-indicator is: "What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier?" (Conway and Nicoletti, 2006). The lack of any threshold scores zero, a threshold less than 250 gigawatts scores one, 250-500 gigawatts scores two, etc. We use the 'wide' version of the indicator, which contains the broadest range of upstream non-manufacturing industries. The precise industries that it covers, and the categories upon which they are scored to generate the aggregate REGNMI indicator, are shown in Figure B.4 in the Appendix. We use the version with country-specific weights to account for differences in input-output patterns across countries.

[15] Figure I in the Online Appendix highlights the pervasive connections between the key upstream non-manufacturing sectors and the broader economy.

[16] Given the lack of quantity data over our whole period, we use only cross-sectional product-wise variation in quality.

[17] Given the relatively broad nature of the COICOP categories, we calculate two HHIs, using markets defined at both the 2-digit and 4-digit NACE levels, in the latter case then averaging across the several HHIs within COICOP categories. Results are similar in both cases.

data from UN Comtrade and consumption data from Eurostat:[18]

$$Openness_{ikt} = \frac{Imports_{ikt} + Exports_{ikt}}{Consumption_{ikt}} \tag{12}$$

A second limitation of the Orbis HHIs is that sales are allocated to markets by firm classification – whereas multi-product firms may sell in many different product markets. We therefore construct an alternative product-level HHI using the product-level trade data, using the range of import origins to proxy for market concentration:[19]

$$ImportConcentration_{ikt} = \sum_{c=1}^{N} s_{ickt}^2 \tag{13}$$

where:

$$s_{ickt} = \frac{M_{ickt}}{\sum_{c=1}^{N} M_{ickt}} = \frac{\text{Imports into } i \text{ from } c}{\text{Total imports into } i} \tag{14}$$

Our results are consistent across these various combinations of controls. This reassures us that, despite the imperfection of each individual measure, we are effectively accounting for variation in competitiveness in the downstream sector.

We standardize the various measures so that their impacts are comparable. The four measures in our main specification are only weakly correlated, as shown in Table B.3 in the Appendix. We also match VAT reforms in the BDKW data to the IMF's new Tax Policy Reform Database (Amaglobeli et al. 2018), which contains announcement dates. Summary statistics for those VAT changes that we can match to announcement dates are shown in Appendix Table B.4. Lastly, we use consumption data from Eurostat to weight observations by their consumption share, and total value added from EU KLEMS in a robustness check. Overall, we use an unbalanced panel of approximately one hundred thousand observations spanning January 1998 to December 2013. The variables are summarized in Table B.5 in the Appendix.

Our empirical approach builds on BDKW, estimating pass-through from VAT changes to price rates

[18] We use the BACI refinement of the Comtrade database, compiled by CEPII, which cleans and harmonizes the data through a series of procedures described in Gaulier & Zignago (2010).

[19] Assuming that firms are evenly distributed across producing countries, a high degree of concentration observed among import origins is a necessary consequence of high market concentration among firms, though not sufficient to guarantee it. For instance, a market dominated by a single foreign firm producing in one country would have $ImportConcentration_{ikt} = 1$, yet having $ImportConcentration_{ikt} = 1$ is also compatible with there being substantial competition in the supply of the good – if all those firms competing are located in the same country.

by regressing country-product prices on taxes:[20]

$$\begin{aligned}\Delta \ln(p_{ikt}) = \beta_0 &+ \sum_{j=-6}^{6} \beta_{1j} \cdot \Delta \ln(1+\tau_{ikt+j}) \\ &+ \sum_{j=-6}^{6} \boldsymbol{\beta}_{2j} \cdot \Delta \ln(1+\tau_{ikt+j}) \cdot \mathbf{X}_{ikt} \\ &+ \boldsymbol{\beta}_3 \cdot \mathbf{X}_{ikt} + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt} \end{aligned} \tag{15}$$

where $p_{ikt}$ denotes the price of product $k$ in country $i$ in month $t$ and $\tau_{ikt+j}$ represents the VAT rate in country $i$ for product $k$ in month $t$. The coefficients of interest $\beta_{1j}$ capture the average pass-through across products at different horizons $j$, while $\boldsymbol{\beta}_{2j}$ measures deviations from the mean pass-through across several covariates. Specifically, the sequences of $\beta_{1j}$ and $\boldsymbol{\beta}_{2j}$ capture the magnitude of pass-through adjustments at different times around the reform dates, i.e. at a number of months j before and after the reform date. Summing these terms reveals the cumulative pass-through over a given time frame.[21] The coefficients $\varphi_{it}$, $\varphi_{kt}$ and $\varphi_{ik}$ are country-time, product-time, and country-product fixed effects, and $\epsilon_{ikt}$ is the error term.[22] $\mathbf{X}_{ikt}$ denotes country-product-time covariates of interest, specifically product market regulation, quality range, openness to trade, and import concentration. In our main specification we de-seasonalize and de-trend all price indices, weight observations by their consumption share, and cluster standard errors at the country-product level to account for possible autocorrelation in the error term.[23]

# 4 Results

This section presents our two main results. The first part, on product market regulation, tests the theory of Section 2.1 and Section 2.2, as summarized in Propositions 1 & 2. The second part, on quality scope, tests the theory of Section 2.3, as summarized in Proposition 3. Various robustness checks and additional results are included in Section 5 and the Appendix.

[20]BDKW in turn follow Poterba (1996) and Besley & Rosen (1999), who consider city-level sales taxes in the USA.

[21]In this paper we focus on the medium-run, i.e. a 12-month window centered on the date of the reform, as we do not find significant effects outside this window.

[22]We also report results using separate country, product and time fixed effects, and no fixed effects, as in BDKW. Our preferred specification includes all three interaction fixed effects, as shown, since this accounts for all industry trends and country-specific macroeconomic conditions.

[23]We de-seasonalize and de-trend because, as in BDKW, our time-indexed fixed effects only remove trends in the first difference of prices, not the levels of prices. Specifically, we regress log prices on month-of-year dummies and linear to quartic time trends, then substitute raw prices with the predicted values. Our main results are very similar when using raw prices, but with slightly larger standard errors.

## 4.1 Product market regulation

Table 1 shows results from the main specification in the full dataset; column (1) shows results with no fixed effects, column (2) shows results with individual fixed effects, and column (3) uses interaction fixed effects. The first four estimates correspond to $\beta_1$ in the main estimating equation above – they estimate the relationship between changes in the VAT rate and changes in prices, i.e. baseline pass-through. 'Pre-Reform' refers to the total effect across the six months preceding the VAT change, and 'Post-Reform' refers to that across the six months afterwards; 'Contemporaneous' refers to effects in the month of the reform, and 'Total' is the sum of effects over the whole window. The remaining estimates correspond to different elements of $\boldsymbol{\beta}_2$, and in turn reflect the impact of variation in the elements of $\boldsymbol{X}_{ikt}$ – specifically, $Openness_{ikt}$, $Concentration_{ikt}$ and $Regimpact_{ikt}$ – on pass-through.[24] Average baseline pass-through of a VAT rise to prices is 33% in column (3).[25] As in BDKW's estimates, this effect is almost entirely driven by the contemporaneous pass-through effect – i.e. by the impact on prices in the month that the reform is introduced. A one standard deviation fall in *Regimpact* (i.e. a one standard deviation rise in the competition-friendliness of upstream regulation, equivalent to the gap between Italy and relatively competitive Austria in 2013) raises pass-through by a further 22 percentage points, a 66 percent increase in pass-through.

These effects are more significant and more important than those of same-level competitiveness, shown in the Total rows for Openness and Concentration in Table 1. This finding is robust across alternative measures of same-level competitiveness, such as defining the relevant market at the 4-digit level when calculating the Orbis HHI, or when instead constructing the concentration measure using import origins (Tables I and II in the Online Appendix). This suggests that the theoretical mechanism outlined in Section 2.2 is stronger than that in Section 2.1, and aligns with findings elsewhere that upstream reforms affecting inputs can have substantial downstream effects (e.g. Amiti & Konings 2007, Arnold et al. 2016, Bertrand et al. 2007). A full analysis of the conditions under which such upstream effects can amplify further downstream, rather than decay into insignificance, is beyond the scope of this paper (for details, see e.g. Acemoglu et al. 2012).

Figure 1 plots the cumulated values of the estimated coefficients $\beta_{1j}$ for the 12 months surrounding a VAT change for the specification with the most stringent set of fixed effects. The dashed line shows pass-through over time for a consumption category with exactly average levels of upstream product market regulation, openness to trade, and market concentration. There is little pass-through

[24] Pre-Reform, Contemporaneous, Post-Reform and Total effects are estimated for each of Openness, Concentration and *Regimpact*. Across the first three, the $p$-values for Openness and Concentration are greater than 0.15 in all but one case (specifically Concentration-Contemporaneous in model (2)), so these rows are omitted from the results tables for brevity. Under the tighter fixed effects of model (3) the strongest effect again corresponds to Concentration-Contemporaneous, with a $p$-value of 0.244 – i.e. only very weak evidence of any effect.

[25] This is close to BDKW's main estimate of 25%; it differs slightly because (i) we use only the subset of their observations for which measures of regulation, openness and concentration are available, and (ii) they sum over a 24-month window around the reform.

TABLE 1: Estimates of pass-through heterogeneity

| | | Dependent variable: change in log prices | | |
|---|---|---|---|---|
| | | No Fes | Individual FEs | Interaction FEs |
| Baseline $\beta_1$ | Pre-Reform | 0.193 | 0.182* | 0.0386 |
| | – i.e. $\sum_{j=1}^{6} \beta_{1j}$ | (0.147) | (0.059) | (0.504) |
| | Contemporaneous | 0.338*** | 0.336*** | 0.263*** |
| | – i.e. $\beta_{10}$ | (0.000) | (0.000) | (0.001) |
| | Post-Reform | 0.177 | 0.148 | 0.0321 |
| | – i.e. $\sum_{j=-6}^{-1} \beta_{1j}$ | (0.106) | (0.144) | (0.649) |
| | Total | 0.709*** | 0.666*** | 0.334*** |
| | – i.e. $\sum_{j=-6}^{6} \beta_{1j}$ | (0.000) | (0.000) | (0.001) |
| Openness: | Total | 0.418 | 0.297 | -0.195 |
| | | (0.445) | (0.580) | (0.618) |
| Concentration: | Total | 0.34 | 0.385 | 0.183 |
| | | (0.222) | (0.145) | (0.192) |
| *Regimpact*: | Pre-Reform | -0.0887 | -0.0525 | 0.062 |
| | | (0.410) | (0.460) | (0.370) |
| | Contemporaneous | -0.185*** | -0.215*** | -0.254*** |
| | | (0.007) | (0.000) | (0.001) |
| | Post-Reform | -0.0469 | -0.0439 | -0.0298 |
| | | (0.579) | (0.531) | (0.555) |
| | Total | -0.321** | -0.311*** | -0.222** |
| | | (0.036) | (0.007) | (0.019) |
| FEs | | None | i,k,t | it,kt,ik |
| Clustering | | None | ik | ik |
| N | | 99361 | 99361 | 99361 |

*Notes:* $p$-values in parentheses. * $p$ <0.10, ** $p$ <0.05, *** $p$ <0.01. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, openness and market concentration are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. Pre-Reform, Contemporaneous and Post-Reform effects are also estimated for Openness and Concentration, but are not significant so omitted for conciseness.

prior to the change, then most of the total effect comes within the first month of the reform. The black line illustrates the marginal impact of upstream regulation on these dynamics: it plots the marginal impact on pass-through of having upstream regulation that is one standard deviation more competition-friendly than the average. Again, most of the marginal impact occurs in the month of the VAT reform, with some additional impact in the six months after the reform. This is consistent with the purchaser-supplier relationships described in Section 2 adjusting to the change reasonably quickly. The extent to which forewarning of the reform speeds up such processes is examined in the Robustness section below.

Reforms over the last thirty years have substantially increased the competition-friendliness of regulation in European product markets (Égert & Wanner 2016). The overall median value of the *Regimpact* measure since 1999 is shown in Figure 2, while the trends in each country and consumption category are shown in Figure B.2 in the Appendix. A back-of-the-envelope calculation takes the observed changes in the *Regimpact* index for each country-product category over the observed period and multiplies them by the coefficient on the VAT-PMR interaction term in Table 1. The smoothed distribution of these estimated changes in VAT pass-though is shown in Figure 3. Because regulations were loosened almost everywhere, our results imply that VAT pass-through increased practically everywhere for all products. The median estimated impact of the large increase in the competition-friendliness of regulation since 1999 is an increase in pass-through of approximately 26 percentage points, while the vast majority of the distribution has an increase in pass-through of more than 10 percentage points. This is a direct extrapolation of our results without proper identification, but illustrates that changes in upstream regulation are likely to have substantially affected the consequences of most VAT reforms in recent history.

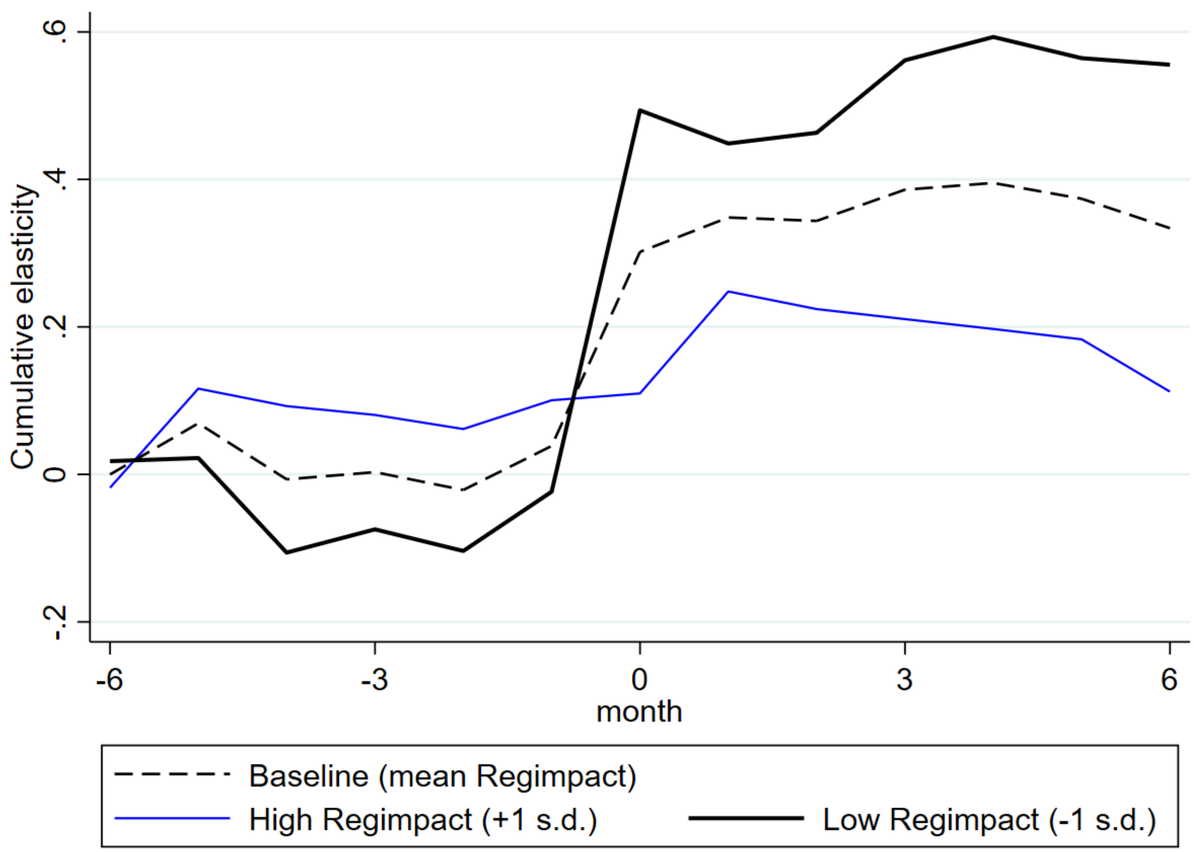
## 4.2 Scope for quality

Table 2 repeats the analysis for those products for which measures of the scope for quality are available.[26] Since the 'quality ladder' data only vary across products, not across countries, we cannot include product-time fixed effects as these would remove all variation. We therefore include only country-product, country-time, product and time fixed effects in the 'Interaction FEs' quality specification. Repeating model (3) of Table 1 with this slightly looser specification has little impact on the *Regimpact* results, which also remain consistent across columns in Table 2, suggesting that the 'lighter' specification still provides informative estimates for the effect of quality range.

The results in Table 2 show that a one standard deviation increase in the length of the 'quality ladder' of a product can raise pass-through by more than 50 percentage points. This fits the theory in Section 2 in the case that demand for quality is relatively more important to consumers when

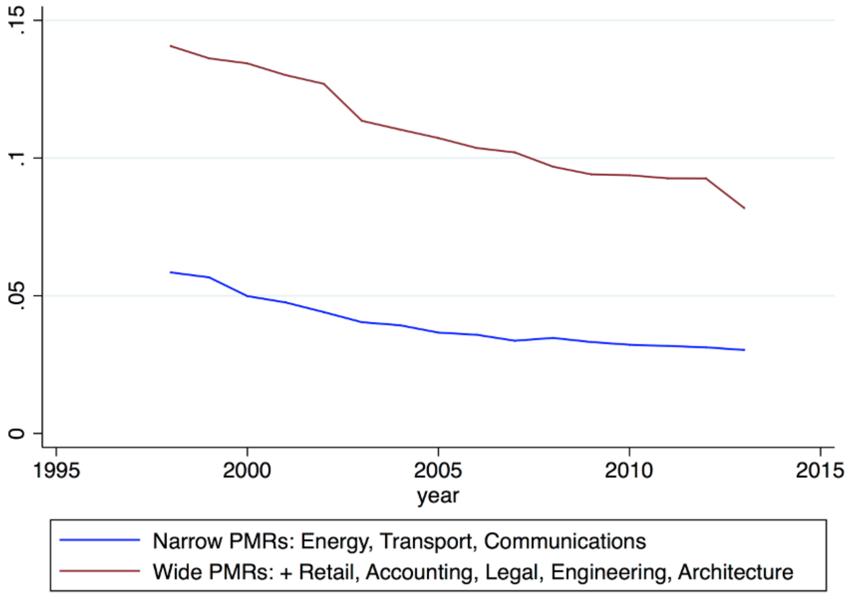
[26] All variables are re-standardized for the regressions on this smaller quality-inclusive sample, so that each estimated coefficient retains its interpretation as the impact on pass-through of a one-standard deviation rise in the variable.

FIGURE 1: Cumulative effect of upstream regulation on pass-through



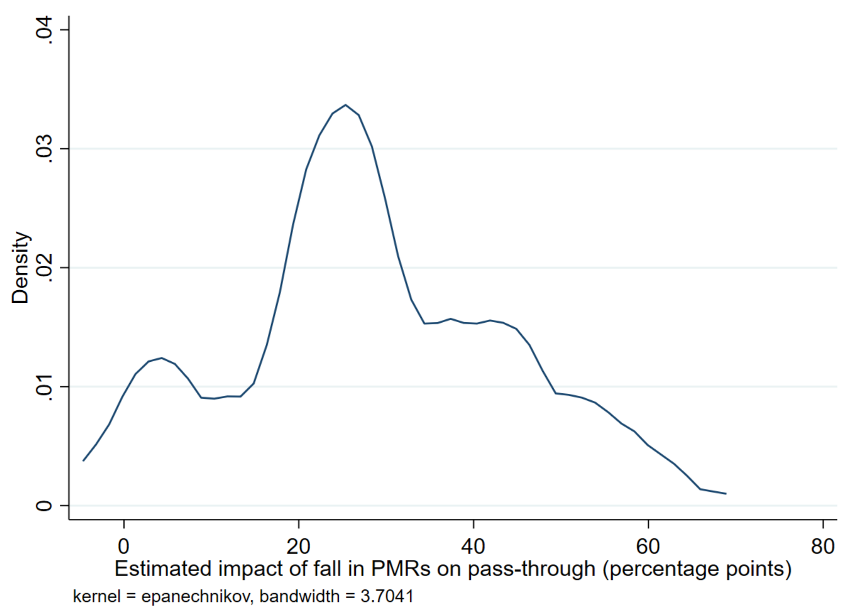

*Notes:* This graph shows cumulative baseline pass-through and the impact upon this of upstream regulation. The black (blue) lines show cumulative pass-through in a country-product pair with regulation that is exactly one standard deviation more (less) competition-friendly.

Figure 2: Median index of regulation over time




*Notes:* This graph shows the trends over time in the median value, across all countries and products, of the 'wide' and 'narrow' *Regimpact* indices of product market regulation. A lower value of the index reflects a more competition-friendly regulatory stance in upstream non-manufacturing industries.

Figure 3: Distribution of estimated impact of regulation on pass-through




*Notes:* This graph shows the smoothed distribution across country-product categories of the estimated increase in pass-through resulting from changes in regulation between 1999 and 2013. It applies the main estimate from Table 1 to the observed change in the *Regimpact* indicator across the period observed, using only those country-product categories with observations spanning at least ten years.

prices are higher – i.e. in the 'complementarity' case. In this scenario, firms opt to pass on more of a VAT rise rather than reduce quality to dampen the impact on prices; the greater the scope for quality differentiation, the stronger this effect, so the higher is pass-through.

Considering Table 1 and Table 2 together, the regulation and quality effects have comparable magnitudes, while the regulation effect is somewhat more robust across different specifications. Figure B.5 in the Appendix below shows the dynamics of the quality scope effect. While there is again a significant effect in the month of the reform, the effect also continues to grow over the six months following the reform.

# 5 Robustness

This section addresses the robustness of our empirical results to a range of considerations. We first note that BDKW – on whose data we build – run a series of tests for endogeneity and measurement error in the VAT reforms, and are unable to reject the null hypotheses of exogenous reforms and limited measurement error. The following sections thus consider further potential threats to identification.

## 5.1 Advance announcement of reforms

Early announcement could, in theory, generate anticipation or amplification effects, i.e. an earlier or larger increase in pass-through. On the supply side, the presence of menu costs or Calvo pricing (Calvo 1983) encourages firms to smooth the price response to an announced VAT change to save on adjustment costs. As examined in Buettner & Madzharova (2021), for durables there is an extra effect through the demand channel: consumers aware of a future tax hike will increase pre-reform consumption, thereby contributing to higher prices before the rate increase – as observed before the German VAT increase in January 2007 (Danninger et al. 2008). Lastly, in a situation of information overload and rational inattention (Sims 2003), early announcement may increase the salience of a particular reform to consumers and firms, increasing total pass-through.

Correlation between early announcement and upstream regulation or the length of the quality ladder could therefore bias the estimates. Defining the 'implementation lag' as the number of days between the announcement and implementation dates of a given reform, we find a significant negative correlation between implementation lag and upstream regulation (coefficient -0.1182, $p$-value 0.0026), but an insignificant positive correlation between implementation lag and quality (coefficient 0.0023, $p$-value 0.9671).[27]

[27] More broadly, controlling for implementation lag accounts for little of the substantial heterogeneity in pass-through, as illustrated in Online Appendix Figure III. We also find little evidence of announcement effects directly increasing pre-reform or total pass-through (Online Appendix Table III).

Table 2: Estimates of pass-through heterogeneity, including quality range

| | | Dependent variable: change in log prices | | |
|---|---|---|---|---|
| | | No Fes | Individual FEs | Interaction FEs |
| Baseline $\beta_1$ | Pre-Reform | 0.234 | 0.257** | 0.188 |
| | – i.e. $\sum_{j=1}^{6} \beta_{1j}$ | (0.506) | (0.014) | (0.176) |
| | Contemporaneous | 0.228 | 0.194** | -0.0162 |
| | – i.e. $\beta_{10}$ | (0.212) | (0.025) | (0.893) |
| | Post-Reform | -0.102 | -0.0737 | -0.159* |
| | – i.e. $\sum_{j=-6}^{-1} \beta_{1j}$ | (0.661) | (0.569) | (0.094) |
| | Total | 0.36 | 0.378** | 0.0126 |
| | – i.e. $\sum_{j=-6}^{6} \beta_{1j}$ | (0.422) | (0.020) | (0.951) |
| Openness: | Total | -0.859 | -0.774 | -0.743 |
| | | (0.554) | (0.211) | (0.320) |
| Concentration: | Total | 0.179 | 0.164 | 0.131 |
| | | (0.868) | (0.345) | (0.440) |
| *Regimpact*: | Pre-Reform | -0.067 | -0.0625 | 0.112 |
| | | (0.628) | (0.401) | (0.437) |
| | Contemporaneous | -0.246*** | -0.306*** | -0.469*** |
| | | (0.010) | (0.000) | (0.002) |
| | Post-Reform | -0.0601 | -0.0765 | -0.0574 |
| | | (0.616) | (0.204) | (0.371) |
| | Total | -0.373* | -0.445*** | -0.415** |
| | | (0.074) | (0.000) | (0.015) |
| Quality range: | Pre-Reform | -0.0744 | -0.0929 | -0.0221 |
| | | (0.845) | (0.327) | (0.834) |
| | Contemporaneous | 0.204 | 0.223** | 0.25** |
| | | (0.336) | (0.047) | (0.012) |
| | Post-Reform | 0.289 | 0.273** | 0.288*** |
| | | (0.377) | (0.046) | (0.004) |
| | Total | 0.419 | 0.402** | 0.516*** |
| | | (0.418) | (0.024) | (0.008) |
| FEs | | None | i,k,t | it,k,t,ik |
| Clustering | | None | ik | ik |
| N | | 48977 | 48977 | 48977 |

*Notes:* $p$-values in parentheses. * $p$ <0.10, ** $p$ <0.05, *** $p$ <0.01. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption.

To check that our results are not affected by such announcement effects, we run two alternative specifications. First, we exclude the 60% of reforms which were announced more than one month in advance (Table B.6 in the Appendix). Second, we include only non-durable goods, noting that these are less susceptible to consumption smoothing in anticipation of a tax increase (Table B.7). In each case, the results are similar to our baseline specification, for both upstream regulation and quality.

## 5.2 Alternative specifications and heterogeneity

To reduce the influence of regulatory outliers, Table B.8 in the Appendix replaces *Regimpact* with $RegimpactHML$, which takes value 1 if the observation is in the top quartile of the *Regimpact* distribution, value -1 if in the bottom quartile, and zero otherwise. Results remain similar, with a strong negative relationship between $RegimpactHML$ and pass-through.

Secondly, we check whether pass-through heterogeneity depends on the direction of the VAT change, following recent work on asymmetric pass-through (e.g. Benzarti et al. 2017, Carbonnier 2007, Politi & Mattos 2011). Pass-through heterogeneity for increases and decreases are estimated by $\boldsymbol{\beta}_{2j}^{(inc)}$ and $\boldsymbol{\beta}_{2j}^{(dec)}$ in:

$$
\begin{aligned}
\Delta \ln(p_{ikt}) = \beta_0 &+ \sum_{d \in \{inc,dec\}} \sum_{j=-6}^{6} \beta_{1j}^{(d)} \cdot \Delta \ln(1 + \tau_{ikt+j}^{(d)}) \\
&+ \sum_{d \in \{inc,dec\}} \sum_{j=-6}^{6} \boldsymbol{\beta}_{2j}^{(d)} \cdot \Delta \ln(1 + \tau_{ikt+j}^{(d)}) \cdot \mathbf{X}_{ikt} \\
&+ \boldsymbol{\beta}_3 \cdot \mathbf{X}_{ikt} + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt}
\end{aligned}
\tag{16}
$$

Results are shown in Table B.9 in the Appendix. The previous literature has found evidence for greater price rigidity with respect to decreases than increases; however, like BDKW, we find little evidence of this in our data – the final column of Table B.9 show few significant differences between the coefficients on increases and decreases. As discussed in BDKW, the mostly insignificant differences are likely due to substantial heterogeneity across product categories in our dataset, without direct association with the reform type (a VAT hike or cut).

Thirdly, we use a similar method to investigate whether pass-through varies with the business cycle. We use recession indicators from the OECD (Federal Reserve Bank of St. Louis 2020, OECD 2020), constructed by using statistical methods to identify turning points in the time series of industrial output and GDP. We run:

$$\Delta \ln(p_{ikt}) = \beta_0 + \sum_{d\in\{exp,rec\}} \sum_{j=-6}^{6} \beta_{1j}^{(d)} \cdot \Delta \ln(1+\tau_{ikt+j}^{(d)}) \tag{17}$$

$$+ \sum_{d\in\{exp,rec\}} \sum_{j=-6}^{6} \boldsymbol{\beta}_{2j}^{(d)} \cdot \Delta \ln(1+\tau_{ikt+j}^{(d)}) \cdot \mathbf{X}_{ikt} \tag{18}$$

$$+ \boldsymbol{\beta}_3 \cdot \mathbf{X}_{ikt} + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt} \tag{19}$$

where $\beta_{1j}^{(rec)}$ and $\beta_{1j}^{(exp)}$ reflect baseline pass-through in recessionary and expansionary periods respectively, and $\boldsymbol{\beta}_{2j}^{(rec)}$ and $\boldsymbol{\beta}_{2j}^{(exp)}$ reflect heterogeneity likewise. The results are shown in Table B.10 in the Appendix. We find some evidence that pass-through effects are stronger in expansions, possibly because prices are more flexible when inflation is higher, but in general cannot reject equality of pass-through coefficients across expansionary/contractionary periods.

In additional specifications (available on request) we allow for differential effects of regulation and quality across types of VAT change – specifically standard rate changes, reduced rate changes and reclassifications, as discussed in detail in BDKW. However, with current data we cannot make clear inferences about the triple interaction between reform, regulation/quality and reform-type, as our results may simply be driven by the composition of reforms in our dataset. For instance, the vast majority of reforms in our data are standard rate changes, affecting relative standard errors in estimates across the varieties. The average sizes of the reforms also vary substantially across type, as shown in Table B.4, which could affect the estimated coefficients if the relationship between reform size and pass-through is non-linear. We therefore focus on the pooled effects, but also note that Figure 2 of BDKW shows similar effects across reform types – particularly once the reform is introduced, i.e. in the period for which we find regulation and quality to be important.[28]

Lastly, we also repeat the main specifications using country-level clustering and product-level clustering in turn. Results are similar with product-level clustering, while with country-level clustering the contemporaneous effect of *Regimpact* remains significant while the total effect is marginally insignificant.

# 6 Conclusion

This paper investigates the roles of imperfect competition and product differentiation in determining VAT pass-through. We extend existing theory by modelling five different settings in which market competitiveness can influence pass-through. We test these relationships empirically using a con-

[28]Noting that VAT changes due to reclassification are of a different character to changes in the standard or reduced rate, we also run our main specification excluding reclassification reforms, and find very similar results.

sumption panel across 14 Eurozone countries, and find that upstream product market regulation and quality have a substantial impact – both in absolute terms and relative to other market characteristics. Our results indicate that pass-through to consumer prices is greater the more competitive the upstream sector or the wider the quality range of the taxed product.

Together our results are relevant for governments considering VAT reforms with various objectives. For a government seeking to mobilize revenue through a VAT hike, a greater share of the burden will fall on consumers relative to firms for products with higher upstream competition or for products characterized by a wider quality range. For a government seeking to stimulate consumption or support firm profits through a VAT cut, the effects are the inverse: firms will retain more of the cut in higher markups, and consumers will experience smaller price reductions, the less competitive the upstream sector or the narrower the range of product quality. In cases where the government aims to influence a particular market whose characteristics make it unresponsive to VAT changes, policymakers could instead look for more cost-effective instruments than VAT changes.

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# A Theoretical Appendix

We examine the four separate case studies presented in the main text one at a time. For every case, we find it is convenient to use an expression of the degree of pass-through based on producer prices that can be derived from the definition (1)

$$\begin{aligned}\gamma - 1 &= \frac{\partial \ln p}{\partial \ln \widetilde{p}} . \frac{\partial \ln \widetilde{p}}{\partial \widetilde{p}} . \frac{\partial \widetilde{p}}{\partial \tau} . \frac{\partial \tau}{\partial \ln (1+\tau)} - 1 \\ \gamma - 1 &= \frac{\partial \widetilde{p}}{\partial \tau} . \frac{(1+\tau)}{\widetilde{p}} \end{aligned} \tag{20}$$

## A.1 Monopolistic Competition in the Downstream Sector

We focus on a good with horizontal differentiation where each of the $N$ firm in this market sells a quantity $q_n$ of its own variety at a price $p_n$.

**Demand side.** Preferences over the different varieties follow a standard Dixit-Stiglitz form and we assume that aggregate demand is $Q = \left(\int_1^N u(q_n)dn\right)^{\frac{\sigma}{\sigma-1}}$, where $u(q) = q_n^{\frac{\sigma-1}{\sigma}}$ is thrice continuously differentiable, strictly increasing, and strictly concave on $(0, +\infty)$.

We assume that there are other goods that we represent with an outside good $Q_o$ and its price $P_o$. A representative consumer chooses consumption $q_n$ and $Q_o$ to buy to maximize utility $U(Q_0, Q)$ with constant elasticity of substitution under the budget constraint $\int_1^N p_n q_n + P_o Q_o dn = I$ where $I$ is aggregate income.

The first order condition (FOC) of the consumer problem with respect to any variety $n$ is

$$u'(q_n) \quad = \quad \eta p_n \tag{21}$$

where $\frac{\partial U}{\partial Q}\frac{\partial Q}{\partial u}\eta$ is the Lagrange multiplier associated with the budget constraint. The variable $\eta$ is related to the marginal utility of income and acts as a demand shifter. It can alternatively be expressed using the budget constraint as $\eta = \frac{\int_1^N q_m u'(q_m)dm}{A}$, where $A = I - P_o Q_o$ is the parameter introduced in the main text to characterize market size.

In what follows, our partial equilibrium approach assumes that variations in the tax rate applied to the varieties $q_n$ affect neither aggregate income nor the amount spend on the outside good. Hence, $A$ and $\eta$ are assumed to be exogenous. We also assume a constant elastic of substitution. Therefore, the first order condition (21) implies that the elasticity of demand, denoted by $\varepsilon_d \equiv -\frac{\partial q_n}{\partial p_n}\frac{p_n}{q_n}$, is equal to a constant denoted by $\sigma$, with $\sigma > 1$.

**Supply side.** On the supply side, we assume that firms compete in price under monopolistic competition. We define the elasticity of supply as $\varepsilon_s$ as the inverse elasticity of marginal cost. To fix ideas, we assume that every firm has the same cost function given by equation (2) in the main text $C_n(q_n) = a + c_n q_n + \frac{b}{2} q_n^2$ with $a > 0$, $c_n = c > 0$ for all $n$, and where $b < 0$ corresponds to decreasing marginal costs and $b > 0$ corresponds to increasing marginal costs. With this functional form, we have that $\varepsilon_s = \frac{C'_n}{C''_n q_n} = \frac{c+bq_n}{bq_n}$.

Because all firms are equally productive, all firm prices and quantities are identical and, from now on, we can drop the subscript $n$ for conciseness. This also implies that $Q = qN^{\frac{\sigma}{\sigma-1}}$, $P = pN^{\frac{1}{1-\sigma}}$. The latter entails that $\gamma = \frac{\partial \ln P}{\partial \ln(1+\tau)} = \frac{\partial \ln p}{\partial \ln(1+\tau)}$. Moreover, the consumed quantity of any variety is given by total spending that is equally divided among all varieties and further divided by the consumer price,

$$q = \frac{A}{\widetilde{p}_n(1+\tau)N} \tag{22}$$

Every firms are price setters and seek to maximize profits $\pi = \widetilde{p}q - C(q)$. The first order condition (FOC) of the maximization problem is

$$\widetilde{p}\left(1 - \frac{1}{\varepsilon_d}\right) = C' \tag{23}$$

and it is equivalent to $p\left(1 - \frac{1}{\varepsilon_d}\right) = C'(1+\tau)$ when using consumer prices.

Additionally, the existence of a unique solution requires that (i) $\lim_{q\to 0}\left[p\left(1 - \frac{1}{\varepsilon_d}\right) - C'(1+\tau)\right] > 0$ and $\lim_{q\to q^{max}}\left[p\left(1 - \frac{1}{\varepsilon_d}\right) - C'(1+\tau)\right] \leq 0$, and (ii) that the following second order condition (SOC) holds

$$\frac{\partial p}{\partial q}\left(1 - \frac{1}{\varepsilon_d}\right) + p\frac{\varepsilon'_d}{\varepsilon_d^2} - C''(1+\tau) < 0$$

We use the defintion of the demand elasiticy to transform it into

$$\left[-\frac{p}{q\varepsilon_d}\right]\left(1 - \frac{1}{\varepsilon_d}\right) + p\frac{\varepsilon'_d}{\varepsilon_d^2} - C''(1+\tau) < 0$$

We then subsitute price using the FOC (23) and multiple the inequality with the negative term $-\frac{q\varepsilon_d}{C'(1+\tau)}$ to obtain another inequality that will prove useful in what follows

$$1 - \frac{q\varepsilon'_d}{\varepsilon_d}\frac{1}{\left(1 - \frac{1}{\varepsilon_d}\right)} + \varepsilon_d\frac{C''q}{C'} > 0 \tag{24}$$

where the last term can also be expressed as $\varepsilon_d/\varepsilon_s$. This inequality means that the elasticity of supply cannot be too negative, or equivalently that marginal costs $(c + bq)$ cannot decrease too fast when output increases.

To obtain the pass-through, we need the derivative of price which we obtain from taking the derivative of the firm FOC (23) with respect to the taxe rate.

$$\frac{\partial p}{\partial \tau}\left(1-\frac{1}{\varepsilon_d}\right)+p\frac{\varepsilon_d'}{\varepsilon_d^2}\frac{\partial q}{\partial \tau}=(1+\tau)C''\frac{\partial q}{\partial \tau}+C'$$

We use the fact that $\frac{\partial q}{\partial \tau}=\frac{\partial p}{\partial \tau}\left[\frac{\partial p}{\partial q}\right]^{-1}=-\frac{\partial p}{\partial \tau}\frac{q\varepsilon_d}{p}$ and the FOC (23) to rearrange terms. We get

$$\begin{aligned}
&\frac{\partial p}{\partial \tau}\left[1-\frac{1}{\varepsilon_d}-\frac{q\varepsilon_d'}{\varepsilon_d}+(1+\tau)C''\frac{q\varepsilon_d}{p}\right]=C'\\
\Leftrightarrow\quad&\frac{\partial p}{\partial \tau}\left[1-\frac{1}{\varepsilon_d}-\frac{q\varepsilon_d'}{\varepsilon_d}+\frac{\varepsilon_d}{\varepsilon_s}\left(1-\frac{1}{\varepsilon_d}\right)\right]=\frac{p}{1+\tau}\left(1-\frac{1}{\varepsilon_d}\right)
\end{aligned}$$

We can then solve for the pass-through and express it as a special case of the results in Adachi & Fabinger (2022).

$$\gamma=\frac{1}{1-\frac{q\varepsilon_d'}{\varepsilon_d}\frac{1}{\left(1-\frac{1}{\varepsilon_d}\right)}+\frac{\varepsilon_d}{\varepsilon_s}} \tag{25}$$

Note that the SOC (24) implies that the pass-through is positive. Using our assumptions about the demand side and the functional forms, we can simplify this expression to get

$$\gamma=\frac{1}{1+\frac{\varepsilon_d}{\varepsilon_s}}=\frac{1}{1+\frac{\sigma bq}{c+bq}} \tag{26}$$

To study how the market equilibrium and its characteristics vary with the number of firms, we start by examining how quantities vary. We use the symmetry assumption and equation (22) to substitute prices with quantities in the FOC (23) to obtain $A\left(1-\frac{1}{\varepsilon_d}\right)=C'(1+\tau)qN$. We then take derivatives with respect to $N$.

$$\begin{aligned}
&A\frac{\varepsilon_d'}{\varepsilon_d^2}\frac{\partial q}{\partial N}=C''(1+\tau)qN\frac{\partial q}{\partial N}+C'(1+\tau)N\frac{\partial q}{\partial N}+C'(1+\tau)q\\
\Leftrightarrow\quad&\frac{\partial q}{\partial N}\frac{N}{q}\left(\frac{AN}{q}\frac{\varepsilon_d'}{\varepsilon_d^2}-C''(1+\tau)q^2-C'(1+\tau)q\right)=C'(1+\tau)q
\end{aligned}$$

We rearrange terms to get

$$\frac{\partial q}{\partial N}\frac{N}{q}=\frac{1}{\frac{q\varepsilon_d'}{\varepsilon_d}\frac{1}{1-\frac{1}{\varepsilon_d}}-\frac{1}{\varepsilon_s}-1} \tag{27}$$

Finally, we can take the derivative of the pass-through (equation (25)) with respect to $N$.

$$\frac{\partial \gamma}{\partial N}\frac{N}{\gamma}=-\frac{(q\varepsilon_d'+q^2\varepsilon_d'')(\varepsilon_d-1)-(q\varepsilon_d')^2}{(\varepsilon_d-1)^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q}-\frac{q\varepsilon_d'}{\varepsilon_s}\gamma\frac{\partial q}{\partial N}\frac{N}{q}+q\varepsilon_s'\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q} \tag{28}$$

The first two terms in the above equation are equal to zero when assuming a constant elasticity of substitution. Moreover, this assumption also implies that quantities decrease with the number of firms. When $\varepsilon_s > 0$, we have that $\frac{\partial q}{\partial N}\frac{N}{q} = \frac{-1}{1/\varepsilon_s+1} < 0$. Conversely when $\varepsilon_s < 0$, $\varepsilon_d > 1$ and the SOC (24) imply that $-\frac{1}{\varepsilon_s} - 1 < -\frac{1}{\varepsilon_s} - 1 + 1 + \frac{\varepsilon_d}{\varepsilon_s} < (\varepsilon_d - 1)\frac{1}{\varepsilon_s}$ and $\frac{\partial q}{\partial N}\frac{N}{q} < 0$ again. Altogether, this implies that $\frac{\partial \gamma}{\partial N}\frac{N}{\gamma}$ has the sign of $-\varepsilon_s'$, which is the sign of $b$ in the case of linear marginal costs $\left(\varepsilon_s' = \partial\left(\frac{c+bq}{bq}\right)/\partial q = -\frac{c}{bq^2}\right)$.

Hence, in the case of a constant elasticity of substitution, we find that the degree of pass-through increases if and only if $b > 0$. This proves that pass-through variations with $N$ under monopolistic competition are as described in **proposition 1**. This proof did not rely on a specific functional form for supply costs, the more general result is that pass-through increases with the number of firms when firm production is characterized by $\varepsilon_s' < 0$, that is when the slope of the marginal costs is positive and steep enough, and/or when marginal costs are convex enough (because $\varepsilon_s' = 1 - \varepsilon_s' - qC'C'''(C''q)^{-2}$).

**Variable elasticity of substitution.** Moving away from the assumption of a constant elasticity of substitution, we introduce the concept of love for variety $r_u(q) \equiv -\frac{qu''(q_n)}{u'(q_n)}$ which is always between 0 and 1. We do not assume a specific functional form for the utility function any more. Nevertheless, the FOC (21) and all the above calculations based on the unspecified elasticity of demand $\varepsilon_d$ are still valid. In this case however, the elasticity of substitution is equal to the inverse of the love $\varepsilon_d = -\frac{\partial q_n}{\partial p_n}\frac{p_n}{q_n} = \frac{1}{r_u(q)}$. Furthermore, its derivative is $\varepsilon_d' = -\frac{r_u'}{r_u^2}$ and second derivative $\varepsilon_d'' = \frac{4r_u'^2 r_u - r_u'' r_u^2}{r_u^4}$.

We distinguish the case of $r_u''$ is small enough so that $\varepsilon_d'' \geq -\frac{\varepsilon_d - 1}{4q}$, or in other words that the love for variety is concave or not too convex. In this case, the quadratic function $g[q\varepsilon_d'] = (q\varepsilon_d')^2 - (q\varepsilon_d' + q^2\varepsilon_d'')(\varepsilon_d - 1)$ admits two solutions $\epsilon_1 = \frac{(\varepsilon_d-1)-\sqrt{(\varepsilon_d-1)^2+4q^2\varepsilon_d''(\varepsilon_d-1)}}{2}$ and $\epsilon_2 = \frac{(\varepsilon_d-1)+\sqrt{(\varepsilon_d-1)^2+4q^2\varepsilon_d''(\varepsilon_d-1)}}{2}$. We note that $0 \leq \epsilon_1 \leq \epsilon_2$. Furthermore, $g < 0$ if $\epsilon_1 < q\varepsilon_d' < \epsilon 2$, and $g \geq 0$ otherwise. If $\varepsilon_d'' < -\frac{\varepsilon_d - 1}{4q}$, then $g[q\varepsilon_d'] > 0$ for all $q\varepsilon_d'$.

Equipped with these definitions, we solve for the variations of pass-through in two steps.

We first consider the case of decreasing returns to scale ($\varepsilon_s > 0$). We study the sign of the different terms in the pass-through equation (28) depending on $q\varepsilon_d'$. The SOC (24) requires that $q\varepsilon_d' < \epsilon_4$ with $\epsilon_4 = (1+\varepsilon_d/\varepsilon_s)(\varepsilon_d - 1)$. The sign of $\frac{\partial q}{\partial N}\frac{N}{q}$ is negative when $q\varepsilon_d' < \epsilon_3$ with $\epsilon_3 = (1+1/\varepsilon_s)(\varepsilon_d - 1)$ and positive otherwise. We have that $0 < \epsilon_3 < \epsilon_4$. While we have that $\epsilon_1 < 0 < \epsilon_3$, we don't know the sign of $\epsilon_2 - \epsilon_3$, nor the sign of $\epsilon_2 - \epsilon_4$.

We can compare terms to obtain the sign of $\frac{\partial \gamma}{\partial N}\frac{N}{\gamma}$ in some specific cases. Comparisons are summarized in Table A.1. For $q\varepsilon_d' \leq \epsilon_3$, we have that $\frac{\partial \gamma}{\partial N}\frac{N}{\gamma} > 0$ if $-\varepsilon_s'$ is large enough ($b$ large enough in the case of linear marginal costs) and specifically if and ony if $-\varepsilon_s' > \frac{\varepsilon_s^2}{q\varepsilon_d}\left(\frac{g[q\varepsilon_d']}{(\varepsilon_d-1)^2} - \frac{q\varepsilon_d'}{\varepsilon_s}\right)$. For $\epsilon_3 < \varepsilon_d' < max(\epsilon_2, \epsilon_3)$, we have that $\frac{\partial \gamma}{\partial N}\frac{N}{\gamma} < 0$. The variations of the pass-through again depend on $\varepsilon_s'$ for larger values of $q\varepsilon_d'$. To summarize for the case of decreasing returns to scale, we obtain that the pass-through increases with the number of firms when the love for variety is strong enough ($\varepsilon_d'$ small enough) and $-\varepsilon_s'$ is large enough.

Table A.1: Variations of quantity and pass-through with $N$ when $\varepsilon_s > 0$

| $\boldsymbol{q\varepsilon'_d}$ | | $\mathbf{0}$ | $\boldsymbol{\epsilon_3}$ | $\boldsymbol{\epsilon_4}$ **ruled out by SOC** |
|---|---|---|---|---|
| $\frac{\partial q}{\partial N}\frac{N}{q}$ | - | - | + | $\times$ |
| $-\frac{q\varepsilon'_d}{\varepsilon_s}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$ | - | + | - | $\times$ |
| $q\varepsilon'_s\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$ | $\text{sign}(-\varepsilon'_s)$ | $\text{sign}(-\varepsilon'_s)$ | $\text{sign}(\varepsilon'_s)$ | $\times$ |

| $\boldsymbol{q\varepsilon'_d}$ | $\boldsymbol{\epsilon_1}$ | $\mathbf{0}$ | | $\boldsymbol{\epsilon_2}$ | | **ruled out** |
|---|---|---|---|---|---|---|
| $\frac{g\gamma}{(\varepsilon_d-1)^2}\frac{\partial q}{\partial N}\frac{N}{q}$ | - | + | + | - | + | $\times$ |
| $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma}$ | + if and only if $-\varepsilon'_s > \frac{\varepsilon_s^2}{q\varepsilon_d}\left(\frac{g[q\varepsilon'_d]}{(\varepsilon_d-1)^2} - \frac{q\varepsilon'_d}{\varepsilon_s}\right)$ | | | - | ? | $\times$ |

*Note: if $\varepsilon''_d < -\frac{\varepsilon_d-1}{4q}$, then $\frac{g\gamma}{(\varepsilon_d-1)^2}\frac{\partial q}{\partial N}\frac{N}{q}$ always has the sign of $\frac{\partial q}{\partial N}\frac{N}{q}$ and the sign of the shaded cell becomes unknown.*

We then consider the case of increasing returns to scale ($\varepsilon_s \leq 0$). Again, we study the sign of the different terms in the pass-through equation (28) depending on $q\varepsilon'_d$. The SOC (24) requires that $q\varepsilon'_d < \epsilon_4$ with $\epsilon_4 = (1 + \varepsilon_d/\varepsilon_s)(\varepsilon_d - 1)$. The SOC also implies that the sign of $\frac{\partial q}{\partial N}\frac{N}{q}$ is always negative, because in this case we have that $\epsilon_4 < \epsilon_3$. We have that $\epsilon_4 < \epsilon_2$ but we don't know the sign of $\epsilon_1 - \epsilon_4$ (it depends on $\varepsilon_s$).

We can compare terms to obtain the sign of $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma}$ in some specific cases. Comparisons are summarized in Table A.2. For all compatible $q\varepsilon'_d$, we have that $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma} > 0$ if $\varepsilon'_s$ is large enough ($b$ negative enough in the case of linear marginal costs) and specifically if and ony if $\varepsilon'_s > \frac{\varepsilon_s^2}{q\varepsilon_d}\left(\frac{q\varepsilon'_d}{\varepsilon_s} - \frac{g[q\varepsilon'_d]}{(\varepsilon_d-1)^2}\right)$. To summarize for the case of increasing returns to scale, we obtain that the pass-through decreases with the number of firms when $\varepsilon'_s$ is large enough.

We can rephrase our conclusions in more generic terms to encompass the two cases of increasing and decreasing returns to scale. When $\|\varepsilon'_s\|$ is large enough and when the love for variety increases fast enough with quantity, the pass-through increases with $N$ in the case of decreasing returns to scale ($\varepsilon_s > 0$) and decreases with $N$ otherwise ($\varepsilon_s \leq 0$). This generalize the results in **proposition 1**.

## A.2 Cournot competition in the downstream sector

We now assume that the first good $Q$ is homogeneous but produced by heterogeneous firms that differ in productivity and who compete in quantities under Cournot competition.

Table A.2: Variations of quantity and pass-through with $N$ when $\varepsilon_s \leq 0$

| $q\varepsilon'_d$ | | $0$ | $\epsilon_4$ | ruled out by SOC |
|---|---|---|---|---|
| $\frac{\partial q}{\partial N}\frac{N}{q}$ | - | | - | $\times$ |
| $-\frac{q\varepsilon'_d}{\varepsilon_s}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$ | + | | - | $\times$ |
| $q\varepsilon'_s\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$ | $\text{sign}(-\varepsilon'_s)$ | | $\text{sign}(-\varepsilon'_s)$ | $\times$ |

| $q\varepsilon'_d$ | $\epsilon_1$ | $0$ | | ruled out |
|---|---|---|---|---|
| $\frac{g\gamma}{(\varepsilon_d-1)^2}\frac{\partial q}{\partial N}\frac{N}{q}$ | - | + | + | $\times$ |
| $\frac{\partial \gamma}{\partial N}\frac{N}{\gamma}$ | + if and only if $\varepsilon'_s > \frac{\varepsilon_s^2}{q\varepsilon_d}\left(\frac{q\varepsilon'_d}{\varepsilon_s} - \frac{g[q\varepsilon'_d]}{(\varepsilon_d-1)^2}\right)$ | | | $\times$ |

*Note: if* $\varepsilon''_d < -\frac{\varepsilon_d-1}{4q}$, *then* $\frac{g\gamma}{(\varepsilon_d-1)^2}\frac{\partial q}{\partial N}\frac{N}{q}$ *always has the sign of* $\frac{\partial q}{\partial N}\frac{N}{q}$ *but it does not change the bottom-line result.*

**Demand side.** Total demand is the sum of every firm's production, $Q = \sum_{n=1}^{N} q_n$. Aggregate consumer preferences continue to be characterized by a constant elasticity of substitution and a utility function that we define as

$$U = \left(aQ^{1-\beta} + (1-a)Q_o^{1-\beta}\right)^{\frac{\nu}{1-\beta}} \tag{29}$$

with parameters $1 > a > 0$, $\nu > 0$, $1 > \beta > 0$.

The two first order conditions of the consumer problem with respect to the differentiated and outside goods are $\nu a Q^{-\beta} U^{\frac{\nu/(1-\beta)-1}{\nu/(1-\beta)}} = \eta p$ and $\nu(1-a)Q_o^{-\beta} U^{\frac{\nu/(1-\beta)-1}{\nu/(1-\beta)}} = \eta P_o$. We combine them to eliminate $\eta$ and get the aggregate demand curve introduced in the main text

$$p(Q) = A' Q^{-\beta} \tag{30}$$

where $A' = P_o Q_o^{\beta}\frac{a}{(1-a)}$. As in the previous case, we adopt a partial equilibrium approach and we here assume that variations in the tax rate applied to the first good $Q$ affect neither the price nor the quantity of the outside good. Hence, $A'$ is assumed to be exogenous. The elasticity of demand $\varepsilon_d = -\frac{\partial Q}{\partial p}\frac{p}{Q}$ is equal to $1/\beta$.

**Supply side.** Each firm $n$ facing the cost function (2) chooses its output $q_n$ independently to maximize profits $\widetilde{p}(q_n)q_n - C_n(q_n)$ and, while doing so, firms internalize their impact on total output. In equilibrium, the first order condition of the profit maximization problem is

$$\widetilde{p} + \frac{\partial \widetilde{p}}{\partial q_n} q_n - C_n = 0 \text{ for all } n \tag{31}$$

Summing (31) across firms, and using the definition of the demand elasticity, we get

$$p\left(N - \frac{1}{\varepsilon_d}\right) = N\bar{C}'(1+\tau) \tag{32}$$

where the function $\bar{C}' = \left(\sum_n c_n + bq_n\right)/N = \bar{c} + bQ/N$ is the average marginal cost function which is evaluated at the mean quantity $Q/N$. Note that we assumed that the mean of the cost distribution $\bar{c} = \sum_n c_n/N$ is fixed and independent from $N$. As before, we further define $\varepsilon_s$ the elasticity of supply as the inverse elasticity of marginal costs, $\varepsilon_s = \frac{\bar{C}'}{\bar{C}''Q/N}$.

The existence of a solution also requires that the demand function is steep enough and that the following second order condition is satisfied.

$$\begin{aligned}
& \tfrac{\partial p}{\partial Q} + \tfrac{\partial^2 p}{\partial Q^2} q_n - \tfrac{\partial C_n}{\partial (Q/N)} \tfrac{(1+\tau)}{N} < 0 && \text{for all } n \\
\Leftrightarrow \quad & \tfrac{-1}{\varepsilon_d} \tfrac{p}{Q} + \tfrac{\varepsilon_d'}{\varepsilon_d^2} \tfrac{p}{Q} q_n - \tfrac{1}{\varepsilon_d} \tfrac{\frac{\partial p}{\partial Q} Q - p}{Q^2} q_n - \tfrac{\partial C_n}{\partial (Q/N)} \tfrac{(1+\tau)}{N} < 0 \\
\Leftrightarrow \quad & p - p \tfrac{\varepsilon_d'}{\varepsilon_d} q_n - p \tfrac{\frac{1}{\varepsilon_d} + 1}{Q} q_n + \tfrac{\partial C_n}{\partial (Q/N)} \tfrac{(1+\tau) Q \varepsilon_d}{N} > 0
\end{aligned} \tag{33}$$

After summing up the second inequality for all $n$, the second order condition (33) becomes

$$p\left(N - \frac{1}{\varepsilon_d}\right) - p\left(\frac{\varepsilon_d'}{\varepsilon_d} Q + 1\right) + \frac{\partial \bar{C}_n}{\partial (Q/N)} (1+\tau) Q \varepsilon_d > 0$$

Dividing the first two terms by the left-hand side of the firm FOC (32) and the third term by the right-hand side of the same FOC yields a useful inequality.

$$1 - \left(\frac{\varepsilon_d'}{\varepsilon_d} Q + 1\right) \frac{1}{N - \frac{1}{\varepsilon_d}} + \frac{\varepsilon_d}{\varepsilon_s} > 0 \tag{34}$$

To obtain an expression for the pass-through, we take the derivative of the above equation

(32) with respect to $\tau$.

$$\begin{aligned} & \frac{\partial p}{\partial \tau}\left(N-\frac{1}{\varepsilon_d}\right)+p\frac{\varepsilon'_d}{\varepsilon_d^2}\frac{\partial Q}{\partial p}\frac{\partial p}{\partial \tau} = N\bar{C}'+(1+\tau)N\bar{C}''\frac{1}{N}\frac{\partial Q}{\partial p}\frac{\partial p}{\partial \tau} \\ \Leftrightarrow \quad & \frac{\partial p}{\partial \tau}\left(N-\frac{1}{\varepsilon_d}-\frac{Q\varepsilon'_d}{\varepsilon_d}+(1+\tau)\frac{Q\bar{C}''}{p}\varepsilon_d\right) = N\bar{C}' \end{aligned}$$

We then use the definition of the supply elasticity and the firm FOC (31) to obtain

$$\gamma = \frac{1}{1-\frac{Q\varepsilon'_d}{\varepsilon_d}\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}} \tag{35}$$

The firm SOC (34) implies that the pass-through is positive.

To see how the pass-through vary with the number of firms, we start by examining the variation of quantities with respect to $N$. We take the derivative of the firm FOC (32).

$$\begin{aligned} & \frac{\partial p}{\partial Q}\frac{\partial Q}{\partial N}\left(N-\frac{1}{\varepsilon_d}\right)+p\left(1+\frac{\varepsilon'_d}{\varepsilon_d^2}\frac{\partial Q}{\partial N}\right) = (1+\tau)\bar{C}'+N(1+\tau)\bar{C}''\frac{\partial(Q/N)}{\partial N} \\ \Leftrightarrow \quad & -\frac{p}{\varepsilon_d Q}\frac{\partial Q}{\partial N}\left(N-\frac{1}{\varepsilon_d}\right)+p\left(1+\frac{\varepsilon'_d}{\varepsilon_d^2}\frac{\partial Q}{\partial N}\right) = (1+\tau)\bar{C}'+N(1+\tau)\bar{C}''\left(\frac{\partial Q}{\partial N}\frac{1}{N}-\frac{Q}{N^2}\right) \\ \Leftrightarrow \quad & \frac{\partial Q}{\partial N}\frac{N}{Q}\left(-\frac{p}{\varepsilon_d}\frac{N-\frac{1}{\varepsilon_d}}{N}+p\frac{Q\varepsilon'_d}{N\varepsilon_d^2}-\frac{Q}{N}(1+\tau)\bar{C}''\right) = -p+(1+\tau)\bar{C}'-(1+\tau)\bar{C}''\frac{Q}{N} \end{aligned}$$

Using the firm FOC (32), we can express the right-hand side of the above either as $(1+\tau)\bar{C}'\left(1-\frac{N}{N-\frac{1}{\varepsilon_d}}-\frac{1}{\varepsilon_s}\right)$ or as $p\frac{N-\frac{1}{\varepsilon_d}}{N}\left(1-\frac{N}{N-\frac{1}{\varepsilon_d}}-\frac{1}{\varepsilon_s}\right)$.After rearranging terms, we get

$$\frac{\partial Q}{\partial N}\frac{N}{Q} = \frac{1-\frac{N}{N-\frac{1}{\varepsilon_d}}-\frac{1}{\varepsilon_s}}{-\frac{1}{\varepsilon_d}+\frac{Q\varepsilon'_d}{\varepsilon_d^2}\frac{1}{N-\frac{1}{\varepsilon_d}}-\frac{1}{\varepsilon_s}} = \frac{\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}}{1-\frac{Q\varepsilon'_d}{\varepsilon_d}\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}} \tag{36}$$

We are also interested in the variation of the average quantity produced in all firms.

$$\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)} = \frac{\partial Q}{\partial N}\frac{N}{Q}-1 = \frac{\left(\frac{Q\varepsilon'_d}{\varepsilon_d}+1\right)\frac{1}{N-\frac{1}{\varepsilon_d}}-1}{1-\frac{Q\varepsilon'_d}{\varepsilon_d}\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}} \tag{37}$$

Finally, we can take the derivative of the pass-through (equation (35)) with respect to $N$

$$\frac{\partial \gamma}{\partial N}\frac{N}{\gamma} = \frac{Q\varepsilon'_d\varepsilon_d\gamma N}{(N\varepsilon_d-1)^2}-\frac{(Q\varepsilon'_d+Q^2\varepsilon''_d)(N\varepsilon_d-1)-(Q\varepsilon'_d)^2}{(N\varepsilon_d-1)^2}\gamma\frac{\partial Q}{\partial N}\frac{N}{Q}-\frac{Q\varepsilon'_d}{\varepsilon_s}\gamma\frac{\partial Q}{\partial N}\frac{N}{Q}+\frac{Q\varepsilon'_s}{N}\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)} \tag{38}$$

The first three terms in the above equation are equal to zero when assuming a constant elasticity of substitution.

Moreover, this assumption also allows us to simply the derivative of average quantities $Q/N$:

$$\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)} = \frac{\frac{1}{N-\frac{1}{\varepsilon_d}} - 1}{1 + \varepsilon_d/\varepsilon_s}$$

where the numerator is always negative because $N > 1 > 1/\varepsilon_d$. When $\varepsilon_s > 0$, the denominator is clearly positive and the derivative is negative. Conversely when $\varepsilon_s < 0$, the SOC (33) implies that the denominator is positive and $\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)} < 0$ again.

Altogether, this implies that $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma}$ has the sign of $-\varepsilon_s'$, which is the sign of $b$ because $\varepsilon_s' = \partial\left(\frac{c+bq}{bq}\right)/\partial q = -\frac{c}{bq^2}$. This proves that pass-through variations with $N$ under monopolistic competition are as described in **proposition 1**.[29]

**Variable elasticity of substitution.** In what follows, we do not assume a specific functional form for the utility function any more and assume $\varepsilon_d'$ can differ from zero. Nevertheless, the FOC (21) and all the above calculations based on the unspecified elasticity of demand $\varepsilon_d$ are still valid. We maintain the assumption that $\varepsilon > 1$.

As before, we distinguish the case when $\varepsilon_d'' \geq -\frac{\varepsilon_d - 1}{4Q}$. In this case, the quadratic function $g[Q\varepsilon_d'] = (Q\varepsilon_d')^2 - (Q\varepsilon_d' + Q^2\varepsilon_d'')(N\varepsilon_d - 1)$ admits two solutions $\epsilon_1 = \frac{(N\varepsilon_d-1)\left(1-\sqrt{1+\frac{4Q^2\varepsilon_d''}{N\varepsilon_d-1}}\right)}{2}$ and $\epsilon_2\frac{(N\varepsilon_d-1)\left(1+\sqrt{1+\frac{4Q^2\varepsilon_d''}{N\varepsilon_d-1}}\right)}{2}$. We note that $0 \leq \epsilon_1 \leq \epsilon_2$. Furthermore, $g < 0$ if $\epsilon_1 < q\varepsilon_d' < \epsilon 2$, and $g \geq 0$ otherwise. If $\varepsilon_d'' < -\frac{\varepsilon_d - 1}{4q}$, then $g[Q\varepsilon_d'] > 0$ for all $Q\varepsilon_d'$.

Equipped with these definitions, we solve for the variations of pass-through in two steps.

We first consider the case of decreasing returns to scale ($b > 0$). We study the sign of the different terms in the pass-through equation (38) depending on $Q\varepsilon_d'$. The SOC (34) requires that $Q\varepsilon_d' < \epsilon_4$ with $\epsilon_4 = (1+\varepsilon_d/\varepsilon_s)(N\varepsilon_d - 1) - \varepsilon_d$. The sign of $\frac{\partial Q}{\partial N}\frac{N}{Q}$ is always positive because of the SOC. The sign of $\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)}$ is negative when $Q\varepsilon_d' < \epsilon_3$ with $\epsilon_3 = N\varepsilon_d - 1 - \varepsilon_d$ and positive otherwise. We have that $0 < \epsilon_3 < \epsilon_4$. While we have that $\epsilon_1 < 0 < \epsilon_3$ and $\epsilon_2 < \epsilon_4$, we don't know the sign of $\epsilon_2 - \epsilon_3$.

We can compare terms to obtain the sign of $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma}$ in some specific cases. Comparisons are summarized in Table A.3. For $Q\varepsilon_d' \leq \epsilon_3$, we have that $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma} > 0$ if $-\varepsilon_s'$ ($b$) is large enough and

[29] In this case, we cannot easily generalize to non-linear marginal costs because our definition of $\varepsilon_s$ cannot be expressed as a function of $Q/N$ anymore.

Table A.3: Variations of quantity and pass-through with $N$ when $\varepsilon_s > 0$

| $Q\varepsilon'_d$ | | 0 $\quad$ $\epsilon_3$ | $\epsilon_4$ | ruled out by SOC |
|---|---|---|---|---|
| $\frac{Q\varepsilon'_d\varepsilon_d\gamma N}{(N\varepsilon_d-1)^2}$ | - | + | + | |
| $-\frac{Q\varepsilon'_d}{\varepsilon_s}\gamma\frac{\partial Q}{\partial N}\frac{N}{Q}$ | + | - | - | $\times$ |
| $\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)}$ | - | - | + | $\times$ |
| $Q\varepsilon'_s\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{N\partial(Q/N)}{(Q/N)\partial N}$ | sign$(-\varepsilon'_s)$ | sign$(-\varepsilon'_s)$ | sign$(\varepsilon'_s)$ | $\times$ |

| $Q\varepsilon'_d$ | $\epsilon_1$ | 0 | | $\epsilon_2$ | | ruled out |
|---|---|---|---|---|---|---|
| $\frac{g\gamma}{(\varepsilon_d-1)^2}\frac{\partial Q}{\partial N}\frac{N}{Q}$ | + | - | - | - | + | $\times$ |
| $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma}$ | + if and only if $-\varepsilon'_s\frac{Q\varepsilon_d}{\varepsilon_s^2} > \left(\frac{g[Q\varepsilon'_d]}{(\varepsilon_d-1)^2} - \frac{q\varepsilon'_d}{\varepsilon_s}\right) - \frac{Q\varepsilon'_d\varepsilon_d\gamma N}{(N\varepsilon_d-1)^2}\left(\frac{\frac{N}{(Q/N)}}{\frac{\partial(Q/N)}{\partial N}}\right)$ | | | ? | | $\times$ |

*Note: if $\varepsilon''_d < -\frac{N\varepsilon_d-1}{4Q}$, then $\frac{g\gamma}{(\varepsilon_d-1)^2}\frac{\partial Q}{\partial N}\frac{N}{Q}$ is always positive.*

specifically if and only if $-\varepsilon'_s > \frac{\varepsilon_s^2}{q\varepsilon_d}\left(\frac{g[q\varepsilon'_d]}{(\varepsilon_d-1)^2} - \frac{q\varepsilon'_d}{\varepsilon_s}\right)$. Hence, we obtain that the pass-through increases with the number of firms when $\varepsilon'_d$ small enough and $-\varepsilon'_s$ ($b$) is large enough.

We then consider the case of increasing returns to scale ($\varepsilon_s \leq 0$). Again, we study the sign of the different terms in the pass-through equation (38) depending on $Q\varepsilon'_d$. The SOC (34) requires that $q\varepsilon'_d < \epsilon_4$. The SOC also implies that the sign of $\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)}$ is always negative, because in this case we have that $\epsilon_4 < \epsilon_3$. We can compare terms to obtain the sign of $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma}$ in a specific case. For all $Q\varepsilon'_d < \epsilon_4$, we have that $\frac{\partial\gamma}{\partial N}\frac{N}{\gamma} < 0$ if $\varepsilon'_s = -b$ is large enough and specifically if and only if $\varepsilon'_s\frac{Q\varepsilon_d}{\varepsilon_s^2} > \left(\frac{q\varepsilon'_d}{\varepsilon_s} - \frac{g[Q\varepsilon'_d]}{(\varepsilon_d-1)^2}\right) + \frac{Q\varepsilon'_d\varepsilon_d\gamma N}{(N\varepsilon_d-1)^2}\left(\frac{\frac{N}{(Q/N)}}{\frac{\partial(Q/N)}{\partial N}}\right)$. To summarize for the case of increasing returns to scale, we obtain that the pass-through decreases with the number of firms when $\varepsilon'_s$ is large enough.

We can rephrase our conclusions in more generic terms to encompass the two cases of increasing and decreasing returns to scale. When $\|\varepsilon'_s\|$ is large enough and when $\varepsilon'_d$ is small enough, the pass-through increases with $N$ in the case of decreasing returns to scale ($\varepsilon_s > 0$) and decreases with $N$ otherwise ($\varepsilon_s \leq 0$). This generalize the results in **proposition 1**.

## A.3 Cournot competition in the upstream sector

We examine the case of two sectors, with perfect competition in the downstream sector and Cournot competition in the upstream sector. For clarity purpose, we assume that inputs $q_I$ produced in the upstream sector are only consumed by producers of the final good and that inputs $q_I$ are not taxed. The representative consumer has the same aggregate utility function

(29) as in the previous section. This implies that aggregate demand for the final good $Q_F$ is given by $Q_F = \left(\frac{p_F}{A'}\right)^{-\frac{1}{\beta}}$ as in equation (30). We define the elasticity of demand for the final good as $\varepsilon_{dF} = -\frac{\partial p_F}{\partial Q_F}\frac{Q_F}{p_F} = \frac{1}{\beta}$.

Taking prices as given because of perfect competition, the representative producer of the final good maximizes profits $\widetilde{p}_F Q_F - p_I Q_I$ by choosing the quantity $Q_F$ to produce given the cost function $Q_I = f(Q_F)$, with $f(Q_F) = d(1-\rho)Q_F^{\frac{1}{1-\rho}}$ with $0 < \rho < 1$ and $d > 0$. The first order condition of the profit maximization problem yields the input demand function:

$$\widetilde{p}_F \quad = \quad p_I f' = p_I d Q_F^{\frac{\rho}{1-\rho}} \tag{39}$$

We define the elasticity of supply in the final good market as $\varepsilon_{sF} = \frac{\partial Q_F}{\partial \widetilde{p}_F}\frac{\widetilde{p}_F}{Q_F}$. The FOC implies $\varepsilon_{sF} = \frac{f'}{Q_F f''}$ and the assumed functional form implies $\varepsilon_{sF} = \frac{1-\rho}{\rho}$.

In the upstream sector, each firm $n$ chooses output independently to maximize profits $\widetilde{p}_I(Q_I)q_{I,n} - C_n(q_{I,n})$ subject to (39) as upstream firms internalize their impact on aggregate production $Q_I = \sum_n q_{I,n}$. In equilibrium, the first order conditions of the profit maximization problem for all upstream firms is such that

$$\widetilde{p}_I + \frac{\partial \widetilde{p}_I}{\partial q_{I,n}} q_{I,n} - c_n - b q_{I,n} = 0 \tag{40}$$

Summing (40) across firms and noting that $\widetilde{p}_I = p_I$ yield

$$\left(N - \frac{1}{\varepsilon_{dI}}\right) p_I = N \sum_n \left(c_n + b\frac{Q_I}{N}\right) = 0$$

$$\left(N - \frac{1}{\varepsilon_{dI}}\right) \frac{p_F}{f'} = (1+\tau) N \bar{C}' \tag{41}$$

where the function $\bar{C}'(.)$ is defined as before as in equation (32). We also define the elasticity of supply in the input market as before and the FOC implies $\varepsilon_{sI} = \frac{\bar{C}'}{\bar{C}''(Q_I/N)} = \frac{\bar{c} + b(Q_I/N)}{b(Q_I/N)}$. The elasticity of demand in the upstream sector is related to the supply characteristics in the downstream sector.[30]

$$\varepsilon_{dI} = -\frac{\partial Q_I}{\partial p_I}\frac{p_I}{Q_I} = \varepsilon_f \varepsilon_{sF} \tag{42}$$

where $\varepsilon_f \equiv \frac{\partial Q_F}{\partial Q_I}\frac{Q_I}{Q_F} = \frac{Q_F f'}{f}$ is the inverse elasticity of the production function and is always

[30] To prove this, it is convenient to obtain the derivative of the input price with respect to quantity using the FOC (39): $\frac{\partial p_I}{\partial Q_I} = \widetilde{p}_F \frac{\partial^2 Q_F}{\partial Q_I^2} = \frac{p_I}{\frac{\partial Q_F}{\partial Q_I}} \frac{\partial^2 Q_F}{\partial Q_I^2}$. It is also useful to note that $\varepsilon_{sF} = \frac{\frac{\partial Q_I}{\partial Q_F}}{Q_F \frac{\partial^2 Q_I}{\partial Q_F^2}} = \frac{-\left(\frac{\partial Q_F}{\partial Q_I}\right)^2}{Q_F \frac{\partial Q_F^2}{\partial^2 Q_I}}$ by using algebra. Then, we get $\varepsilon_{dI} = -\left(\frac{\partial p_I}{\partial Q_I}\right)^{-1} \frac{p_I}{Q_I} = -\frac{1}{Q_I}\frac{\partial Q_F}{\partial Q_I}\left(\frac{\partial^2 Q_F}{\partial Q_I^2}\right)^{-1} = \frac{\varepsilon_{sF}}{\frac{\partial Q_F}{\partial Q_I}\frac{Q_I}{Q_F}}$.

positive. Using the assumed functional form, we get $\varepsilon_{dI} = \frac{1}{\rho}$.

The existence of a solution also requires that the demand function is steep enough and that the following second order condition is satisfied.

$$\frac{\partial p_I}{\partial Q_I} + \frac{\partial^2 p_I}{\partial Q_I^2} q_{I,n} - \frac{\partial C_n}{\partial (Q_I/N)} \frac{1}{N} < 0 \quad \text{for all } n$$

We sum across all $n$ and use the same steps as in the single-sector case in equations (33) and (34) to rewrite the SOC into

$$1 - \left( \frac{\varepsilon'_{dI}}{\varepsilon_{dI}} Q_I + 1 \right) \frac{1}{N - \frac{1}{\varepsilon_{dI}}} + \frac{\varepsilon_{dI}}{\varepsilon_{sI}} > 0 \tag{43}$$

To obtain an expression for the pass-through, we take the derivative of the above equation (41) with respect to $\tau$ and use the notation $\varepsilon'_{dI} = \partial \varepsilon_{dI} / \partial Q_I$. We get

$$\begin{aligned} &\frac{\partial p_F}{\partial \tau} \left( N - \frac{1}{\varepsilon_{dI}} \right) \frac{1}{f'} - \frac{f''}{f'^2} \frac{\partial Q_F}{\partial p_F} \frac{\partial p_F}{\partial \tau} p_F \left( N - \frac{1}{\varepsilon_{dI}} \right) + \frac{p_F}{f'} \frac{\varepsilon'_{dI}}{\varepsilon_{dI}^2} \frac{\partial Q_I}{\partial p_F} \frac{\partial p_F}{\partial \tau} = N\bar{C}' + (1+\tau) N \bar{C}'' \frac{1}{N} \frac{\partial Q_I}{\partial p_F} \frac{\partial p_F}{\partial \tau} \\ \Leftrightarrow\ &\frac{\partial p_F}{\partial \tau} \left( \left( N - \frac{1}{\varepsilon_{dI}} \right) \frac{1}{f'} + \frac{f''}{f'^2} \left( N - \frac{1}{\varepsilon_{dI}} \right) \varepsilon_{dF} Q_F - \frac{\varepsilon'_{dI}}{\varepsilon_{dI}^2} \varepsilon_{dF} Q_F + (1+\tau) \bar{C}'' f' \frac{\varepsilon_{dF} Q_F}{p_F} \right) = N\bar{C}' \end{aligned}$$

We then use the definition of the supply elasticity and the firm FOC (41) to obtain

$$\gamma_F = \frac{1}{1 + \frac{Q_F f''}{f'} \varepsilon_{dF} - \frac{Q_F \varepsilon'_{dI}}{\varepsilon_{dI}^2} \frac{\varepsilon_{dF} f'}{N - \frac{1}{\varepsilon_{dI}}} + \varepsilon_{dF} \frac{Q_F f'}{Q_I \varepsilon_{sI}}} = \frac{1}{1 + \varepsilon_{dF} \left( \frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} - \frac{Q_I \varepsilon'_{dI}}{\varepsilon_{dI}^2} \frac{\varepsilon_f}{N - \frac{1}{\varepsilon_{dI}}} \right)} \tag{44}$$

Once again, the firm SOC (43) implies that the pass-through is positive.

We obtain the derivative of the final good and the average input quantity per firm with respect to $N$ using the FOC (41).

$$
\begin{aligned}
&\frac{\partial p_F}{\partial Q_F}\frac{\partial Q_F}{\partial N}\left(N-\frac{1}{\varepsilon_{dI}}\right)\frac{1}{f'}+\frac{p_F}{f'}-\left(N-\frac{1}{\varepsilon_{dI}}\right)\frac{p_F f''}{f'^2}\frac{\partial Q_F}{\partial N}+\frac{\varepsilon'_{dI}}{\varepsilon_{dI}}\frac{\partial Q_I}{\partial Q_F}\frac{\partial Q_F}{\partial N}\frac{p_F}{f'}=(1+\tau)\bar{C}'+N(1+\tau)\bar{C}''\frac{\partial(Q_I/N)}{\partial N}\\
&\Leftrightarrow -\frac{\partial Q_F}{\partial N}\frac{\left(N-\frac{1}{\varepsilon_{dI}}\right)p_F}{f'\varepsilon_{dF}Q_F}+\frac{p_F}{f'}-\left(N-\frac{1}{\varepsilon_{dI}}\right)\frac{p_F f''}{f'^2}\frac{\partial Q_F}{\partial N}+\frac{\varepsilon'_{dI}}{\varepsilon_{dI}}\frac{\partial Q_F}{\partial N}p_F=(1+\tau)\bar{C}'+(1+\tau)\bar{C}''f'\frac{\partial Q_F}{\partial N}-(1+\tau)\bar{C}''\frac{f}{N}\\
&\frac{\partial Q_F}{\partial N}\frac{N}{Q_F}=\frac{1-\frac{1}{\varepsilon_{sI}}-\frac{N}{N-\frac{1}{\varepsilon_{dI}}}}{-\frac{1}{\varepsilon_{dF}}-\frac{Q_F f''}{f'}+\frac{\varepsilon'_{dI}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}Q_F f'-\frac{\varepsilon_f}{\varepsilon_{sI}}}\\
&\frac{\partial Q_F}{\partial N}\frac{N}{Q_F}=\frac{\frac{\varepsilon_{dF}}{\varepsilon_{sI}}+\frac{\varepsilon_{dF}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(N-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \qquad (45)\\
&\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)}=\frac{\partial Q_I}{\partial N}\frac{1}{N}\frac{N}{(Q_I/N)}-\frac{Q_I}{N^2}\frac{N}{(Q_I/N)}=\varepsilon_f\frac{\partial Q_F}{\partial N}\frac{N}{Q_F}-1\\
&\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)}=\frac{\varepsilon_{dF}\left(\frac{\varepsilon_f}{\varepsilon_{sI}}+\frac{1}{\varepsilon_{sF}}\frac{1}{N-\frac{1}{\varepsilon_{dI}}}\right)-1-\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}\varepsilon_f\right)}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}\varepsilon_f\right)}\\
&\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)}=\frac{-1-\frac{\varepsilon_{dF}}{\varepsilon_{sF}}\left(1-\frac{1+Q_I\varepsilon'_{dI}}{N-\frac{1}{\varepsilon_{dI}}}\right)}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(N-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \qquad (46)
\end{aligned}
$$

Focusing our attention on the case of the functional form $Q_I = d(1-\rho)Q_F^{\frac{1}{1-\rho}}$ where $\varepsilon'_{dI} = 0$, we can simply equations (44) and (46), and obtain the derivative of the pass-through with respect to $N$.

$$
\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)} = \frac{-1-\frac{\varepsilon_{dF}}{\varepsilon_{sF}}\left(1-\frac{1}{N-\frac{1}{\varepsilon_{dI}}}\right)}{1+\frac{\varepsilon_{dF}}{\tilde{\varepsilon}_s}} \qquad (47)
$$

$$
\gamma_F = \frac{1}{1+\frac{\varepsilon_{dF}}{\tilde{\varepsilon}_s}} \qquad (48)
$$

$$
\frac{\partial \gamma_F}{\partial N}\frac{N}{\gamma_F} = \varepsilon'_{sI}\frac{\partial(Q_I/N)}{\partial N}\frac{\varepsilon_{dF}\varepsilon_f}{\tilde{\varepsilon}_s^2}\gamma_F N \qquad (49)
$$

where $\frac{1}{\tilde{\varepsilon}_s} = \frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} = \frac{1}{1-\rho}\left(\rho + \frac{1}{\varepsilon_{sI}}\right)$. Note that $\varepsilon_f$, $\varepsilon_{sF}$, and $\varepsilon_{dF}$ are all positive. The SOC (43) additionally implies that $1+\varepsilon_{dF}/\tilde{\varepsilon}_s > 0$. We can see that the average input quantity per firm decreases with the number of firms $\frac{\partial(Q_I/N)}{\partial N} < 0$ and that pass-through in the downstream sector has the sign of $-\varepsilon'_{sI}$ and, therefore, the sign of $b$ as stated in **proposition 2**.

## A.4 Monopolistic competition in the upstream sector

We examine the case of two sectors, with perfect competition in the downstream sector and Monopolistic competition in the upstream sector. The derivation of this case will follow closely the assumption and calculations presented in the previous section. Similarly, we assume that inputs $q_I$ produced in the upstream sector are only consumed by producers of the final good and that inputs $q_I$ are not taxed. The representative consumer has the same aggregate utility function (29) as in the previous section and the elasticity of demand for the final good is the same, $\varepsilon_{dF} = -\frac{\partial p_F}{\partial Q_F}\frac{Q_F}{p_F} = \frac{1}{\beta}$.

Taking prices as given because of perfect competition, the representative producer faces the same cost function its maximization problem yields the same first order condition $\widetilde{p}_F = P_I f' = P_I d Q_F^{\frac{\rho}{1-\rho}}$ and implies the same elasticity of supply, $\varepsilon_{sF} = \frac{1-\rho}{\rho}$.

The variety of inputs to the final good production are produced by firms under monopolistic competition with the same cost function as in the single-sector case. Aggregate input is given by $Q_I = \left(\int_1^N q_{I,n}^{\frac{\sigma-1}{\sigma}} dn\right)^{\frac{\sigma}{\sigma-1}}$ and sold at prices denoted by $p_{I,n}$. Because all firms are assumed equally productive, all firm prices and quantities are identical and, from now on, we can drop the subscript $n$ for conciseness. This also implies that $Q_I = q_I N^{\frac{\sigma}{\sigma-1}}$, $P_I = p_I N^{\frac{1}{1-\sigma}}$.

Each input producer maximize profits after internalizing their impact on demand from the final good producer and we get the same first order condition

$$p_I\left(1 - \frac{1}{\varepsilon_{dI}}\right) = C' \tag{50}$$

where the elasticity of demand in the upstream sector is related to supply in the downstream sector. We go through the same steps as described in equation (42) and obtain $\varepsilon_{dI} = -\frac{\partial q_I}{\partial p_I}\frac{p_I}{q_I} = -\frac{\partial q_I}{\partial Q_I}\frac{Q_I}{q_I}\frac{\partial Q_I}{\partial p_I}\frac{p_I}{Q_I} = \varepsilon_f \varepsilon_{sF} = \frac{1}{\rho}$. We also define the elasticity of supply in the input market in the same way, $\varepsilon_{sI} = \frac{C'}{C'' q_I}$.

The existence of a solution also requires that the demand function is steep enough and that the following second order condition is satisfied. We go through the same calculation as in the single-sector case and obtain

$$1 - \frac{q_I \varepsilon'_{dI}}{\varepsilon_{dI}} \frac{1}{\left(1 - \frac{1}{\varepsilon_{dI}}\right)} + \frac{\varepsilon_{dI}}{\varepsilon_{sI}} > 0 \tag{51}$$

To find an expression for the pass-through, we take the derivative of equation (50) with respect to $\tau$ after substituting prices $\left(p_F\left(1 - \frac{1}{\varepsilon_{dI}}\right) N^{\frac{1}{\sigma-1}}/f' = (1+\tau)C'\right)$. We get

$$\begin{aligned} &\frac{\partial p_F}{\partial \tau}\left(1 - \frac{1}{\varepsilon_{dI}}\right)\frac{1}{f'} - \frac{f''}{f'^2}\frac{\partial Q_F}{\partial p_F}\frac{\partial p_F}{\partial \tau} p_F \left(1 - \frac{1}{\varepsilon_{dI}}\right) + \frac{p_F}{f'}\frac{\varepsilon'_{dI}}{\varepsilon_{dI}^2}\frac{\partial q_I}{\partial p_F}\frac{\partial p_F}{\partial \tau} = N^{\frac{-1}{\sigma-1}}\bar{C}' + (1+\tau)N^{\frac{-1}{\sigma-1}}\bar{C}''\frac{\partial q_I}{\partial Q_I}\frac{\partial Q_I}{\partial p_F}\frac{\partial p_F}{\partial \tau} \\ \Leftrightarrow &\frac{\partial p_F}{\partial \tau}\left(\left(1 - \frac{1}{\varepsilon_{dI}}\right)\frac{1}{f'} + \frac{f''}{f'^2}\left(1 - \frac{1}{\varepsilon_{dI}}\right)\varepsilon_{dF} Q_F - \frac{\varepsilon'_{dI}}{\varepsilon_{dI}^2} N^{\frac{-\sigma}{\sigma-1}}\varepsilon_{dF} Q_F + (1+\tau)N^{\frac{-1}{\sigma-1}}\bar{C}'' f' \frac{\varepsilon_{dF} Q_F}{p_F} N^{\frac{-\sigma}{\sigma-1}}\right) = N^{\frac{-1}{\sigma-1}}\bar{C}' \end{aligned}$$

We then use the definition of the supply elasticity and the firm FOC (50) to obtain

$$\gamma_F = \frac{1}{1 + \varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} - \frac{q_I \varepsilon'_{dI}}{\varepsilon_{dI}^2}\frac{\varepsilon_f}{1-\frac{1}{\varepsilon_{dI}}}\right)} \tag{52}$$

This pass-through follows a similar expression as under Cournot competition (equation 44). Once again, the input producer SOC (51) implies that the pass-through is positive.

We obtain the derivative of quantities with respect to $N$ using the FOC (50) and the relation between aggregate input and varieties $\left(q_I = Q_I N^{\frac{-\sigma}{\sigma-1}}\right)$.

$$\frac{\partial p_F}{\partial Q_F}\frac{\partial Q_F}{\partial N}\left(1 - \frac{1}{\varepsilon_{dI}}\right)\frac{1}{f'} - \left(1 - \frac{1}{\varepsilon_{dI}}\right)\frac{p_F f''}{f'^2}\frac{\partial Q_F}{\partial N} + \frac{\varepsilon'_{dI}}{\varepsilon_{dI}}\frac{\partial q_I}{\partial Q_F}\frac{\partial Q_F}{\partial N}\frac{p_F}{f'} = (1+\tau)N^{\frac{-1}{\sigma-1}}\bar{C}''\frac{\partial q_I}{\partial N} - \frac{(1+\tau)N^{\frac{-1}{\sigma-1}-1}}{\sigma-1}\bar{C}'$$

$$-\frac{\partial Q_F}{\partial N}\left(\frac{\left(1-\frac{1}{\varepsilon_{dI}}\right)p_F}{f'\varepsilon_{dF}Q_F} - \left(1 - \frac{1}{\varepsilon_{dI}}\right)\frac{p_F f''}{f'^2} + \frac{\varepsilon'_{dI}}{\varepsilon_{dI}}p_F\right) = \frac{(1+\tau)\bar{C}''}{N^{\frac{1}{\sigma-1}}}\left(N^{\frac{-\sigma}{\sigma-1}}\frac{\partial Q_I}{\partial Q_F}\frac{\partial Q_F}{\partial N} - \frac{q_I\frac{\sigma}{\sigma-1}}{N}\right) - \frac{(1+\tau)\bar{C}'}{(\sigma-1)N^{\frac{1}{\sigma-1}+1}}$$

$$\frac{\partial Q_F}{\partial N}\frac{N}{Q_F} = \frac{\frac{\sigma}{\sigma-1}\frac{\varepsilon_{dF}}{\varepsilon_{sI}} + \frac{1}{\sigma-1}}{1 + \varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} - \frac{q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(1-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \tag{53}$$

$$\frac{\partial q_I}{\partial N}\frac{N}{q_I} = \frac{\partial Q_I}{\partial Q_F}\frac{\partial Q_F}{\partial N}N^{-\frac{\sigma}{\sigma-1}}\frac{N}{q_I} - \frac{\sigma}{\sigma-1}Q_I N^{-\frac{\sigma}{\sigma-1}-1}\frac{N}{q_I} = \varepsilon_f\frac{\partial Q_F}{\partial N}\frac{N}{Q_F} - \frac{\sigma}{\sigma-1}$$

$$\frac{\partial q_I}{\partial N}\frac{N}{q_I} = \frac{\frac{\sigma}{\sigma-1}\frac{\varepsilon_{dF}\varepsilon_f}{\varepsilon_{sI}} + \frac{1}{\sigma-1}\varepsilon_f - \frac{\sigma}{\sigma-1} - \varepsilon_{dF}\frac{\sigma}{\sigma-1}\left(\frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} - \frac{q_I\varepsilon'_{dI}/\varepsilon_{dI}}{1-\frac{1}{\varepsilon_{dI}}}\varepsilon_f\right)}{1 + \varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} - \frac{q_I\varepsilon'_{dI}/\varepsilon_{dI}}{1-\frac{1}{\varepsilon_{dI}}}\varepsilon_f\right)}$$

$$\frac{\partial q_I}{\partial N}\frac{N}{q_I} = \frac{\frac{1}{\sigma-1}\varepsilon_f - \frac{\sigma}{\sigma-1} - \frac{\sigma}{\sigma-1}\frac{\varepsilon_{dF}}{\varepsilon_{sF}}\left(1 - \frac{q_I\varepsilon'_{dI}}{1-\frac{1}{\varepsilon_{dI}}}\right)}{1 + \varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} - \frac{q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(1-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \tag{54}$$

Focusing our attention on the case of the functional form $Q_I = d(1-\rho)Q_F^{\frac{1}{1-\rho}}$ where $\varepsilon'_{dI} = 0$, we can simply equations (44) and (46), and obtain the derivative of the pass-through with respect to $N$.

$$\frac{\partial q_I}{\partial N}\frac{N}{q_I} = \frac{-\frac{\sigma}{\sigma-1}\left(1 + \frac{\varepsilon_{dF}}{\varepsilon_{sF}} - \frac{\varepsilon_f}{\sigma}\right)}{1 + \frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} = \frac{-\frac{\sigma}{\sigma-1}\left(\frac{\frac{\sigma-1}{\sigma} + \rho\left(\frac{1}{\beta}-1\right)}{1-\rho}\right)}{1 + \frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} \tag{55}$$

$$\gamma_F = \frac{1}{1 + \frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} \tag{56}$$

$$\frac{\partial \gamma_F}{\partial N}\frac{N}{\gamma_F} = \varepsilon'_{sI}\frac{\partial q_I}{\partial N}\frac{\varepsilon_{dF}\varepsilon_f}{\widetilde{\varepsilon}_s^2}\gamma_F N \tag{57}$$

where $\frac{1}{\widetilde{\varepsilon}_s} = \frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} = \frac{1}{1-\rho}\left(\rho + \frac{1}{\varepsilon_{sI}}\right)$. Note that $\varepsilon_f$, $\varepsilon_{sF}$, and $\varepsilon_{dF}$ are all positive. The SOC (51) additionally implies that $1 + \varepsilon_{dF}/\widetilde{\varepsilon}_s > 0$. We can see that the input quantity decreases with the number of firms $\frac{\partial q_I}{\partial N} < 0$ and therefore, that pass-through in the downstream sector has the sign of $-\varepsilon'_{sI}$ and, therefore, the sign of $b$ as stated in **proposition 2**.

## A.5 Differences in scope for quality in the final good

We examine a sector characterized by 'discrete choices', meaning that consumers can decide to purchase at most one variety of the product. For any consumer, not buying any variety and spending all her income on an outside good is always an option. We consider a partial equilibrium in which income and the outside good are unaffected by changes in the tax rate in the sector that we examine. $N$ homogeneous firms compete by manufacturing horizontally and vertically distinct varieties as in Khandelwal (2010). Horizontal differentiation is assumed to be costless, implying that in equilibrium, all firms produce horizontally distinct varieties.

Consumer $k$ observes all varieties and chooses the variety $n$ with price $p_n$ and quality $\lambda_n$ that provides her with the highest indirect utility

$$V_{nk} = \delta_n + \xi_{nk}, \qquad \text{with } \delta_n \equiv \left(\theta\lambda_n^{\psi} - p_n^{\psi}\right)^{1/\psi} \qquad \text{and } \psi < 1 \tag{7}$$

Quality is defined as an attribute whose valuation is agreed upon by all consumers: holding prices fixed, all consumers would prefer higher quality objects. The "quality ladder" parameter $\theta$ reflects the consumers' valuation for quality.

The price-quality indifference curves are given by $p_n = \left(\theta\lambda_n^{\psi} - \delta_n^{\psi}\right)^{1/\psi}$. The marginal willingness to pay $\frac{\partial \ln p_n}{\partial \ln \lambda_n} = \left[1 - \frac{1}{\theta}\left(\frac{p_n}{\lambda}\right)^{\psi}\right]^{-1}$ is increasing in the quality-price ratio if $\psi > 0$ and decreasing with the the quality-price ratio if $\psi < 0$. In other words in the case when $\psi < 0$, consumers demand cheaper quality when quality increases.

Horizontal product differentiation is introduced in (7) through the consumer-variety-specific term, $\xi_{nk}$. Following standard practice in the discrete choice literature, $\xi_{nk}$ is assumed to be distributed i.i.d. type-I extreme value. Unlike the vertical attribute, the horizontal attribute has the property that some people prefer it while others do not, and on average, it provides zero utility. Therefore, the mean valuation for variety $n$ is $\delta_n$. Under the distributional assumption, the market share of variety $n$ is given by the familiar logit formula $m_n = \frac{e^{\delta_n}}{\sum_m e^{\delta_m}}$.

Each firm $n$ produces a variety subject to a marginal cost function that is increasing with quality, $w + \frac{\lambda_n}{Z}$. We assume that the market is characterized by monopolistic competition with a sufficiently large number of firms so that no one firm can influence the market equilibrium prices and qualities. A firm $n$ maximizes profits by choosing the price and quality.

$$\max_{\widetilde{p}_n, \lambda_n} \left[\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right] \frac{e^{\delta_n}}{\sum_m e^{\delta_m}} \tag{58}$$

The two first order conditions are

$$0 = e^{\delta_n} - \left(\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right)(1+\tau)^{\psi}\widetilde{p}_n^{\psi-1}\left(\theta\lambda_n^{\psi} - (\widetilde{p}_n(1+\tau))^{\psi}\right)^{\frac{1-\psi}{\psi}} e^{\delta_n} \tag{59}$$

$$0 = -\frac{1}{Z}e^{\delta_n} + \left(\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right)\theta\lambda_n^{\psi-1}\left(\theta\lambda_n^{\psi} - (\widetilde{p}_n(1+\tau))^{\psi}\right)^{\frac{1-\psi}{\psi}} e^{\delta_n} \tag{60}$$

We obtain quality and mean valuation as functions of price by combining the first order conditions.

$$\lambda_n^{1-\psi} = \frac{\theta Z}{(1+\tau)^{\psi}}\widetilde{p}_n^{1-\psi} \tag{61}$$

$$\begin{aligned} \delta_n &= \left(\theta\left(\frac{\theta Z}{(1+\tau)^{\psi}}\right)^{\frac{\psi}{1-\psi}}\widetilde{p}_n^{\psi} - (\widetilde{p}_n(1+\tau))^{\psi}\right)^{\frac{1}{\psi}} \\ &= \left(\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}}(1+\tau)^{\frac{\psi}{\psi-1}} - 1\right)^{\frac{1}{\psi}}(1+\tau)\widetilde{p}_n \end{aligned} \tag{62}$$

We solve for prices by substituting quality and mean valuation using equations (61) and (62) in the first order condition (59).

$$0 = 1 - \left(\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right)(1+\tau)^{\psi}\widetilde{p}_n^{\psi-1}\left(\theta^{\frac{1}{1-\psi}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} - 1\right)^{\frac{1-\psi}{\psi}}((1+\tau)\widetilde{p}_n)^{1-\psi}$$

$$0 = 1 - \left(\widetilde{p}_n - w - \frac{\widetilde{p}_n}{Z}\left(\frac{\theta Z}{(1+\tau)^{\psi}}\right)^{\frac{1}{1-\psi}}\right)\left(\theta^{\frac{1}{1-\psi}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} - 1\right)^{\frac{1-\psi}{\psi}}(1+\tau)$$

$$\widetilde{p}_n = w\left(1 - \theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}}(1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-1} + \frac{1}{(1+\tau)}\left(1 - \theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}}(1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}} \tag{63}$$

The existence of a positive price solution therefore requires that $\theta < \left(\frac{1+\tau}{Z}\right)^{\psi}$.

We obtain pass-through as stated in **proposition 3** by taking the derivative of the equation

(63) and multiplying by $\frac{(1+\tau)}{\widetilde{p}_n}$.

$$
\begin{aligned}
(\gamma-1) = & -w\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}} \frac{\psi}{1-\psi} \frac{(1+\tau)^{\frac{\psi}{\psi-1}}}{\widetilde{p}_n} \left(1-\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-2} \\
& -\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}} \frac{1}{1-\psi} \frac{(1+\tau)^{\frac{\psi}{\psi-1}}}{\widetilde{p}_n} \frac{1}{(1+\tau)} \left(1-Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}-1} \\
& -\frac{1}{\widetilde{p}_n} \frac{1}{(1+\tau)} \left(1-Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}} \\
(\gamma-1) = & -w\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}} \frac{\psi}{1-\psi} \frac{(1+\tau)^{\frac{\psi}{\psi-1}}}{\widetilde{p}_n} \left(1-\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-2} \\
& -\frac{1}{\widetilde{p}_n} \frac{1}{(1+\tau)} \left(1-Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}-1} \left(1+\frac{\psi}{1-\psi} Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right) \\
= & -\frac{\psi}{1-\psi} \frac{Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}}{\left(1-\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)} - \frac{1}{\widetilde{p}_n} \frac{1}{(1+\tau)} \left(1-Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}-1} \\
= & -\frac{\psi}{1-\psi} \frac{Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}}{\left(1-\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)} - \frac{\frac{1}{(1+\tau)} \left(1-Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}}}{w+\frac{1}{(1+\tau)} \left(1-Z^{\frac{\psi}{1-\psi}} \theta^{\frac{1}{1-\psi}} (1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}+1}} \\
= & \frac{-\psi/(1-\psi)}{\theta^{\frac{1}{\psi-1}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{\psi-1}} - 1} - \frac{1}{1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} + w(1+\tau)\left(1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1}{\psi}}}
\end{aligned} \tag{9}
$$

We take the derivative of the above with respect to $\theta$ to examine the variations of pass-through with respect to the scope for quality.

$$
\begin{aligned}
\frac{\partial\gamma}{\partial\theta} = & -\frac{\psi}{(1-\psi)^2} Z^{\frac{\psi}{\psi-1}} \theta^{\frac{\psi}{1-\psi}} (1+\tau)^{\frac{\psi}{1-\psi}} \left(\theta^{\frac{1}{\psi-1}} Z^{\frac{\psi}{\psi-1}} (1+\tau)^{\frac{\psi}{1-\psi}} - 1\right)^{-2} \\
& - \frac{\frac{\theta^{\frac{\psi}{1-\psi}}}{1-\psi} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} \left[1+\frac{w(1+\tau)}{\psi}\left(1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1}{\psi}-1}\right]}{\left[1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} + w(1+\tau)\left(1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1}{\psi}}\right]^2}
\end{aligned} \tag{64}
$$

When $0 < \psi < 1$, the above is negative. When $\psi < 0$, the above is positive when $\psi$ is negative enough and for example when $\psi < -\frac{1}{w(1+\tau)} < -\frac{1}{w(1+\tau)} \left(1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1-\psi}{-\psi}}$.

The above proves the remaining results in **proposition 3**. A tax hike implies higher consumer prices. Note that the marginal cost of increasing quality does not depend on price. Quality adjustments by producers crucially depends on changes in consumers' valuation for quality which are characterized by the degree of substitution/complementarity. If substitution dominates (as in Khandelwal (2010)) consumers faced with a higher price prefer a reduction in quality as it allows producers to reduce prices. If complementarity dominates, consumers would rather get higher quality when they pay more, and producers will increase prices at the expense of a lower reduction in producer prices (possibly an increase in producer prices). Those effects are magnified by the scope for quality. Therefore, pass-through decreases with the quality ladder in the substitution case, while the opposite is true in the complementarity case.

# B Empirical Appendix

## B.1 Descriptive Statistics

Table B.1: Summary of VAT reforms by country

| | First year in data | Number of reforms | Products affected | Product-Months affected |
|---|---|---|---|---|
| Austria | 1998 | 1 | 1 | 1 |
| Finland | 1998 | 2 | 48 | 59 |
| France | 1998 | 3 | 35 | 36 |
| Germany | 1998 | 2 | 36 | 72 |
| Greece | 2000 | 3 | 48 | 144 |
| Ireland | 1998 | 7 | 34 | 153 |
| Italy | 1998 | 2 | 36 | 36 |
| Luxembourg | 2003 | 1 | 1 | 1 |
| Netherlands | 1998 | 1 | 29 | 29 |
| Portugal | 1998 | 7 | 49 | 193 |
| Slovakia | 2008 | 1 | 45 | 45 |
| Slovenia | 2006 | 1 | 1 | 1 |
| Spain | 1998 | 2 | 38 | 76 |
| Total | | 33 | 401 | 846 |

Table B.2: Summary of observed VAT rates and prices

| | | Obs | Mean | S.D. | Min | Max |
|---|---|---|---|---|---|---|
| VAT levels | Reduced rate | 31,147 | 0.075 | 0.033 | 0.021 | 0.17 |
| | Standard rate | 74,010 | 0.194 | 0.02 | 0.15 | 0.23 |
| | Zero rate | 2,393 | 0 | 0 | 0 | 0 |
| VAT changes | All | 846 | 0.01 | 0.02 | -0.15 | 0.17 |
| | Standard | 722 | 0.01 | 0.01 | -0.01 | 0.03 |
| | Reduced | 116 | 0.01 | 0.02 | -0.05 | 0.07 |
| | Reclassification | 8 | -0.03 | 0.12 | -0.15 | 0.17 |
| | VAT decrease | 143 | -0.02 | 0.03 | -0.15 | -0.01 |
| | VAT increase | 703 | 0.02 | 0.01 | 0.01 | 0.17 |
| Price levels | | 108,000 | 102.5 | 19.9 | 18.8 | 527.6 |

Table B.3: Pairwise correlations between regressors

| Variables | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| (1) *Regimpact* | 1.000 | | | | | |
| (2) Quality range | 0.030* | 1.000 | | | | |
| (3) Openness | -0.119* | 0.050* | 1.000 | | | |
| (4) Concentration† | -0.168* | -0.039* | 0.096* | 1.000 | | |
| (5) Concentration‡ | -0.157* | 0.050* | 0.042* | 0.531* | 1.000 | |
| (6) Concentration§ | -0.045* | -0.056* | 0.023* | 0.205* | -0.022* | 1.000 |

* shows signficance at the 1% level.

† baseline from Orbis, mapped from 2-digit NACE to COICOP.

‡ as above, but defining the relevant market at the 4-digit level.

§ constructed from import origins using trade data, as described in the text.

Table B.4: VAT changes for which announcement dates are observed

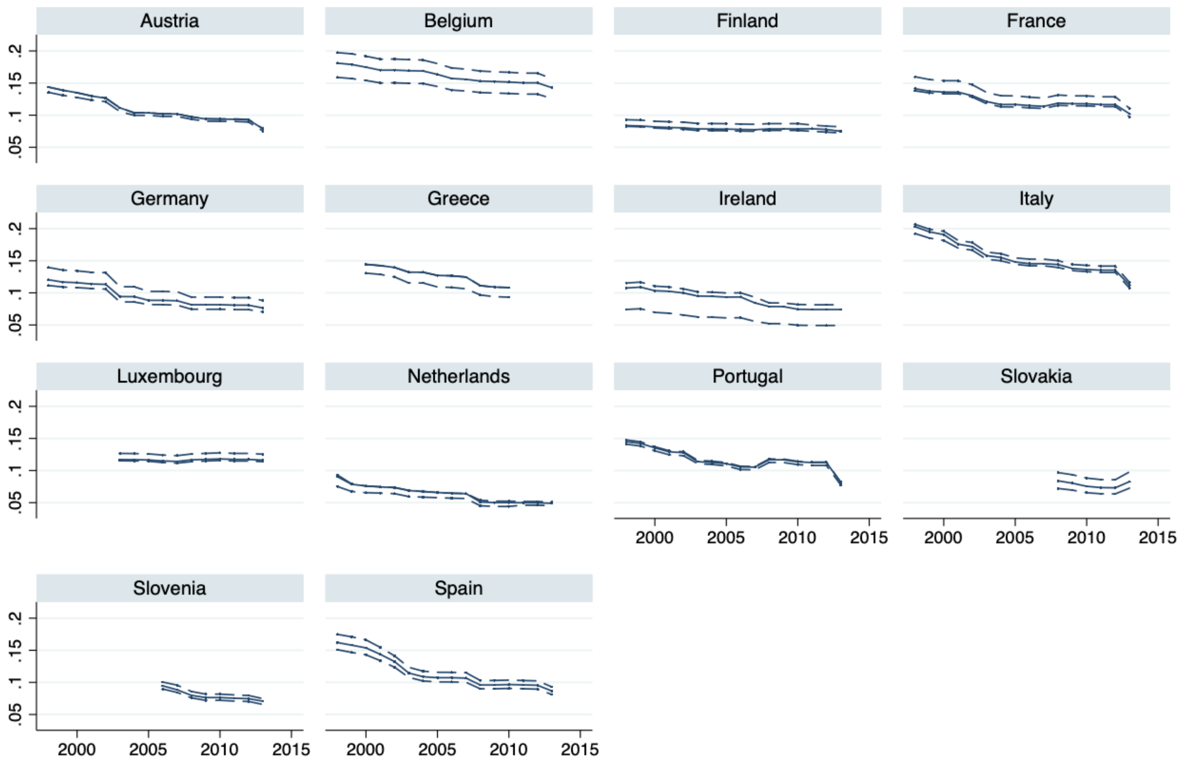
| | | Obs | Mean | S.D. | Min | Max |
|---|---|---|---|---|---|---|
| VAT changes | All | 565 | 0.01 | 0.02 | -0.15 | 0.17 |
| | Standard | 489 | 0.01 | 0.01 | -0.01 | 0.03 |
| | Reduced | 71 | 0.01 | 0.01 | -0.05 | 0.02 |
| | Reclassification | 5 | -0.01 | 0.14 | -0.15 | 0.17 |
| | VAT decrease | 101 | -0.01 | 0.02 | -0.15 | -0.01 |
| | VAT increase | 464 | 0.02 | 0.01 | 0.01 | 0.17 |

Figure B.1: Distribution of regulation across consumption categories


*Notes:* These plots summarize the distribution of the *Regimpact* measure across consumption categories. A lower value of the indicator reflects a more competition-friendly regulatory stance among input industries. Each box depicts the 25th, 50th and 75th percentiles, with extending lines to the minimum and maximum values, excluding outliers (defined as 1.5IQR below/above the lower/upper quartile).

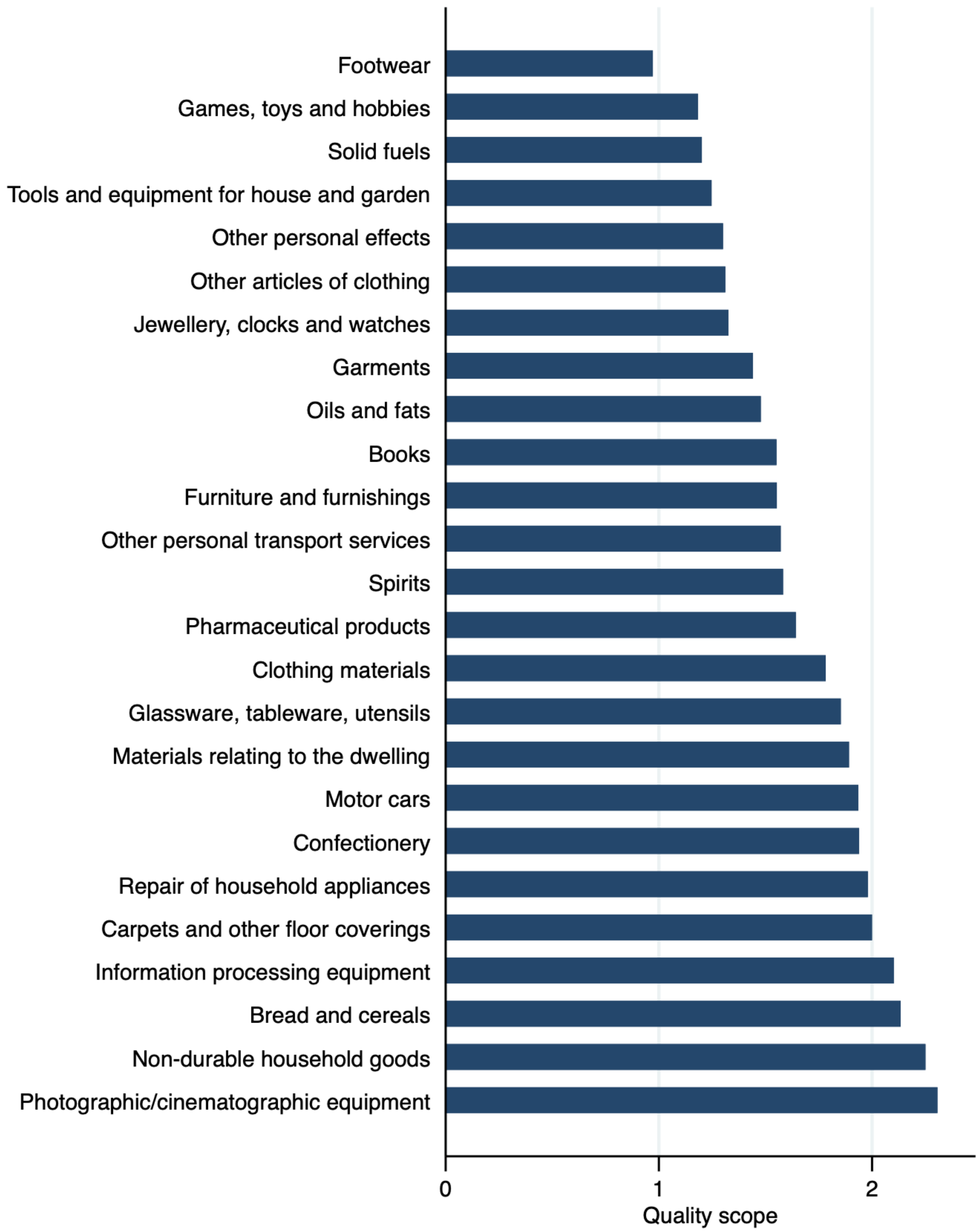
Figure B.2: Changes in upstream regulation by country and consumption category

(a) Median *Regimpact* by country over time – 25th, 50th and 75th percentiles




(b) Median *Regimpact* by consumption category over time – 25th, 50th and 75th percentiles

FIGURE B.3: Distribution of quality scope across consumption categories

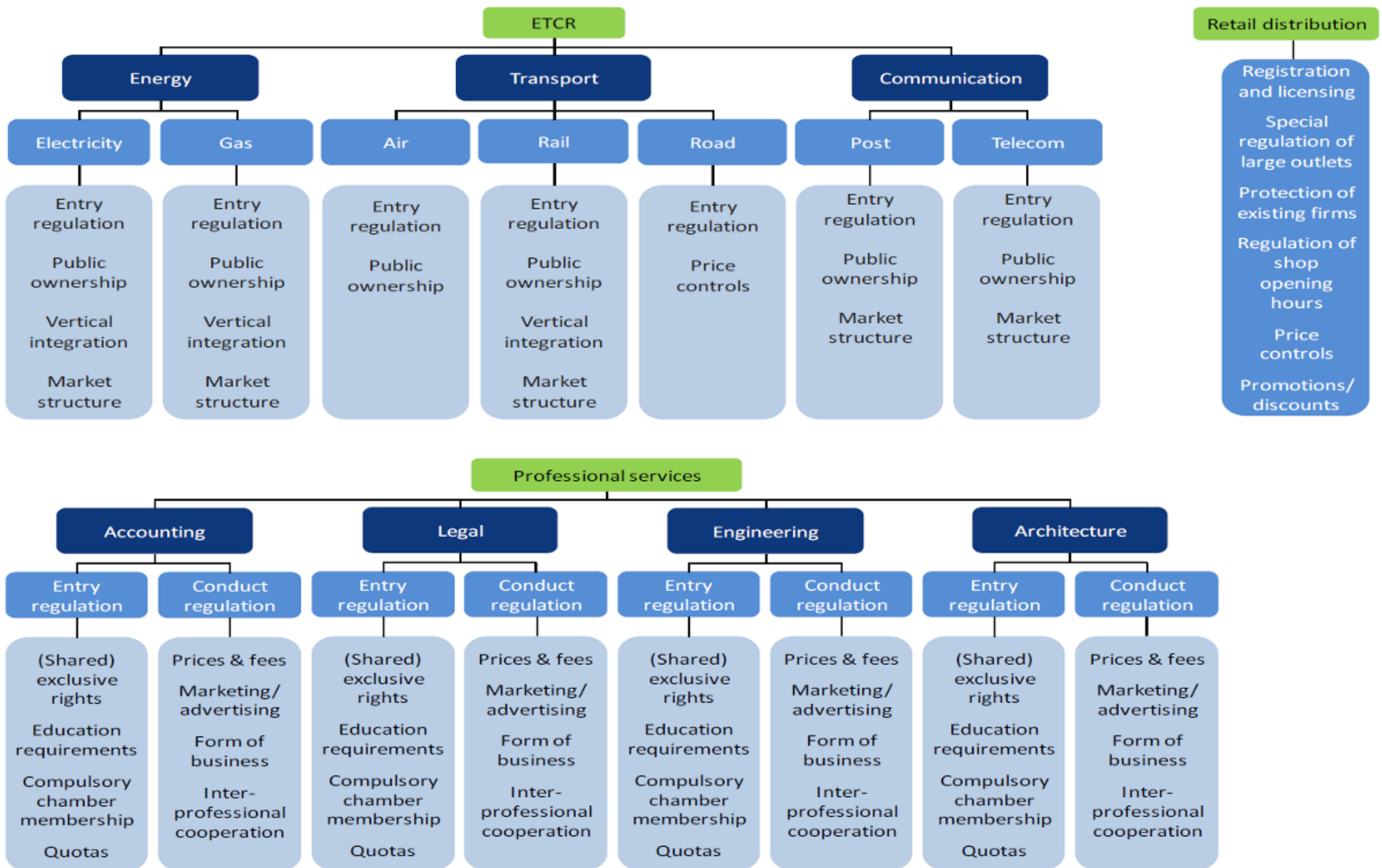



*Notes:* This graph depicts the estimated quality range across different consumption categories. A higher value of the indicator reflects a longer average 'quality ladder' (Khandelwal 2010).

Table B.5: Summary statistics for main variables

| Variable | Obs | Mean | S.D. | Min | Max |
|---|---|---|---|---|---|
| $\Delta \ln(\text{Price})$ | 105,527 | .001 | .024 | -.414 | .415 |
| $\Delta \ln(1 + \text{VAT})$ | 105,527 | 0 | .002 | -.134 | .149 |
| *Regimpact* | 105,527 | .118 | 1.008 | -2.098 | 3.774 |
| Quality range | 52,407 | .06 | .993 | -1.933 | 1.785 |
| Openness | 105,527 | .022 | 1.146 | -.224 | 92.187 |
| Concentration | 105,527 | -.023 | .971 | -.77 | 3.121 |
| TAX_package | 105,527 | .005 | .069 | 0 | 1 |
| Consumption | 105,527 | 1.210e+08 | 3.380e+08 | 1456.954 | 1.670e+09 |
| ValueAdded | 104,705 | 18455.248 | 45391.111 | .4 | 559000 |

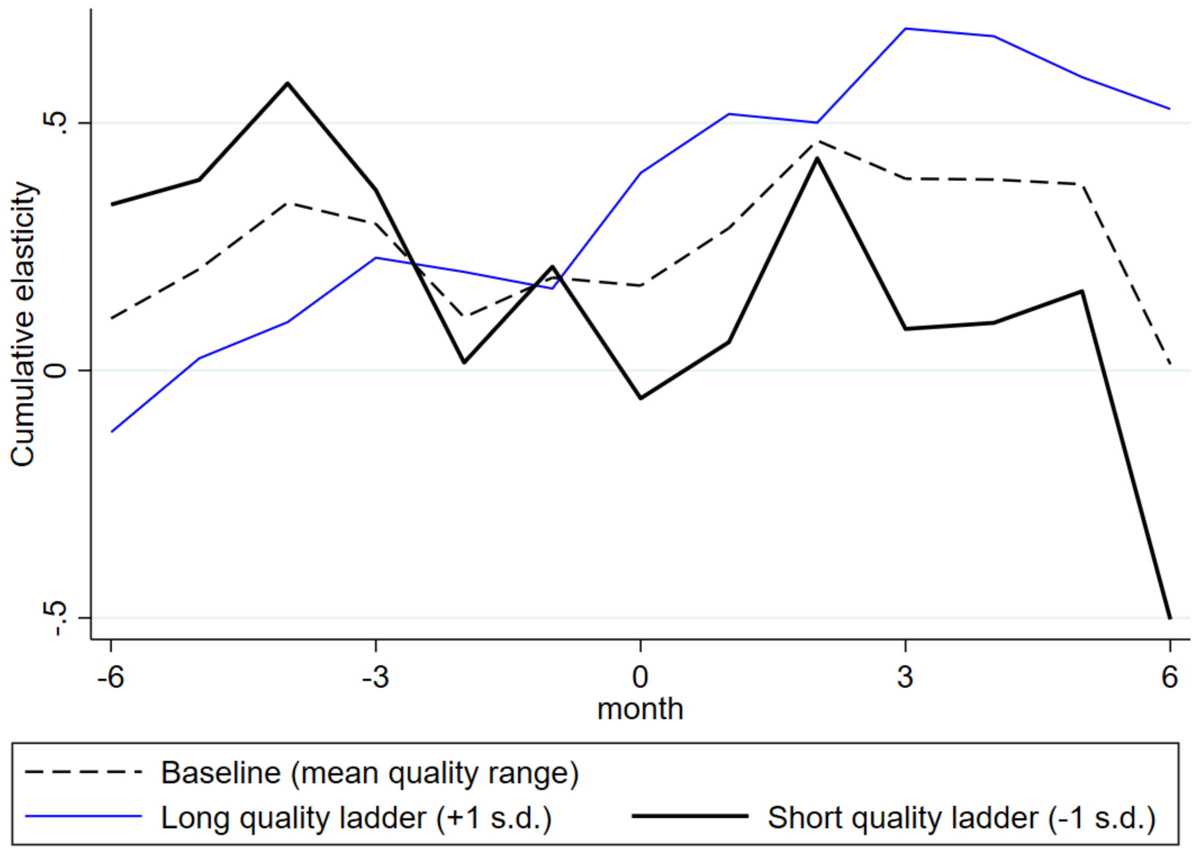
FIGURE B.4: Upstream industries included in *Regimpact* indicator, and the categories upon which they are scored




*Notes:* The *Regimpact* measure is the average score of the pro-competitiveness of regulation in the upstream services sectors (shown above), weighted by the proportions in which they are used in a given industry (from input-output tables). For example, one question used for 'entry regulation' in the electricity sector is: "What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier?" (Conway & Nicoletti 2006). The lack of any threshold scores zero, a threshold less than 250 gigawatts scores one, 250-500 gigawatts scores two, etc. *Source:* Égert & Wanner (2016)

## B.2 Additional Figures and Results

Figure B.5: Cumulative effect of quality scope on pass-through




*Notes:* This graph shows cumulative baseline pass-through and the impact upon this of quality scope. The blue (black) lines show cumulative pass-through in a country-product pair with a quality ladder that is exactly one standard deviation longer (shorter) than the mean.

Table B.6: Estimates for reforms announced less than a month in advance

| | | Dependent variable: change in log prices | | | |
|---|---|---|---|---|---|
| | | Individual FEs | Interaction FEs | Individual FEs | Interaction FEs |
| Baseline: | Pre-Reform | 0.167 | 0.00431 | 0.134 | 0.0824 |
| | | (0.135) | (0.939) | (0.189) | (0.479) |
| | Contemporaneous | 0.346*** | 0.273*** | 0.104 | -0.0286 |
| | | (0.000) | (0.003) | (0.280) | (0.833) |
| | Post-Reform | 0.157* | 0.0453 | 0.183** | 0.0793 |
| | | (0.093) | (0.559) | (0.044) | (0.281) |
| | Total | 0.67*** | 0.322*** | 0.421** | 0.133 |
| | | (0.001) | (0.005) | (0.035) | (0.560) |
| Openness: | Total | 0.024 | -0.208 | -1.419** | -1.667** |
| | | (0.966) | (0.631) | (0.039) | (0.033) |
| Concentration: | Total | 0.335 | 0.103 | 0.0119 | -0.00642 |
| | | (0.276) | (0.562) | (0.964) | (0.980) |
| *Regimpact*: | Pre-Reform | -0.0609 | 0.0931 | -0.0966 | 0.0508 |
| | | (0.414) | (0.200) | (0.274) | (0.694) |
| | Contemporaneous | -0.249*** | -0.28*** | -0.317*** | -0.516*** |
| | | (0.001) | (0.002) | (0.000) | (0.001) |
| | Post-Reform | -0.0533 | -0.0276 | -0.18*** | -0.163*** |
| | | (0.476) | (0.611) | (0.000) | (0.008) |
| | Total | -0.363*** | -0.214** | -0.593*** | -0.628*** |
| | | (0.006) | (0.047) | (0.000) | (0.000) |
| Quality range: | Pre-Reform | | | -0.0586 | 0.041 |
| | | | | (0.613) | (0.774) |
| | Contemporaneous | | | 0.373*** | 0.376*** |
| | | | | (0.002) | (0.000) |
| | Post-Reform | | | -0.0406 | 0.0208 |
| | | | | (0.707) | (0.847) |
| | Total | | | 0.274 | 0.437* |
| | | | | (0.150) | (0.053) |
| FEs | | i,k,t | it,kt,ik | i,k,t | it,k,t,ik |
| Clustering | | ik | ik | ik | ik |
| N | | 95,670 | 95,670 | 47,006 | 47,006 |

*Notes:* $p$-values in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. Reforms which were announced more than a month in advance are excluded.

TABLE B.7: Estimates for non-durable products only

| | | Dependent variable: change in log prices | | | |
|---|---|---|---|---|---|
| | | Individual FEs | Interaction FEs | Individual FEs | Interaction FEs |
| Baseline: | Pre-Reform | 0.181 | 0.0338 | 0.272* | 0.0871 |
| | | (0.139) | (0.606) | (0.091) | (0.657) |
| | Contemporaneous | 0.339*** | 0.293*** | 0.126 | -0.075 |
| | | (0.000) | (0.001) | (0.307) | (0.642) |
| | Post-Reform | 0.194 | 0.0472 | -0.195 | -0.223 |
| | | (0.140) | (0.545) | (0.483) | (0.227) |
| | Total | 0.714*** | 0.374*** | 0.203 | -0.211 |
| | | (0.004) | (0.001) | (0.281) | (0.458) |
| Openness: | Total | 0.726 | 0.102 | -0.21 | -0.0074 |
| | | (0.450) | (0.869) | (0.419) | (0.982) |
| Concentration: | Total | 0.397 | 0.179 | 0.131 | -0.0688 |
| | | (0.136) | (0.249) | (0.482) | (0.694) |
| *Regimpact*: | Pre-Reform | -0.0792 | -0.00105 | -0.0426 | -0.00603 |
| | | (0.417) | (0.987) | (0.644) | (0.935) |
| | Contemporaneous | -0.235** | -0.22* | -0.45*** | -0.571*** |
| | | (0.033) | (0.079) | (0.000) | (0.001) |
| | Post-Reform | 0.0102 | 0.036 | -0.103 | -0.038 |
| | | (0.935) | (0.628) | (0.195) | (0.581) |
| | Total | -0.304 | -0.185 | -0.595*** | -0.615*** |
| | | (0.181) | (0.288) | (0.002) | (0.005) |
| Quality range: | Pre-Reform | | | -0.193** | -0.157 |
| | | | | (0.026) | (0.104) |
| | Contemporaneous | | | 0.229* | 0.23* |
| | | | | (0.074) | (0.053) |
| | Post-Reform | | | 0.283** | 0.269*** |
| | | | | (0.010) | (0.004) |
| | Total | | | 0.319* | 0.342** |
| | | | | (0.064) | (0.033) |
| FEs | | i,k,t | it,kt,ik | i,k,t | it,k,t,ik |
| Clustering | | ik | ik | ik | ik |
| N | | 82,328 | 82,328 | 34,192 | 34,192 |

*Notes:* $p$-values in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption.

Table B.8: Estimates using discrete PMR variable

| | | Dependent variable: change in log prices | | |
|---|---|---|---|---|
| | | No Fes | Individual FEs | Interaction FEs |
| Baseline: | Pre-Reform | 0.213 | 0.195* | 0.0519 |
| | | (0.130) | (0.060) | (0.415) |
| | Contemporaneous | 0.324*** | 0.323*** | 0.24*** |
| | | (0.000) | (0.000) | (0.002) |
| | Post-Reform | 0.181 | 0.144 | 0.0411 |
| | | (0.100) | (0.163) | (0.561) |
| | Total | 0.718*** | 0.662*** | 0.333*** |
| | | (0.000) | (0.000) | (0.002) |
| Openness: | Total | 0.481 | 0.385 | -0.195 |
| | | (0.364) | (0.468) | (0.612) |
| Concentration: | Total | 0.304 | 0.344 | 0.163 |
| | | (0.263) | (0.194) | (0.246) |
| $RegimpactHML$: | Pre-Reform | -0.17 | -0.0983 | 0.0507 |
| | | (0.340) | (0.434) | (0.670) |
| | Contemporaneous | -0.24* | -0.302*** | -0.378** |
| | | (0.061) | (0.005) | (0.012) |
| | Post-Reform | -0.118 | -0.0792 | -0.0862 |
| | | (0.509) | (0.567) | (0.371) |
| | Total | -0.528* | -0.479** | -0.414** |
| | | (0.060) | (0.045) | (0.027) |
| FEs | | None | i,k,t | it,kt,ik |
| Clustering | | None | ik | ik |
| N | | 99361 | 99361 | 99361 |

*Notes:* $p$-values in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. $RegimpactHML$ is a discrete variable taking value 1 if the observation is in the top quartile of the *Regimpact* distribution, value -1 if in the bottom quartile, and zero otherwise. Openness and market concentration are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. Pre-Reform, Contemporaneous and Post-Reform effects are also estimated for Openness and Concentration, but are not significant so omitted for conciseness.

Table B.9: Estimates by direction of VAT change

| | | Dependent variable: change in log prices | | | | | |
|---|---|---|---|---|---|---|---|
| | | Increases | Decreases | Coeff.s Equal | Increases | Decreases | Coeff.s Equal |
| Baseline: | Pre-Reform | 0.0453 | -0.0576 | 0.43 | 0.154 | 0.0658 | 0.77 |
| | | (0.708) | (0.260) | | (0.558) | (0.626) | |
| | Contemporaneous | 0.0000288 | 0.284*** | 0.01 | 0.0000169 | 0.551*** | 0.01 |
| | | (0.303) | (0.006) | | (0.193) | (0.008) | |
| | Post-Reform | -0.0013 | 0.0553 | 0.61 | -0.282** | 0.0336 | 0.13 |
| | | (0.988) | (0.410) | | (0.044) | (0.825) | |
| | Total | 0.044 | 0.281** | 0.25 | -0.128 | 0.65** | 0.06 |
| | | (0.768) | (0.030) | | (0.653) | (0.023) | |
| Openness: | Total | 0.166 | -1.131* | 0.12 | -0.343 | -1.829 | 0.42 |
| | | (0.747) | (0.092) | | (0.727) | (0.182) | |
| Concentration: | Total | 0.355* | -0.196 | 0.07 | 0.217 | -0.16 | 0.50 |
| | | (0.091) | (0.332) | | (0.299) | (0.754) | |
| *Regimpact*: | Pre-Reform | 0.0157 | 0.00936 | 0.95 | 0.121 | 0.414 | 0.36 |
| | | (0.841) | (0.899) | | (0.512) | (0.114) | |
| | Contemporaneous | -0.258** | -0.145 | 0.59 | -0.431** | 0.0747 | 0.13 |
| | | (0.011) | (0.425) | | (0.015) | (0.796) | |
| | Post-Reform | -0.016 | 0.162 | 0.13 | 0.00371 | -0.14 | 0.62 |
| | | (0.778) | (0.122) | | (0.967) | (0.606) | |
| | Total | -0.258* | 0.0256 | 0.33 | -0.307 | 0.349 | 0.18 |
| | | (0.090) | (0.919) | | (0.174) | (0.416) | |
| Quality range: | Pre-Reform | | | | -0.0381 | 0.214 | 0.21 |
| | | | | | (0.747) | (0.265) | |
| | Contemporaneous | | | | 0.185* | 0.366* | 0.46 |
| | | | | | (0.094) | (0.082) | |
| | Post-Reform | | | | 0.334*** | 0.016 | 0.23 |
| | | | | | (0.009) | (0.933) | |
| | Total | | | | 0.481** | 0.597 | 0.81 |
| | | | | | (0.035) | (0.116) | |
| # of VAT changes: | | 701 | 149 | | 373 | 80 | |
| FEs | | it,kt,ik | | | it,k,t,ik | | |
| Clustering | | ik | | | ik | | |
| N | | 103,924 | | | 48,977 | | |

*Notes:* $p$-values in parentheses. * $p$ <0.10, ** $p$ <0.05, *** $p$ <0.01. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, openness and market concentration are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. The 'Coeff.s Equal' columns report the $p$-value from a Wald test of equality of the coefficients on 'Increases' and 'Decreases'.

Table B.10: Estimates across the business cycle

| | | Dependent variable: change in log prices | | | | | |
|---|---|---|---|---|---|---|---|
| | | Expansions | Contractions | Coeff.s Equal | Expansions | Contractions | Coeff.s Equal |
| Baseline: | Pre-Reform | -0.0312 | 0.096 | 0.32 | 0.176 | 0.0605 | 0.74 |
| | | (0.663) | (0.384) | | (0.489) | (0.807) | |
| | Contemporaneous | 0.299** | 0.19 | 0.57 | -0.257 | -0.0476 | 0.56 |
| | | (0.016) | (0.159) | | (0.316) | (0.805) | |
| | Post-Reform | 0.168 | -0.0518 | 0.09 | -0.152 | -0.201 | 0.81 |
| | | (0.114) | (0.511) | | (0.300) | (0.166) | |
| | Total | 0.436*** | 0.234 | 0.44 | -0.233 | -0.188 | 0.94 |
| | | (0.006) | (0.233) | | (0.586) | (0.638) | |
| Openness: | Total | -0.387 | -0.374 | 0.99 | -0.578 | 0.194 | 0.68 |
| | | (0.424) | (0.512) | | (0.542) | (0.899) | |
| Concentration: | Total | -0.0864 | 0.489* | 0.10 | -0.704 | 0.76** | 0.08 |
| | | (0.569) | (0.069) | | (0.204) | (0.040) | |
| *Regimpact*: | Pre-Reform | 0.174* | 0.0894 | 0.51 | 0.0137 | 0.0515 | 0.92 |
| | | (0.079) | (0.283) | | (0.969) | (0.727) | |
| | Contemporaneous | -0.291*** | -0.188 | 0.61 | -0.422** | -0.381* | 0.89 |
| | | (0.005) | (0.285) | | (0.043) | (0.059) | |
| | Post-Reform | -0.0827 | 0.0997 | 0.05 | -0.0144 | -0.00228 | 0.93 |
| | | (0.231) | (0.110) | | (0.877) | (0.983) | |
| | Total | -0.2 | 0.000946 | 0.46 | -0.423 | -0.332 | 0.84 |
| | | (0.123) | (0.997) | | (0.233) | (0.256) | |
| Quality range: | Pre-Reform | | | | -0.122 | 0.0308 | 0.31 |
| | | | | | (0.179) | (0.821) | |
| | Contemporaneous | | | | 0.683*** | -0.134 | 0.00 |
| | | | | | (0.000) | (0.417) | |
| | Post-Reform | | | | 0.175 | 0.133 | 0.80 |
| | | | | | (0.138) | (0.233) | |
| | Total | | | | 0.736*** | 0.03 | 0.08 |
| | | | | | (0.003) | (0.918) | |
| # of VAT changes: | | 298 | 552 | | 149 | 304 | |
| Average size of VAT change (pp) | | 0.54 | 1.2 | | 0.8 | 1.3 | |
| FEs | | it,kt,ik | | | it,k,t,ik | | |
| Clustering | | ik | | | ik | | |
| N | | 99,361 | | | 48,977 | | |

*Notes:* $p$-values in parentheses. * $p$ <0.10, ** $p$ <0.05, *** $p$ <0.01. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, openness and market concentration are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. The 'Coeff.s Equal' columns report the $p$-value from a Wald test of equality of the coefficients on 'Increases' and 'Decreases'.

# Supply and Demand Determinants of Heterogeneous VAT Pass-Through

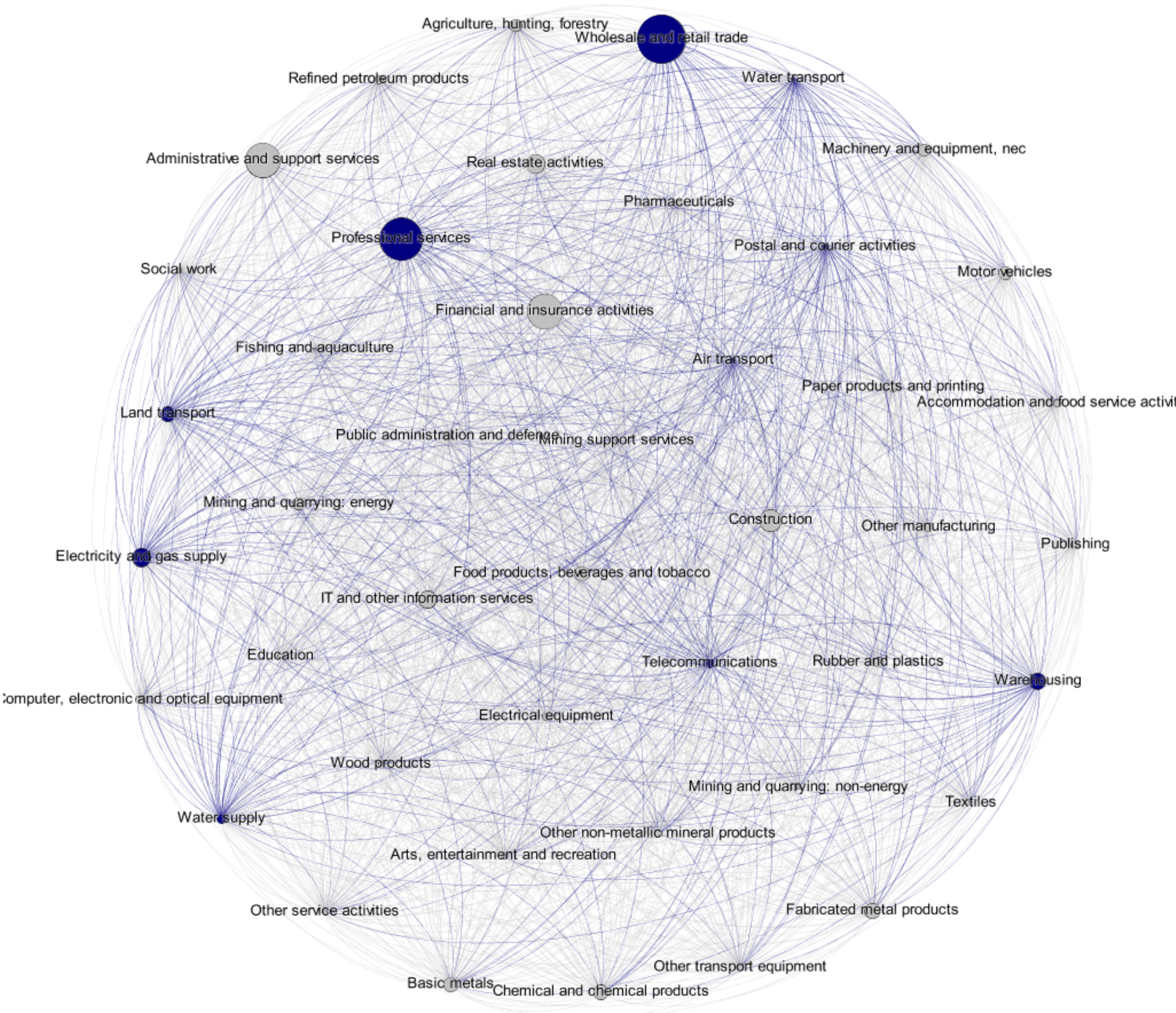
Matthieu Bellon, Alexander Copestake

August 21, 2022

**ONLINE APPENDIX**

**Supplementary Figures and Tables**

FIGURE I: Upstream non-manufacturing industries




*Notes:* This graph shows, in blue, the key upstream non-manufacturing industries included in the *Regimpact* measure, and their use as intermediate inputs by other sectors. Flows are aggregated across all countries in the sample, and nodes are scaled by total usage as an intermediate input. *Source:* OECD (2021).

Table I: Defining markets at 4-digit level for concentration measure

| | | Dependent variable: change in log prices | | |
|---|---|---|---|---|
| | | No Fes | Individual FEs | Interaction FEs |
| Baseline: | Pre-Reform | 0.217 | 0.199 | 0.0506 |
| | | (0.113) | (0.121) | (0.439) |
| | Contemporaneous | 0.361*** | 0.358*** | 0.283*** |
| | | (0.000) | (0.000) | (0.001) |
| | Post-Reform | 0.205* | 0.176 | 0.0336 |
| | | (0.060) | (0.123) | (0.644) |
| | Total | 0.782*** | 0.732*** | 0.367*** |
| | | (0.000) | (0.002) | (0.003) |
| Openness: | Total | 0.283 | 0.172 | -0.292 |
| | | (0.581) | (0.772) | (0.471) |
| Concentration: | Total | 0.429* | 0.419 | 0.228 |
| | | (0.059) | (0.117) | (0.149) |
| *Regimpact*: | Pre-Reform | -0.0581 | -0.0219 | 0.0825 |
| | | (0.404) | (0.682) | (0.211) |
| | Contemporaneous | -0.18*** | -0.207*** | -0.252*** |
| | | (0.001) | (0.000) | (0.001) |
| | Post-Reform | -0.0399 | -0.0324 | -0.0239 |
| | | (0.565) | (0.567) | (0.616) |
| | Total | -0.278** | -0.261*** | -0.193** |
| | | (0.014) | (0.007) | (0.034) |
| FEs | | None | i,k,t | it,kt,ik |
| Clustering | | None | ik | ik |
| N | | 99361 | 99361 | 99361 |

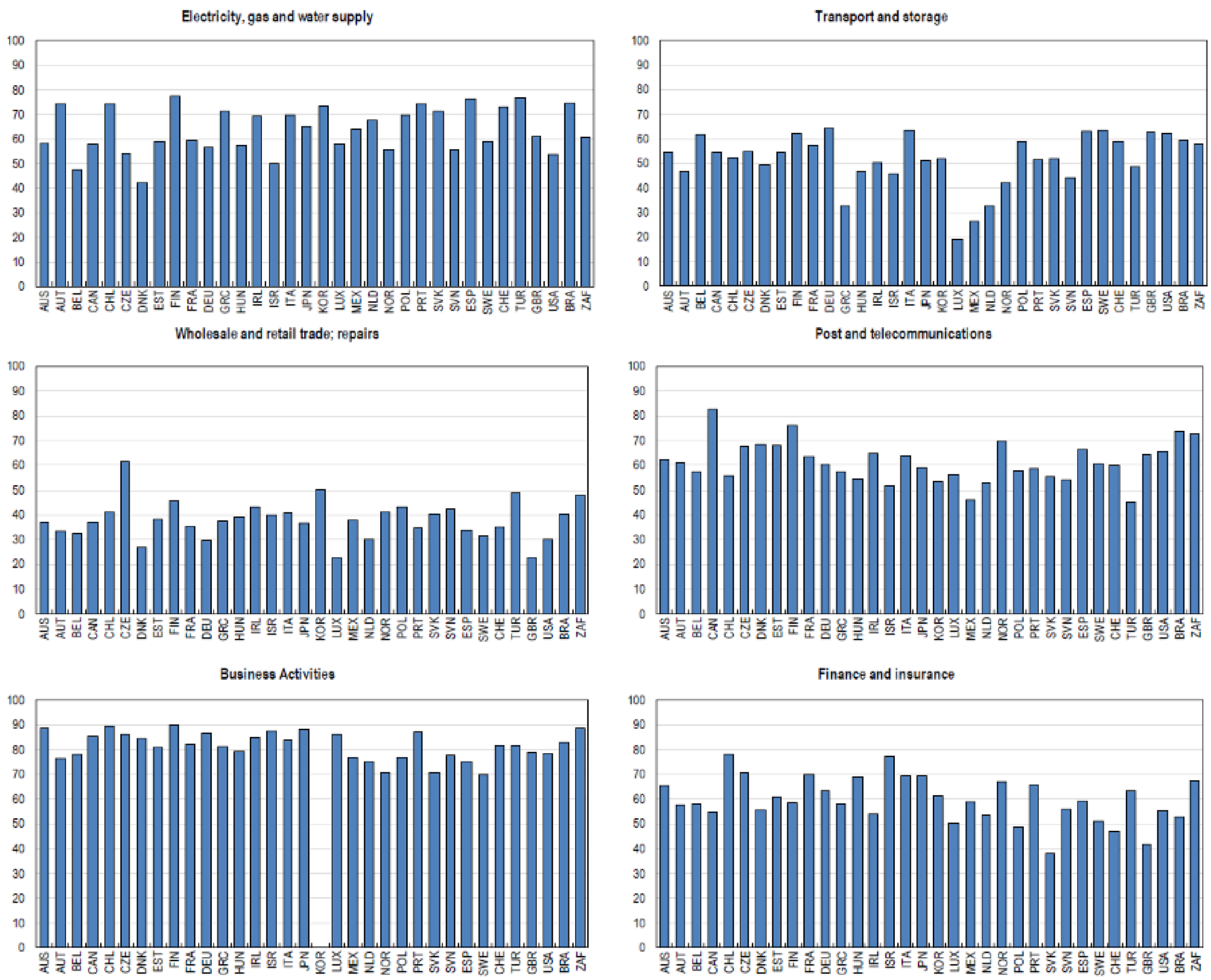
*Notes:* $p$-values in parentheses. * $p$ <0.10, ** $p$ <0.05, *** $p$ <0.01. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, openness and market concentration are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. Pre-Reform, Contemporaneous and Post-Reform effects are also estimated for Openness and Concentration, but are not significant so omitted for conciseness. Concentration is measured by a Herfindahl-Hirschman Index based on Orbis data, defining markets at the 4-digit level then averaging across these to map onto the main COICOP product classification, as described in the text.

Table II: Using alternative measure of horizontal concentration

| | | Dependent variable: change in log prices | | |
|---|---|---|---|---|
| | | No Fes | Individual FEs | Interaction FEs |
| Baseline $\beta_1$ | Pre-Reform | 0.193 | 0.181* | 0.0247 |
| | – i.e. $\sum_{j=1}^{6} \beta_{1j}$ | (0.152) | (0.056) | (0.641) |
| | Contemporaneous | 0.331*** | 0.325*** | 0.257*** |
| | – i.e. $\beta_{10}$ | (0.000) | (0.000) | (0.001) |
| | Post-Reform | 0.156 | 0.114 | 0.0267 |
| | – i.e. $\sum_{j=-6}^{-1} \beta_{1j}$ | (0.142) | (0.226) | (0.711) |
| | Total | 0.681*** | 0.62*** | 0.309*** |
| | – i.e. $\sum_{j=-6}^{6} \beta_{1j}$ | (0.000) | (0.000) | (0.001) |
| Openness: | Total | 0.638 | 0.522 | 0.00249 |
| | | (0.172) | (0.377) | (0.995) |
| Concentration: | Total | -0.0209 | -0.00423 | -0.0351 |
| | | (0.896) | (0.978) | (0.754) |
| *Regimpact*: | Pre-Reform | -0.0553 | -0.0188 | 0.0639 |
| | | (0.430) | (0.724) | (0.289) |
| | Contemporaneous | -0.157*** | -0.18*** | -0.228*** |
| | | (0.005) | (0.001) | (0.002) |
| | Post-Reform | -0.0172 | -0.00686 | -0.0123 |
| | | (0.797) | (0.897) | (0.783) |
| | Total | -0.229** | -0.206** | -0.177* |
| | | (0.041) | (0.038) | (0.052) |
| FEs | | None | i,k,t | it,kt,ik |
| Clustering | | None | ik | ik |
| N | | 100983 | 100983 | 100983 |

*Notes:* $p$-values in parentheses. * $p$ <0.10, ** $p$ <0.05, *** $p$ <0.01. Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, openness and market concentration are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. Pre-Reform, Contemporaneous and Post-Reform effects are also estimated for Openness and Concentration, but are not significant so omitted for conciseness. Concentration is measured by a Herfindahl-Hirschman Index based on import origins, as described in the text.

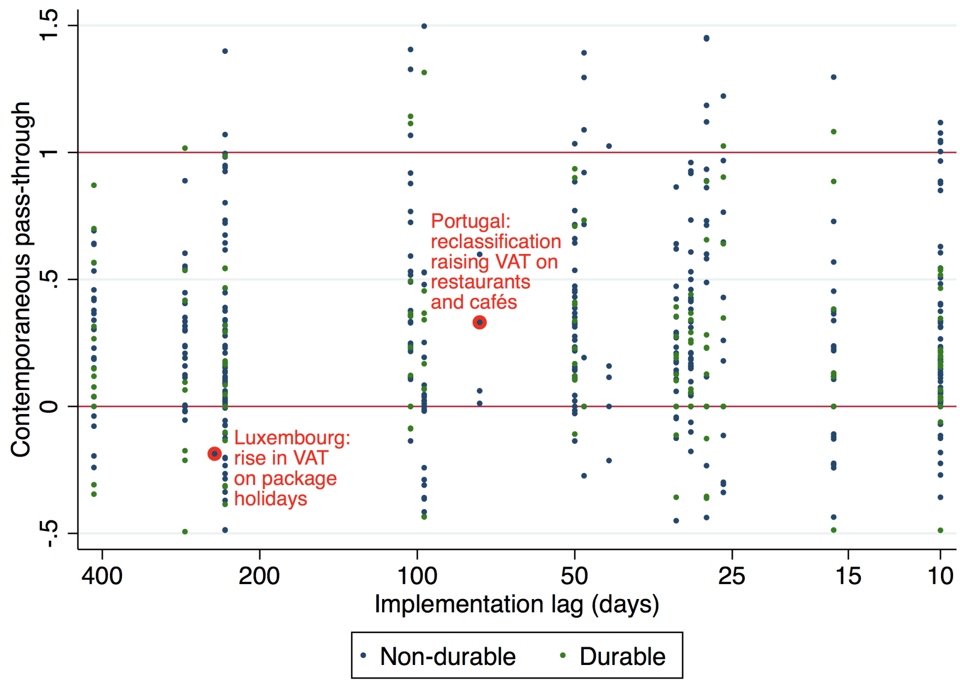
FIGURE II: Share of intermediate demand in gross output of non-manufacturing sectors




*Notes:* These graphs show the share of intermediate demand in gross output of non-manufacturing sectors across countries in the mid-2000s. The 'wide' *Regimpact* measure includes the first five sectors, while the 'narrow' measure includes only 'Electricity, gas and water supply', 'Transport and storage', and 'Post and telecommunications'. *Source:* Égert & Wanner (2016).

Figure III: Heterogeneity in announcement effects

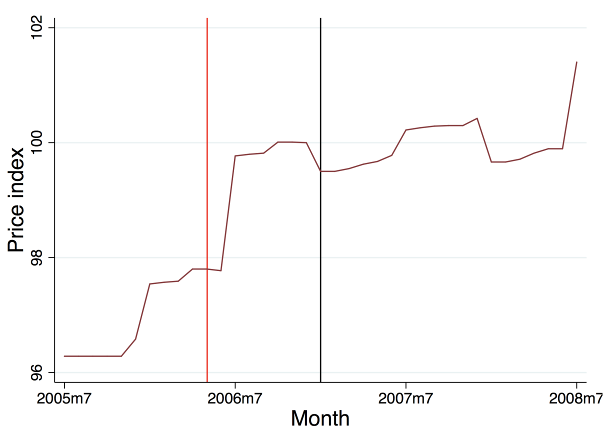
(a) Heterogeneity of pass-through by implementation lag




*Notes:* This graph shows the distribution of contemporaneous pass-through by implementation lag, across reforms for which announcement date data is available. The vertical spread illustrates the substantial heterogeneity in pass-through, even after controlling for implementation lags. The two reform episodes circled in red are shown in detail below.

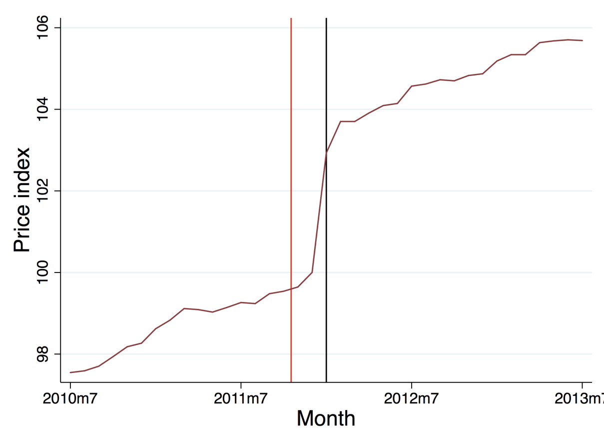
(b) Possible announcement effect:

Package holidays in Luxembourg




(c) No announcement effect:

Restaurants and cafés in Portugal




*Notes:* These two graphs show prices for two example goods over their respective reform episodes. In each case the first vertical line is the date the reform was announced, and the second is the date it was implemented. The lefthand graph shows a potential anticipation effect, unlike that on the right.

Table III: Impact of early announcement on pass-through

| | | Dependent variable: change in log prices | | | | |
|---|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) | (5) |
| | | No Fes | Individual FEs | Interaction FEs | Individual FEs + Controls | Interaction FEs + Controls |
| Baseline: | Pre-Reform | 0.165 | 0.166* | 0.0543 | 0.162* | 0.0535 |
| | | (0.189) | (0.064) | (0.475) | (0.063) | (0.478) |
| | Contemporaneous | 0.312*** | 0.264** | 0.117 | 0.266** | 0.118 |
| | | (0.003) | (0.015) | (0.325) | (0.020) | (0.322) |
| | Post-Reform | 0.0912 | 0.101 | 0.0153 | 0.0897 | 0.0147 |
| | | (0.300) | (0.219) | (0.798) | (0.269) | (0.809) |
| | Total | 0.568*** | 0.53*** | 0.187* | 0.518*** | 0.187* |
| | | (0.002) | (0.004) | (0.078) | (0.004) | (0.082) |
| Implementation lag: | Pre-Reform | -0.00215 | 0.0039 | 0.0289 | 0.0083 | 0.0288 |
| | | (0.958) | (0.876) | (0.207) | (0.742) | (0.208) |
| | Contemporaneous | -0.0269 | -0.0112 | 0.00347 | -0.00875 | 0.0188 |
| | | (0.181) | (0.553) | (0.880) | (0.660) | (0.422) |
| | Post-Reform | 0.03 | 0.0072 | 0.00655 | 0.00993 | 0.00617 |
| | | (0.338) | (0.759) | (0.738) | (0.675) | (0.754) |
| | Total | 0.00101 | -0.00013 | 0.0389 | 0.00947 | 0.0538* |
| | | (0.985) | (0.997) | (0.177) | (0.813) | (0.066) |
| Controls | | No | No | No | Yes | Yes |
| $X_{ikt}$ | | No | No | No | Yes | Yes |
| FEs | | None | i,k,t | it,kt,ik | i,k,t | it,kt,ik |
| Clustering | | None | ik | ik | ik | ik |
| N | | 99361 | 99361 | 99361 | 98581 | 98581 |

*Notes:* $p$-values in parentheses. * $p$ <0.10, ** $p$ <0.05, *** $p$ <0.01. $X_{ikt}$ refers to the inclusion of *Regimpact*, openness to trade and concentration in the regression. Specifications (4) and (5) also controls for value added, consumption and whether the reform was part of a package. 'Implementation Lag' is measured in months, so a coefficient of 0.01, for example, implies that announcing a VAT reform one additional month in advance is associated with a 1% increase in pass-through.