Supply and Demand Determinants of Heterogeneous VAT Pass-Through

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Abstract

We examine whether value-added tax pass-through depends on market structure. We 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. Relative to baseline total pass-through of up to 33 percent, we estimate that a one-standard-deviation rise in the competition-friendliness of regulation in upstream markets increases pass-through by up to 22 percentage points, and an equivalent rise in the scope for quality differentiation increases pass-through by up to 38 percentage points.

Keywords: VAT; Price Effect; Pass Through; Competition; Product Differentiation

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I. INTRODUCTION

Value-added taxes raise about a fifth of total tax revenues both worldwide and among the members of the OECD (OECD, 2024). 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 towards—or to minimize the tax burden imposed upon—firms or consumers. Who bears the consequences of a VAT reform crucially depends on the key parameter of 'pass-through'—the elasticity of consumer prices with respect to the VAT rate (Adachi and Fabinger, 2022).[2] Full pass-through to consumer prices of a VAT cut implies that producer prices remain unchanged, while zero pass-through implies the opposite.

There is a growing literature estimating the impact of VAT changes on prices (see e.g. Benedek et al., 2020; Benzarti et al., 2020; Buettner and Madzharova, 2021; Dimitrakopoulou et al., 2023; Fuest et al., 2024). Estimates of VAT pass-through to consumer prices can vary substantially across studies, suggesting that more work is needed to understand what shapes the heterogeneity in results.[3] Building on the empirical framework of Benedek, De Mooij, Keen, and Wingender (2020, hereafter BDKW), we empirically explore how pass-through is affected by differences in market structure.

Specifically, we investigate how the pass-through of VAT reforms is modulated by (i) different drivers of horizontal market competition and (ii) differences in the scope for vertical differentiation. On (i), measures of market competition by product category are notoriously hard to obtain (OECD, 2021b), so we focus on measures that are arguably exogenous and unaffected by taxation. Following the literature, we use the OECD Indicator of Product Market Regulation (Égert and Wanner, 2016) because it is commonly accepted, detailed, and available consistently and widely across countries and product markets (Gutierrez and Philippon, 2023). We also consider elasticity of substitution measures from Broda and Weinstein (2006) because the elasticity

[1]More than 80 countries undertook VAT reforms 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]VAT pass-through is a necessary but not a sufficient statistic to determine full welfare effects. Evaluating welfare effects would require additional information about the importance of a market (product) in national production (consumption), and information about initial taxation and competition levels.

[3]Pass-through estimates vary, for instance, from 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 and Carloni, 2017).

of substitution is another well-identified structural determinant of competition intensity. Lastly, we also consider other measures like concentration indexes because of their widespread use, even though they are endogenous (Syverson, 2019). On (ii), we note that markets can also differ in the extent to which it is possible for sellers to distinguish their products based on quality rather than price. To measure the scope for this vertical differentiation in different markets, we therefore use the 'quality ladder' measure from Khandelwal (2010), which reflects the range of estimated qualities within each product market.[4]

To guide our empirical analysis, we extend existing theory to consider how the degree of competition affects pass-through. We build on the taxation framework developed in Adachi and Fabinger (2022). We depart from their model by specifying market structures and functional forms that are necessary for the characterization of market competition and vertical differentiation. Our modeling choices are driven by our empirical approach and, in particular, we introduce and focus on the number of firms to capture the varying degree of competition that results from entry barriers and product market regulation (Gutierrez and Philippon, 2023). We supplement this approach by examining the role of the elasticity of substitution.

Our models allow us to derive new results on the relationship between VAT pass-through and market structures and remain flexible enough to encompass many cases including horizontal and vertical differentiation, a variable elasticity of substitution, and variable marginal costs. Our analysis reveals that competition has a surprisingly complex influence on VAT pass-through, depending both on which dimension of competition one considers and on the convexity of the production cost function.

We begin by considering equally productive firms selling horizontally differentiated goods and competing on price under monopolistic competition. We then examine firms with heterogeneous marginal costs selling a 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 the cases we consider, we find that the effect of market characteristics on pass-through is theoretically ambiguous. First, we examine competition resulting from a higher number of competitors and show that VAT pass-through increases with the number of firms in the case of

[4]Prior work demonstrating the importance of this concept and using this measure includes Levchenko et al. (2011), Bajgar and Javorcik (2020), and Guerra (2024).

constant elasticity of substitution if marginal costs of production are increasing with quantity. Intuitively, pass-through increases with the number of firms because more firms mean smaller firms and less relevant economies of scale. A small size prevents producers from realizing and passing on savings from scaling down in response to a tax hike. We show that the result continues to hold when we vary competition in the upstream sector.

Second, we derive how greater competition due to a higher elasticity of substitution determines VAT pass-through and obtain an opposite result. VAT pass-through decreases with the elasticity of substitution when marginal costs of production are increasing with quantity. This is because a greater elasticity of substitution implies *larger* firms who, in this case, realize and pass-on more cost-savings when scaling down after a tax hike. In the alternative case of decreasing marginal costs, larger firms realize and pass-on less cost-savings when scaling down, and the pass-through increases with this dimension of competition. Our theoretical results thus highlight that different dimensions of competition can have different effects.

Third, we investigate the role of quality differentiation. We generalize the 'quality ladder' model in Khandelwal (2010) to allow for substitution or complementarity effects between consumers' valuations of affordability and quality. We find that variations in pass-through depend 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. In our main sample, we estimate a total baseline pass-through of between 21% and 33%, in line with BDKW's main estimate of 25%. We examine the heterogeneity of this pass-through 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.

We find that pro-competitive regulation in supplier markets has a substantial positive impact on pass-through. Through the lens of our model, this is consistent with the effect of having more upstream firms competing in a market characterized by decreasing returns to scale. Alternatively, this could also be consistent with a larger elasticity of substitution and large increasing returns to scale. A one-standard-deviation rise in the competition-friendliness of regulation in upstream markets—roughly equal to the difference between Austria and relatively uncompetitive Italy in 2013—increases pass-through by a further 22 percentage points. We benchmark this effect against other competition measures, including concentration measures and direct measures of the elasticity of substitution in upstream and downstream markets, 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 on average be passed on to consumers substantially more than in the past. Combining our estimates with observed increases in the competition-friendliness of regulation between 1999 and 2013 implies a median increase in pass-through of approximately 26 percentage points, while 84% of country-products have an increase in pass-through of more than 10 percentage points.

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. A one-standard-deviation rise in the length of the quality ladder—for instance, comparing 'information processing equipment' to the relatively less differentiated 'clothing materials'—increases pass-through by 38 percentage points.

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 is expected to 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 inverse. 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.

Related literature: Our main contribution to the theoretical literature is to provide a framework that allows for (i) the study of the effect of upstream competition on VAT pass-through in the downstream market, and (ii) the effect of vertical differentiation on VAT pass-through. These two features are outside the taxation framework of Adachi and Fabinger (2022) and have not been considered before. Adachi and Fabinger (2022) only examine the role of downstream competition in a few numerical examples. Therefore, our secondary contribution is to use their framework to derive the effects of various drivers of competition in the downstream market on pass-through in a more systematic manner. To this end, we resort to restrictive assumptions, but these are general enough to cover many options (including varying marginal costs) and yield tractable results. These results are notably more general than the numerical examples in Adachi and Fabinger (2022) which all assume constant marginal costs. Our results thus also show that theoretical results on the effect of competition on pass-through can be overturned by assuming a different cost function.

Our main empirical contribution is to provide evidence on these theoretical mechanisms using comprehensive cross-country and cross-product data. This allows us to identify average effects across a wide range of reform contexts and introduce tighter controls than are possible in studies of specific countries and products.[5]

The rest of this paper proceeds as follows. The next section outlines the theoretical motivation, then Section III describes the data, outlines the empirical strategy, and addresses challenges to identification. Section IV presents the main empirical results, and Section V addresses their robustness. Section VI concludes. The Online Appendix contains additional descriptives and robustness checks along with detailed theoretical derivations.

II. THEORETICAL MOTIVATION

We theoretically examine the role of structural characteristics of horizontal and vertical market competition in determining pass-through by considering five specific cases, building on the framework developed in Adachi and Fabinger (2022).

When investigating the role of horizontal market competition, we will distinguish between two dimensions that contribute to greater competition, namely the number of competitors and the elasticity of substitution. In the case where we consider both upstream and downstream

[5] We provide a detailed comparison of our results to prior empirical literature in Section VI.

markets, we restrict our attention to one dimension of competition, the number of firms, for conciseness. We initially make strong assumptions regarding functional forms, then we discuss results under more general settings at the end of the next subsection.

Consider a good i with consumer price p_i and producer price $\widetilde{p}_i$ subject to ad valorem tax rates τ_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:

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

The empirical analysis in Section III will estimate the extent to which pass-through γ^i varies by different aspects of market structure. The theoretical work in the next three subsections will show that the signs of these relationships cannot be ascertained from theory alone and thus must be estimated empirically. In Sections II.A and II.B, the theoretical ambiguity is shown to depend on which aspect of competition is considered (the elasticity of demand denoted by ε_d, or the number of competitors, N) and the convexity of producers' marginal costs. In Section II.C that introduces vertical differentiation, the theoretical ambiguity is shown to depend on a parameter ψ controlling the degree of substitution between price and quality. All proofs are in the Online Appendix.

A. Imperfect competition in a downstream market

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-Stiglitz 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. 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.[6]

Second, we consider a more general case with heterogeneous firms that have different production costs. We use q to denote the average quantity per firm and for convenience we 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 contrast to monopolistic competition, in this case there is no product differentiation and firms are competing in quantities at a common price $\widetilde{p}$ under Cournot competition.[7] 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. Again, each firm chooses its output q_n independently to maximize profits $\widetilde{p}_n(q_n)q_n - C_n(q_n)$.

In both of these cases, we can derive the following result:[8]

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

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

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

$$\frac{\partial \gamma}{\partial \varepsilon_d}\frac{\varepsilon_d}{\gamma} = \frac{\gamma\varepsilon_d}{\varepsilon_s^2}\left(\varepsilon_s' q\left[\frac{\partial q}{\partial \varepsilon_d}\frac{\varepsilon_d}{q}\right] - \varepsilon_s\right) \tag{5}$$

where ε_d is the elasticity of demand ($\varepsilon_d^{monopolistic} = \sigma$ and $\varepsilon_d^{cournot} = 1/\beta$), ε_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 but increases with the elasticity of substitution. As a result, the pass-through increases with N if and only if $b > 0$, when marginal costs are increasing. Conversely, the pass-through decreases with ε_d if and only if $1/b > 1/b_0$, where $b_0 \equiv \frac{-\sigma c}{2(\sigma-1)q}$ in the monopolistic competition case and $b_0 \equiv \frac{-(N+1-\beta)c}{(N-\beta)(1+1/\beta)Q/N}$

[6] We also show in the appendix that tax pass-through is the same whether it is computed at the individual or aggregate price level.

[7] This case was previously described in Dierickx et al. (1988).

[8] Proofs are provided in Appendix A.

in the Cournot competition case.

Proxying 'competitiveness' by the number of firms in the market, we thus show that the impact of the number of competitors on pass-through depends on the cost function.[9] For any cost function, lower demand resulting from higher taxes induces producers to scale back production.

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.[10] A smaller number of firms means larger firms and larger sizes amplify 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, a greater number of competitor and 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. The reduction in scale leads to higher marginal costs in this case, and producers choose to sell at higher producer prices and pass-through is greater than one ($\gamma > 1$ when $\varepsilon_s' < 0$). Once again, a greater number of competitors dampens producer price adjustments but, in this case of decreasing marginal costs, a greater number of competitors leads to a lower increase in prices in response to a tax hike and implies a lower pass-through.

The derivations in the appendix show that **proposition 1** equation (4) continues to hold even after we relax some assumptions.[11] In the case of monopolistic competition, the results are valid for any cost function (linear or otherwise). The derivative of the pass-through with respect to N has the sign of $-\varepsilon_s'$. In other words, pass-through increases with the number of competitors when the slope of the marginal costs is positive and steep enough, and equivalently

[9]Note that the case of constant marginal costs (together with constant elasticity of substitution) is such that $\gamma = 1$.

[10]This can be seen because $\gamma < 1$ when $\varepsilon_s > 0$.

[11]Adachi and Fabinger (2022) solves for the pass-through in an even more general setting. However, their general framework does not specify the nature of market competition and does not introduce parameters that can measure market competition. They consider a few specific examples with restrictive assumptions that differ from our setup because they assume constant marginal costs and other demand functions. In these specific cases, all with constant marginal costs, they find that pass-through can increase or decrease with the number of firms. Consistent with our results under less restrictive assumptions, this shows that alternative demand functions introduce alternative channels that strengthen or act against the cost channel presented in **proposition 1**. More details on comparing our setup with theirs can be found in Appendix A.A.

when production costs are convex enough.

Both in the case of monopolistic and Cournot competition, we also examine the variations of pass-through with the number of competitors when the elasticity of demand varies with total output.[12] In the appendix, we derive the formulas governing output, pass-through, and their variations with N. These are more complex than equations (3) and (4). We find that the average output continues to decrease with the number of firms if and only if the elasticity of demand decreases or does not increase too rapidly with output.[13] Under this condition, we additionally show that pass-through variation with the number of competitors is as described in **proposition 1** when the absolute value of the derivative of the elasticity of supply ($|\varepsilon'_s|$) is large enough. However, this also means that pass-through variation with the number of competitors can exhibit more complex patterns when the elasticity of substitution is not constant and when marginal costs do not vary much.

We additionally consider an alternative dimension of market competition and examine the role of the elasticity of substitution in the case when we assume it to be constant. Both under monopolistic and Cournot competition, **proposition 1** equation (5) implies that a larger elasticity of substitution is associated with a lower pass-through when $b > 0$ (increasing marginal costs) and a higher pass-through when b is very negative (rapidly decreasing marginal costs). The difference stems from differences in how competition affect firm sizes and translate into cost variations after a tax hike: everything else held constant, larger elasticity of substitution means larger firms, who when scaling down, realize more savings when marginal costs are increasing with quantity and incur higher costs when marginal costs are decreasing with quantity.

In the empirical section, we investigate the role of various measures of market competition in modulating VAT pass-through and discuss what theoretical assumptions can rationalize the observed variation.

B. Imperfect competition in the upstream market

We now examine the case of two interlinked markets, with perfect competition in the downstream market for the final good and with Cournot or monopolistic competition in the upstream input market. Demand for the final good is characterized by $p_F(Q_F) = A'Q_F^{-\beta}$ and is the same as in

[12]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).

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

the previous case with Cournot competition. Assuming perfect competition in the downstream market allows us to consider a representative final good producer who 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 market 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 market 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, operations in the upstream market are very similar to those described in the single market cases in the previous section.

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

$$\gamma_F = \frac{1}{1 + \varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}}\right)} \tag{6}$$

$$\frac{\partial \gamma_F}{\partial N}\frac{N}{\gamma_F} = \varepsilon'_{sI}\frac{\partial q_I}{\partial N}\frac{\varepsilon_{dF}\varepsilon_f}{\widetilde{\varepsilon}_s^2}\gamma_F N \tag{7}$$

where $\varepsilon_{dF} = 1/\beta$ is the elasticity of demand for the final good, ε_{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 with N 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 costs, which are then passed through to input prices. Cheaper input costs allow for lower producer prices in the downstream market. 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 market 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 markets on pass-through is consistent with increasing or decreasing marginal costs.

C. Differences in the scope for quality in the final good

We now examine a market 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.[14] Following standard practice in the discrete choice literature, horizontal characteristics denoted ξ_{nk} are assumed to be distributed i.i.d. type-I extreme value with mean zero.

In 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 knows her valuation of the horizontal (ξ_{nk}) and vertical (λ_n) characteristics of every variety and chooses the variety that gives her the highest indirect utility.

$$V_{nk} = \delta_n + \xi_{nk}, \qquad \text{with } \delta_n \equiv \left(\theta \lambda_n^{\psi} - p_n^{\psi}\right)^{1/\psi} \qquad \text{and } \psi < 1 \tag{8}$$

where δ_n represents the mean consumer valuation of variety n. δ_n increases with quality and decreases with price.[15] The parameter ψ controls the degree of substitution between price and quality, with higher ψ indicating that the two characteristics are more easily substituted—i.e.

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

[15]Equation (8) is a generalization of the specification in Khandelwal (2010) which would be obtained when $\psi \to 1$.

consumers are happy to sacrifice quality for a lower price—while a lower, possibly negative, ψ 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 ψ is positive while it decreases with the quality-price ratio when ψ is negative. Greater values of the parameter θ indicate a longer 'quality ladder', as defined in Khandelwal (2010), and imply that firms have stronger incentives to produce higher quality. Put differently, a firm's product quality increases with the firm's productivity, and even more so when θ is higher.

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 of its product:

$$\max_{\widetilde{p}_n, \lambda_n} \left[\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right] \frac{e^{\delta_n}}{\sum_m e^{\delta_m}} \,. \tag{9}$$

We then derive the following result:

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

$$\gamma = 1 + \frac{-\psi/(1-\psi)}{\theta^{\frac{1}{\psi-1}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{\psi-1}} - 1} - \frac{1}{1-\theta^{\frac{1}{1-\psi}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} + w(1+\tau)\left(1-\theta^{\frac{1}{1-\psi}}\left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1}{\psi}}} \tag{10}$$

This pass-through decreases with the length of the quality ladder θ 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 θ when ψ is negative enough, for example when $\psi < -\frac{1}{w(1+\tau)}$.

The effect of quality on VAT pass-through thus depends on ψ, the degree of substitution-complementarity 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', θ. 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.

The preceding subsections showed that the variation of VAT pass-through with these different aspects of market structure cannot be determined from theory alone: it depends on which aspect of competition is considered and the convexity of producers' marginal costs (Sections II.A and II.B), or on the degree of substitution between price and quality (Section II.C).

III. EMPIRICAL SPECIFICATION

In this section we describe our methodology for estimating pass-through across several hundred VAT changes in Europe and assessing how it varies with important market characteristics. We first describe our data and how we measure quality and market competitiveness, then we outline our main specification before addressing potential challenges to identification.

A. Data and measurement

Prices. Data on monthly prices across countries are from Eurostat's Harmonized Index of Consumer Prices, categorized according to the 'Classification of Individual Consumption According to Purpose' (COICOP). We accordingly run our analysis at the country-COICOP-month level, and therefore map other variables onto the COICOP classification as described below.[16] 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.

VAT rates. 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 1 and 2.[17] All the countries studied are in the Eurozone, reducing distortions due to differing exchange rates or monetary policies.[18] We discuss

[16]For convenience we also refer to the COICOP level using the shorthand 'product', acknowledging that some COICOP categories are services, such as vehicle maintenance.

[17]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.

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

the relationship between the characteristics of the reforms and our identification requirements in Section III.C below.

Competitiveness of upstream markets. We gauge the competitiveness of upstream markets using the annual *Regimpact* indicator from the Organization for Economic Co-operation and Development (Conway and Nicoletti, 2006; Égert and Wanner, 2016; Koske et al., 2015).[19] This uses predetermined country-specific input-output weights w_{ijk} to combine survey-based measures of pro-competitive regulation in upstream non-manufacturing markets ($REGNMI_{ijt}$), producing a measure of the impact of regulation on final output markets:

$$Regimpact_{ikt} = \sum_{j=1}^{J} REGNMI_{ijt} \cdot w_{ijk} \tag{11}$$

where k denotes the output market of interest in country i and j denotes upstream non-manufacturing sectors.[20] The resulting $Regimpact_{ikt}$ measure varies across country-products annually.

This measure has several advantages. It is arguably exogenous to the level of tax rates as it relates to entry barriers, which in turn determine entry and ultimately the intensity of competition. It has been shown to proxy for independently measured competitiveness outcomes and is more widely accepted, detailed and specific than alternatives (Gutierrez and Philippon, 2023). It captures the most important upstream input sectors, which are tightly interlinked with downstream markets.[21] The outputs of these sectors are generally produced and consumed in the same country—whether due to non-tradeability (e.g., transport) or country-specific licensing requirements (e.g., legal services)—which keeps the institutional setting constant, minimizing

[19]This measure 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 and Dougherty, 2012), on competitiveness (Braila et al., 2010), and on firms' input sourcing decisions (Di Ubaldo and Siedschlag, 2018). To the best of our knowledge the indicator has not previously been used to investigate VAT pass-through.

[20]The lower the *Regimpact* score, the more competition-friendly the upstream regulatory environment. For instance, one question on 'entry regulation' for the electricity sector 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 sectors. The sectors that it covers, and the categories upon which they are scored to generate the aggregate REGNMI indicator, are shown in Appendix Figure B.2. We use the version with country-specific weights to account for differences in input-output patterns across countries. We manually map the final *Regimpact* measure from the ISIC 2-digit level at which it is constructed onto our COICOP consumption categories.

[21]Appendix Figure B.1 highlights the pervasive connections between the key upstream non-manufacturing sectors and the broader economy.

complexities introduced by cross-border supply chains, as discussed below. Lastly, by scoring the competitiveness of upstream markets based on regulation, the *Regimpact* indicator takes into account the environment for both public and private providers, unlike measures based only on data on private firms.

While *Regimpact* has been used as a measure of competition in previous empirical studies (e.g., Amoroso and Martino, 2020; Bourlès et al., 2013), there is little evidence on *how* it impacts competition. In theory, product market regulation could affect the number of market participants, the ease of substituting across brands and products, or both. Establishing direct links between *Regimpact* and relevant dimensions of competition is beyond the scope of this paper. Indeed, our theoretical results show that the complexity of the interplay between competition and pass-through prohibits any straightforward mapping between theory and data.

Figure 1 plots the trends in *Regimpact* for each country and consumption category. Reforms over the last thirty years have substantially increased the competition-friendliness of regulation in upstream European sectors (Égert and Wanner, 2016), as seen in the steady downward trend in *Regimpact*.[22] Most of the variation in *Regimpact* is across countries and across time, rather than across consumption categories, which can be seen by comparing the relatively tight interquartile range in Figure 1A to the wider ranges in Figure 1B. As countries converged on relatively more competition-friendly policies over the 2000s, the degree of variation in *Regimpact* within each country and within each consumption category fell.

Competitiveness of the downstream sector. We use a variety of approaches to control for same-level market competitiveness (or equivalently, competitiveness in the 'downstream' sector). We consider concentration measures because they are frequently used in the literature despite their shortcomings, particularly the fact that their link to market competition is ambiguous in theory (Syverson, 2019). We use a Herfindahl-Hirschman index:

$$Concentration_{ikt} = \sum_f s_{fikt}^2 \tag{12}$$

[22]For example, Austria liberalized its energy sector in 2000 through the Electricity Industry and Organization Act and the Gas Act, which by 2002 gave all electricity and natural gas customers the right to choose their supplier (IEA, 2003). This corresponds to achieving the minimum score (i.e., the most competition-friendly rating) on the example question given in footnote 20.

where s is the market share of producer f in country i, product market k and month t. We compute markets shares using two alternative sources. We first use firm-level data from Orbis.[23] A limitation of the Orbis HHI is that sales are allocated to markets by firm classification—whereas multi-product firms may sell in many different product markets. We therefore also use product-level import data and assume source countries correspond to different producers.[24] In turn, one limitation of this approach is that it takes into account sales by domestic and foreign firms separately. We thus supplement this control with a measure of openness to trade, using annual data from UN Comtrade and consumption data from Eurostat:[25]

$$Openness_{ikt} = \frac{Imports_{ikt} + Exports_{ikt}}{Consumption_{ikt}} \ . \tag{13}$$

Alternative competition measures. We also consider alternative measures of downstream and upstream competition using product-level elasticities of substitution. We obtain export supply elasticity from Broda et al. (2008) and import elasticity from Broda and Weinstein (2006). The export elasticity is estimated for the 1994-2003 period at 4-digit HS level, and the import elasticity for the 1991-2001 period at 3-digit SITC level, both of which only vary across products and are time- and country-invariant.[26] We construct two versions of this measure, first at the downstream level, and second at the upstream level in the same vein as for the $Regimpact_{ikt}$ measure. For the second measure, we use elasticities for upstream products weighted by the proportions in which they are used downstream, taking the weights from input-output tables.[27]

Scope for quality differentiation. We use the measure of product differentiability $QualityLadder_k$ from Khandelwal (2010), as described in Section II.C, which ensures consistency between our theory and empirical analysis. The scope for quality, or 'quality ladder', is backed out from price and quantity data. High market share conditional on price suggests that a given variety is high quality, then products with a large dispersion in estimated quality are

[23]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.

[24]Specifically, we compute $s_{fikt} = \frac{\text{Imports of } k \text{ into } i \text{ from } f \text{ in } t}{\text{Total imports of } k \text{ into } i \text{ in } t}$.

[25]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 and Zignago (2010).

[26]To compute the two types of elasticity at the COICOP category level in the main specification, we first map the elasticities to HS products, and then take averages to aggregate to COICOP categories.

[27]We use country-specific input-output tables from the OECD and use the first available year (1995) to prevent any endogeneity that may arise if, for instance, VAT reforms in a product category affect the distribution of inputs used to produce it.

classified as having long quality ladders.[28] Khandelwal constructs his continuous product-level measure using trade data on goods, which means 'quality ladder' estimates are only available for the subset of goods products and do not vary across countries. This prevents us from using the full price and VAT dataset with this measure—so we also perform several robustness checks to verify that our results are not driven by these restrictions. Khandelwal (2010) argues that 'the scope for quality differentiation is an intrinsic feature of products', so we use only cross-sectional product-wise variation in quality—hence $QualityLadder_k$ does not vary over time.

The distribution of quality scope across consumption categories is shown in Figure 2. Relatively undifferentiated products, such as solid fuels or oils and fats, have low scores on $QualityLadder_k$, while highly specialized products with wide scope for quality variation, such as computer hardware or photographic equipment, have high values of $QualityLadder_k$.

Transformations, summary statistics and further controls. We standardize our competition and differentiation measures so that the magnitudes of their estimated impacts are comparable. The four measures in our main specification are only weakly correlated, as shown in Appendix Table B.1.[29] The distributions of the main variables are plotted in Appendix Figure B.3. Overall, in our main specifications we use an unbalanced panel of approximately one hundred thousand observations spanning January 1998 to December 2013. The variables are summarized in Appendix Table B.2. We also match VAT reforms in the BDKW data to the IMF's Tax Policy Reform Database (Amaglobeli et al., 2018), which contains announcement dates.[30] Finally, we use consumption data from Eurostat to weight observations by their consumption share, and we use total value added from EU KLEMS in one robustness check.

[28]We choose the Khandelwal (2010) measure because—given reasonable assumptions on the structure of demand—it can produce estimates for a broad class of consumption categories. In contrast, papers using directly observed quality measures are generally confined to a very limited range of products (e.g. rugs, wine or coffee respectively in Atkin et al., 2017; Chen and Juvenal, 2016; Macchiavello and Miquel-Florensa, 2017), so cannot be used to study VAT reforms that affect a wide range of products simultaneously.

[29]The five measures of *Regimpact*, openness, market concentration, elasticity of substitution, and quality ladder are continuous variables. In a robustness check in Section V.D, we use discretized versions of the *Regimpact* and quality ladder variables that indicate only low, medium and high values.

[30]Summary statistics for those VAT changes that we can match to announcement dates are shown in Appendix Table B.3. The total number of VAT reforms available falls by approximately one third, but the distribution across the different types of VAT changes remains similar.

B. Estimation

Our empirical approach builds on BDKW, estimating the pass-through of VAT changes by regressing country-product prices on taxes using an event-study design.[31] We start with the BDKW specification, assessing the cumulative impact of VAT changes on prices:

$$\Delta \ln(p_{ikt}) = \beta_0 + \sum_{j=-6}^{6} \beta_{1j} \cdot \Delta \ln(1 + \tau_{ikt+j}) + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt} \tag{14}$$

where p_{ikt} denotes the price of product k in country i in month t and τ_{ikt+j} represents the VAT rate in country i for product k in month t. The coefficients of interest β_{1j} capture the average pass-through across products at different horizons j, i.e. at a number of months j before or after the reform date.[32] Summing these terms reveals the cumulative pass-through over a given timeframe. The coefficients φ_{it}, φ_{kt} and φ_{ik} are country-time, product-time, and country-product fixed effects—accounting for product-level trends and country-specific macroeconomic developments—and ϵ_{ikt} is the error term. As in BDKW, we de-seasonalize and de-trend all price indices, weight observations by their consumption share, and cluster standard errors at the country-product level.[33]

To assess the cumulative impacts of upstream product market regulation on pass-through, we then interact $Regimpact_{ikt}$ with tax changes at every horizon.

$$\begin{aligned}\Delta \ln(p_{ikt}) = \beta_0 &+ \sum_{j=-6}^{6} \beta_{1j} \cdot \Delta \ln(1 + \tau_{ikt+j}) \\ &+ \sum_{j=-6}^{6} \beta_{2j} \cdot \Delta \ln(1 + \tau_{ikt+j}) \cdot Regimpact_{ikt} \\ &+ \beta_3 \cdot Regimpact_{ikt} + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt}\end{aligned} \tag{15}$$

The coefficients β_{2j} thus capture the average difference in pass-through β_{1j} at horizon j for a

[31] BDKW in turn follow Poterba (1996) and Besley and Rosen (1999), who consider city-level sales taxes in the USA. Benzarti et al. (2020) and Benzarti and Tazhitdinova (2021) also adopt a similar approach.

[32] 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 any significant effects outside this window.

[33] While our fixed effects account for country-specific and product-specific trends in the first difference of prices, they do not eliminate country-product-specific autocorrelation in price levels, such as that which results for seasonal products in countries with climatic or cultural events that are not shared with the rest of the sample. We therefore regress log prices on month-of-year dummies and linear to quartic time trends, then substitute raw prices with the predicted values. We consider alternatives to this approach in Section V.

country-product whose upstream suppliers face regulation that is one standard deviation less supportive of competition than average. Summing these terms again reveals the cumulative impact over a given timeframe.

In a third specification, we also control for alternative measures of competition, as described in the previous section. We include a vector of covariates $\mathbf{X}_{ikt}$, which in our baseline regressions contains $Concentration_{ikt}$ and $Openness_{ikt}$:

$$\begin{aligned}
\Delta \ln(p_{ikt}) = \beta_0 &+ \sum_{j=-6}^{6} \beta_{1j} \cdot \Delta \ln(1 + \tau_{ikt+j}) \\
&+ \sum_{j=-6}^{6} \beta_{2j} \cdot \Delta \ln(1 + \tau_{ikt+j}) \cdot Regimpact_{ikt} \\
&+ \sum_{j=-6}^{6} \boldsymbol{\beta}_{3j} \cdot \Delta \ln(1 + \tau_{ikt+j}) \cdot \mathbf{X}_{ikt} \\
&+ \beta_4 \cdot Regimpact_{ikt} + \boldsymbol{\beta}_5 \cdot \mathbf{X}_{ikt} + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt}
\end{aligned} \tag{16}$$

To gauge the relationship between the scope for quality differentiation and pass-through, we follow the same process, adding $QualityLadder_k$ to the set of covariates $\mathbf{X}_{ikt}$.[34]

C. Identification

For our primary coefficients of interest—β_{2j} in equation 16—to have a causal interpretation, we require that the parallel trends assumption holds for our 'treated' country-products relative to

[34] We do not include $QualityLadder_k$ from the start because it is only available for a subset of products, so would limit the sample available to estimate the role of *Regimpact*.

the rest of the sample. Specifically, we require that:[35]

$$
\begin{aligned}
E\big[\epsilon_{ikt}|\, & \ln(1+\tau_{ikt-6}), \\
& \vdots \\
& \ln(1+\tau_{ikt+6}), \\
& \ln(1+\tau_{ikt-6}) \cdot Regimpact_{ikt}, \\
& \vdots \\
& \ln(1+\tau_{ikt+6}) \cdot Regimpact_{ikt}, \\
& Regimpact_{ikt}, \mathbf{X}_{ikt}, \varphi_{it}, \varphi_{kt}, \varphi_{ik}\big] \\
= E\big[\epsilon_{ikt}| & Regimpact_{ikt}, \mathbf{X}_{ikt}, \varphi_{it}, \varphi_{kt}, \varphi_{ik}\big]
\end{aligned} \tag{17}
$$

Intuitively, we require that: (i) country-products ik whose VAT rate was changed at each given month $t+j$ would have otherwise experienced the same changes in prices as those whose rate remained the same, after controlling for the fixed effects, and (ii) given that a VAT change did in fact occur in ik, the impact of this change on prices would have been the same as the average across other country-products facing an equivalent VAT change, if the markets upstream of ik had instead faced an average degree of product market regulation—all after controlling for the fixed effects, the general trend in ik's upstream regulation relative to the average, and our measures of downstream market competitiveness.

Statement (i) relates to the first three rows in equation 17, and corresponds to the identification assumption in BDKW. The primary concern is that a common factor causes both price changes and tax changes—for instance, an economic downturn that both lowers prices and prompts a fiscal response in the form of tax cuts. Using the same tax data as our paper, BDKW alleviate this concern by showing that the reforms are initiated independently of economic conditions, with no significant differences between coefficients estimated using reforms identified as exogenous to business cycles using a Romer and Romer (2010) approach and coefficients estimated from the remaining reforms. Benzarti and Tazhitdinova (2021) also find no evidence of pre-existing trends in the response of trade flows to VAT rate changes, using similar European VAT data and a similar empirical design. A second concern is that the country-product cate-

[35] The following logic applies similarly for the results on quality differentiation, with the interaction terms involving $QualityLadder_k$ needing to satisfy a condition analogous to that shown for the interaction terms involving $Regimpact_{ikt}$.

gories selected for VAT reforms are fundamentally different to those that are not, such that the prices of the latter are a poor counterfactual for the former, even after controlling for country and product trends. To alleviate this concern, we compare pre-reform paths in Section V and find no evidence of differing pre-trends. Lastly, BDKW also test for the presence of measurement error in the VAT measures, by comparing their estimates to IV estimates using an alternative source of VAT changes from Eurostat, and find no evidence of a significant impact on the results.

Statement (ii) relates to the next three rows of equation 17, i.e. the interactions between VAT reforms and $Regimpact_{ikt}$ (or, equivalently, $QualityLadder_k$). First note that the existence of common determinants of prices and $Regimpact_{ikt}$ would not necessarily undermine our interpretation of β_{2j}: since we control for $Regimpact_{ikt}$ in the regression, such endogeneity is only sufficient to bias β_4, preventing a causal interpretation of a control variable that is not of interest to our study. The primary concern is instead that the impact of VAT reforms on prices is itself related to a common factor that is also correlated with $Regimpact_{ikt}$. Since different varieties of VAT reform could have different impacts on prices, as described in BDKW, a relationship between the type of reform and the characteristics of a particular country-product pair could induce such a bias. However, as shown in Table 3, our reforms are evenly spread across country-product pairs with high and low values of $Regimpact_{ikt}$ and $QualityLadder_k$. Both the high and low groups have the same average size of reform—which could otherwise bias β_{2j} if VAT reforms have non-linear effects on prices—and similar distributions across types of reform. We do find, in contrast, that VAT reforms in country-product pairs with more competition-friendly upstream regulation tend to be announced slightly earlier than in other country-product pairs. We investigate such announcement effects in Section V, alongside other robustness checks, and find no significant impact on our results.

In our context of staggered treatment, a final potential concern is that post-treatment periods of an earlier-treated unit can be used as counterfactuals when estimating treatment effects for later-treated units (Roth et al., 2023). If treatment effects are heterogeneous, such 'forbidden comparisons' can undermine the interpretation of regression coefficients.[36] We first note that our setup differs conceptually from the conventional treatments discussed in the literature, as

[36]For instance, if treatments effects increase over time since treatment, the growing impact of early treatment of unit A reduces the treatment effect estimated for later-treated unit B, for which it forms the 'forbidden' counterfactual. While this issue has been extensively discussed in the context of binary treatments, extensions to continuous treatment remain at an earlier stage (Callaway and Sant'Anna, 2021; Callaway et al., 2024).

‘treatment’ does not change the fundamental nature of the product. Compare VAT pass-through to the impact of a vaccine on health outcomes, or of permanent Medicaid expansion on insurance coverage (as in Roth et al., 2023). The VAT changes can be positive, negative, or even in both directions for some country-products that experience multiple changes during the sample period. Indeed, all country-products could to some extent be considered ‘already-treated’ ever since the VAT was initially imposed, prior to our sample period. Each VAT change does not therefore imply the type of qualitative change in the nature of a country-product that would make it an invalid comparator for country-products subsequently receiving VAT changes. Supporting this view, our results indicate that there are no persistent impacts of a VAT reform after six months, as shown in Figures 3 and 5 (unlike, for instance, the canonical case of a vaccine treatment, where the benefits could compound over time). Thus, we consider post-treatment country-products valid comparators for newly treated units.

Second, the potential role for ‘forbidden comparisons’ is small in our context, limiting the extent to which they could bias our results. For each wave of VAT reforms, the ‘ideal’ comparisons may be considered those between the ‘currently treated’ and ‘never treated’. The proportion of ‘previously treated’ at each wave of reforms then gauges the potential for our results to be affected by forbidden comparisons. It is intuitive that when the first reform takes place, the proportion of the ‘previously treated’ in our sample is zero. By the time of the last reform in our sample, when the proportion of ‘previously treated’ country-product observations reaches a maximum, this proportion is only 31.9%. Across all reform waves, the average proportion is 21.1%, so the vast majority of our counterfactuals are constructed using country-products that were never previously treated within our sample.

IV. RESULTS

This section presents our two main results. The first part, on upstream product market regulation, relates to Section II.A and Section II.B, as summarized in **propositions 1 & 2**. The second part, on quality scope, relates to Section II.C, as summarized in **proposition 3**. Various robustness checks and additional results are included in Section V and the Appendix.

A. Upstream product market regulation

Following our empirical specification outlined in equations 14-16, columns (1)-(3) of Table 4 first present estimates of VAT pass-through following BDKW, then interact VAT pass-through with market competition measured with *Regimpact*, and finally include controls for alternative competition measures (*Openness* and *Concentration*). In short, the first column shows that our sample generates similar pass-through estimates to BDKW, confirming the validity of the sample. The second column shows that greater upstream competition implies a greater pass-through, an effect that is consistent with our theoretical prediction under decreasing returns to scale and assuming that upstream regulation constrains the number of firms. Finally, the third column strengthens this finding by controlling for downstream concentration and openness.

Across all specifications, we present the estimated dynamic effects on pass-through for four timeframes: Pre-reform, Contemporaneous, Post-reform, and Total. For example, the first four rows of estimates correspond to β_1 in estimating equation 14—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. We generally focus on the 'Total' impact, as it shows the overall impact on pass-through over the 13-month window around the reform, and highlight the corresponding estimates in bold.

Column (1) in Table 4 follows the BDKW specification detailed in equation 14. As shown in the estimates for baseline β_1, average baseline 'total' pass-through of a VAT rise to prices is 21% in Column (1), close to BDKW's main estimate of 25%.[37] This effect is predominantly driven by the contemporaneous pass-through effect—i.e. by the impact on prices in the month that the reform is introduced—as in BDKW.

Column (2) augments this regression with the interaction between VAT changes and $Regimpact_{ikt}$, as in equation 15. Average pass-through in the first four rows is consistent with the relationship under BDKW. To see the impact of upstream competition on pass-through, we turn to the next four rows of estimates for $Regimpact_{ikt}$, corresponding to the β_2 estimates across horizons. From the 'Total' row in Column (2), a one-standard-deviation lower value of $Regimpact_{ikt}$, corresponding to a one-standard-deviation increase in the competition-friendliness of upstream regulation, raises pass-through by a further 17 percentage points.

Column (3) tightens the identification by additionally controlling for measures of down-

[37]Our results differ slightly from BDKW because (i) we use only the subset of their observations for which our measures of regulation, openness and concentration are available, and (ii) they sum over a 24-month window around the reform.

stream concentration, as in equation 16.[38] In this case (our preferred, most stringent specification), we find that 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% increase relative to the estimated baseline pass-through. This impact is both larger and more statistically significant than the estimated coefficients on the downstream competition measures, shown in the 'Total' rows for Openness and Concentration.

We can use the theoretical framework of Section II.B to reflect on our result. Our empirical result shows that more competition-friendly regulation is associated with higher VAT pass-through. This is consistent with **proposition 2** for the case where we assume that upstream producers face increasing marginal costs and that more competition-friendly regulation leads to more firms: higher competition means that input prices are less elastic and contribute to a lesser degree to shock absorption. However, our theoretical results emphasize the multi-dimensional nature of competition. Alternatively, regulation as captured by *Regimpact* could be related to the elasticity of substitution and our empirical findings could be compatible with another cost function. We revisit this possibility in Section V below.

The role of upstream regulation is robust to alternative controls for downstream competition, such as defining the relevant market at the 4-digit level when calculating the Orbis HHI, or constructing the concentration measure using import origins (Appendix Tables B.4 and B.5). This suggests that the theoretical mechanism outlined in Section II.B is stronger than that in Section II.A, and aligns with findings elsewhere that upstream reforms affecting inputs can have substantial downstream effects (e.g. Amiti and Konings, 2007; Arnold et al., 2016; Bertrand et al., 2007).[39]

Figure 3 plots the cumulative effects of relatively pro- and anti-competitive upstream regulation on pass-through, where the blue line shows the average pass-through for a country-product with upstream regulation that is one standard deviation more supportive of competition than the sample average, and conversely the red line shows that for a country-product with upstream

[38] While we only show a subset of results in the tables, we estimate the full series of $\boldsymbol{\beta}_{3j}$ coefficients for $Concentration_{ikt}$ and $Openness_{ikt}$, as in equation 16. When summing over the relevant intervals to estimate Pre-Reform, Contemporaneous and Post-Reform effects, the p-values are greater than 0.15 in all cases, so we omit these rows from the results tables for brevity.

[39] 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).

regulation that is one standard deviation less supportive of competition. The underlying regression is our preferred specification, equation 16 (i.e., the results shown in Column (3) of Table 4), so both lines reflect an average level of downstream market concentration and openness to trade. Over the whole window, total cumulative pass-through is 56% for the blue line and 11% for the red line. In the latter case (relatively anti-competitive upstream regulation), the vast majority (89%) of the impact of the reform is absorbed by firms rather than passed on to consumer prices. For both pro- and anti-competitive upstream regulation, there is little pass-through prior to the change, then most of the total effect comes within the first two months after the reform. This is consistent with the purchaser-supplier relationships described in Section II 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.

In general, regulation became much more pro-competitive over our sample period, as shown in Figure 4A. To gauge the impact of this transition, a back-of-the-envelope calculation takes the observed changes in the *Regimpact* index for each country-product category (as shown in Figure 1) over the observed period and multiplies them by the coefficient on the VAT-PMR interaction term in Table 4. The smoothed distribution of these estimated changes in VAT pass-though is shown in Figure 4B. 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 84% 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.

B. Scope for quality

The final three columns of Table 4 relate to the role of quality differentiation. First, Column (4) repeats Column (3) but on the smaller sample for which measures of the scope for quality differentiation are available.[40] The estimated relationship between *Regimpact* and pass-through remains qualitatively similar, albeit substantially less significant due to the smaller sample.[41]

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

[41] When combined with our demanding fixed effects, the smaller sample does, however, occlude most of the variation in baseline pass-through.

When we introduce quality alone (Column (5)), paralleling Column (2) for *Regimpact*, we again cannot detect a significant impact, reflecting both the small sample and the confounding influences of the omitted *Regimpact*, *Concentration* and *Openness* variables. However, in our main specification—where we control for these effects—we detect a substantial positive role for quality differentiation, of a similar magnitude to that for *Regimpact*. This is shown in Column (6), which parallels Column (3) for the full sample.

We find that a one-standard-deviation increase in the length of the 'quality ladder' of a product—roughly equivalent to the gap between the relatively differentiated 'information processing equipment' and the less differentiated 'clothing materials'—can raise pass-through by more than 38 percentage points, shown in Column (6). In light of the theoretical framework of Section II.A, this is consistent with **proposition 3** for the 'complementarity' case, i.e., where demand for quality is relatively more important to consumers when prices are higher. 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.

Figure 5 shows the dynamics of the quality scope effect, where the blue (red) line represents a country-product with a one-standard-deviation longer (shorter) quality ladder than average. Both lines reflect an average level of upstream regulation, downstream market concentration and openness, and show little change in price prior to the VAT reforms. While there is again a substantial impact in the month of the reform (26% for the case of a longer quality ladder), the effect also continues to grow over the subsequent three months.

V. ROBUSTNESS

This section addresses the robustness of our empirical results to a range of considerations. Building on the discussion of announcement effects and pre-trends in Section III.C, we first address remaining concerns over the identification of our regressions. We then check that our results are not sensitive to alternative choices in the implementation of our empirical strategy, before finally confirming that we are also not omitting important forms of heterogeneity.

A. 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, uncertainty about future opportunities for price adjustment (e.g., following Calvo, 1983) or convex adjustment costs (e.g., following Rotemberg, 1982) could encourage firms to smooth their price response to an announced VAT change. As examined in Buettner and 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 and Carare, 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).[42]

To check that our results are not affected by such announcement effects, we run two alternative specifications. First, we exclude the 60% of reforms that were announced more than one month in advance (Appendix Table B.7). Second, we include only non-durable goods, noting that these are less susceptible to consumption smoothing in anticipation of a tax increase (Appendix Table B.8). In each case, the results are similar to our baseline specification for both upstream regulation and quality, albeit less significant for quality due to the smaller number of reforms (in the first case) or smaller number of products (in the second case).

B. Pre-trends

Other selection issues, beyond announcement effects, could also bias our results. Broadly, we require that our 'non-treated' observations—i.e., country-products without VAT changes in a given period, or with an average score for upstream regulation and quality differentiation—provide a valid counterfactual for the 'treated' observations. Differing price trends prior to the reform would suggest that this is not the case. Figures 3 and 5 provide initial reassurance: neither regulation nor quality have significant impacts on pass-through in the months before the reform.

[42] More broadly, controlling for implementation lag accounts for little of the substantial heterogeneity in pass-through, as illustrated in Appendix Figure B.4. We also consistently find little evidence of announcement effects directly increasing pre-reform or total pass-through, across a wide range of specifications (Appendix Table B.6).

However, as noted in the previous section, post-announcement anticipation effects could also be present in this period, which could offset and obscure the impact of other underlying selection effects if those unobservables are correlated with early announcement. We therefore repeat the event-study figures for the sub-samples described in the previous section, i.e., excluding reforms announced more than one month in advance, and excluding durable goods. The results, in Appendix Figures B.5, B.6, B.7 and B.8, again show no significant differences in pre-reform trends—confirming that we have no reason to reject the parallel trends assumption even after removing the possible confounding effects of advance announcement of reforms.[43]

C. Overlapping reform windows

A further concern is that contamination may occur between overlapping reform windows within the same country-product. For instance, if one country-product experiences two reforms fewer than 12 months apart, the 'post-period' of the first reform (i.e. within 6 months after the first reform) will overlap with the 'pre-period' of the second reform (i.e. within 6 months before the second reform). Thus, lagged impacts of the earlier reform may show up as anticipation effects of the latter. To deal with the issue, we re-run our baseline specification when excluding all subsequent reforms within a given country-product. The results, shown in Appendix Table B.9, are quantitatively and qualitatively similar to the baseline, suggesting that overlapping reform periods do not drive our main results.

D. Alternative specifications

While our main regressions follow BDKW, other recent work on similar questions has used a variety of specifications. Drawing on Benzarti, Carloni, Harju, and Kosonen (2020, hereafter BCHK), we repeat our analysis using raw (rather than detrended and de-seasonalized) prices and with country-specific controls for economic conditions (specifically, unemployment, real GDP growth and the interest rate) replacing the country-time fixed effect. We modify equation 16 as

[43]In Appendix Figure B.8, the set of products that are both non-durable and have quality data is very limited, resulting in an especially small sample and negative baseline pass-through (see the final column of Appendix Table B.8 for full details). Nonetheless, even in this specification there are no significant pre-trends and pass-through is larger for more pro-competitive upstream regulation or a longer quality ladder (again, see the final column of Appendix Table B.8).

follows:

$$
\begin{aligned}
\Delta \ln(p_{ikt}) = \beta_0 &+ \sum_{j=-6}^{6} \beta_{1j} \cdot \Delta \ln(1+\tau_{ikt+j}) \\
&+ \sum_{j=-6}^{6} \beta_{2j} \cdot \Delta \ln(1+\tau_{ikt+j}) \cdot Regimpact_{ikt} \\
&+ \sum_{j=-6}^{6} \boldsymbol{\beta}_{3j} \cdot \Delta \ln(1+\tau_{ikt+j}) \cdot \mathbf{X}_{ikt} \\
&+ \beta_4 \cdot Regimpact_{ikt} + \boldsymbol{\beta}_5 \cdot \mathbf{X}_{ikt} + \boldsymbol{\beta}_6 \cdot \boldsymbol{Controls}_{it} \\
&+ \varphi_{ik} + \varphi_t + \epsilon_{ikt}
\end{aligned} \tag{18}
$$

The results are presented in Appendix Table B.10; our main results remain similar, with larger baseline pass-through.

A second concern is that our results are driven by a small number of country-products with extreme values of our upstream regulation or quality differentiation variables. We therefore construct the new discrete variable $RegimpactHML_{ikt}$, which takes value 1 if the observation is in the top quartile of the $Regimpact_{ikt}$ distribution, value -1 if in the bottom quartile, and zero otherwise. We also repeat this process for quality differentiation. Appendix Table B.11 shows the results. Our main results are qualitatively robust in both cases, albeit at marginal significance levels for quality given the limited variation and small sample.

A third concern is that the VAT reforms may also affect upstream product market regulation, concentration, or openness, since these three measures vary over time.[44] We take two approaches to address the issue: (i) fix the variables using their first available observation, and (ii) use the one-year-lagged value of the variables, since the event-study estimates are computed for six months before and after the reforms. The results, presented in Appendix Tables B.12 and B.13 respectively, are similar to and consistent with the baseline.

A fourth possible concern is that our method of de-seasonalizing and de-trending raw prices could affect our results. We explore two alternative approaches. First, we adopt an alternative de-seasonalizing and de-trending procedure. Specifically, we include raw prices in the regressions but (i) interact the country-product fixed effect with calendar month fixed effects (to account for seasonality) and (ii) also interact the country-product fixed effect with a trend variable

[44]The fourth measure, $QualityLadder_k$, only varies across products so is not subject to this concern.

(taking value 1 in the first month of our data, value 2 in the second month, and so on) to account for country-product-specific trends. While this procedure performs the de-seasonalizing and de-trending adjustment only on prices changes, rather than price levels (as in our baseline specification), it has the upside of accounting for degrees of freedom used in the de-seasonalizing and de-trending directly in the regressions. Results are shown in Appendix Table B.14. The estimated coefficients remain statistically significant and quantitatively similar to our baseline results. Second, we simply use raw prices directly (Appendix Table B.15), accepting that, for instance, prices may include country-product-specific autocorrelation resulting from country-product specific climatic or cultural events. In general the coefficients remain similar, though in the quality sample only the upstream competition effect remains significant. This is driven by the increased noise in the raw prices combined with the much smaller quality-inclusive sample.

We also repeat the main specifications using country-level clustering and product-level clustering in turn. Results are similar with product-level clustering for both upstream regulation and quality differentiation. When clustering at the country level, the effect of upstream regulation remains significant while the effect of quality differentiation is marginally insignificant.

E. Alternative drivers of competition

As discussed above, we focus on investigating the impacts of competition resulting from product market regulation, but we don't know whether the impacts operate through a change in the number of competitors or through the elasticity of substitution. To try to disentangle the two, we repeat our main regressions and add measures of the elasticity of substitution at both the downstream and upstream levels (as described in Section III). Our main results are qualitatively and quantitatively robust to the inclusion of measures of elasticity of substitution, as shown in Appendix Tables B.16 and B.17 at the downstream level, and Appendix Tables B.18 and B.19 at the upstream level. Indeed, the newly introduced measures based on the elasticity of substitution are almost never significant. In light of **proposition 1** equation 5 in Section II.A, this suggests that differences in the elasticity of substitution may have only small quantitative implications for VAT pass-through. It also suggests that our baseline results on the impact of product market regulation may be related to changes in the number of firms.

F. Heterogeneity

Finally, we consider whether our results vary with the direction of the VAT change, the position of the business cycle, or the type of VAT reform. First, we check whether the roles of upstream regulation or quality are different for increases versus decreases, following recent work on asymmetric pass-through (e.g. Benzarti et al., 2020; Carbonnier, 2007; Politi and Mattos, 2011). We estimate these distinct effects with $\boldsymbol{\beta}_{2j}^{(inc)}$ and $\boldsymbol{\beta}_{2j}^{(dec)}$ in:

$$
\begin{aligned}
\Delta \ln(p_{ikt}) = \beta_0 &+ \sum_{d \in \{inc,dec\}} \sum_{j=-6}^{6} \beta_{1j}^{(d)} \cdot \Delta \ln(1 + \tau_{ikt+j}^{(d)}) \\
&+ \sum_{d \in \{inc,dec\}} \sum_{j=-6}^{6} \beta_{2j}^{(d)} \cdot \Delta \ln(1 + \tau_{ikt+j}^{(d)}) \cdot \mathit{Regimpact}_{ikt} \\
&+ \sum_{d \in \{inc,dec\}} \sum_{j=-6}^{6} \boldsymbol{\beta}_{3j}^{(d)} \cdot \Delta \ln(1 + \tau_{ikt+j}^{(d)}) \cdot \mathbf{X}_{ikt} \\
&+ \beta_4 \cdot \mathit{Regimpact}_{ikt} + \boldsymbol{\beta}_5 \cdot \mathbf{X}_{ikt} + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt}
\end{aligned}
\tag{19}
$$

Results are shown in Appendix Table B.20. 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 Appendix Table B.20 shows 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).

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

$$
\begin{aligned}
\Delta \ln(p_{ikt}) = \beta_0 &+ \sum_{d\in\{exp,rec\}} \sum_{j=-6}^{6} \beta_{1j}^{(d)} \cdot \Delta \ln(1+\tau_{ikt+j}^{(d)}) \\
&+ \sum_{d\in\{exp,rec\}} \sum_{j=-6}^{6} \beta_{2j}^{(d)} \cdot \Delta \ln(1+\tau_{ikt+j}^{(d)}) \cdot Regimpact_{ikt} \\
&+ \sum_{d\in\{exp,rec\}} \sum_{j=-6}^{6} \boldsymbol{\beta}_{3j}^{(d)} \cdot \Delta \ln(1+\tau_{ikt+j}^{(d)}) \cdot \mathbf{X}_{ikt} \\
&+ \beta_4 \cdot Regimpact_{ikt} + \boldsymbol{\beta}_5 \cdot \mathbf{X}_{ikt} + \varphi_{it} + \varphi_{kt} + \varphi_{ik} + \epsilon_{ikt}
\end{aligned} \tag{20}
$$

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 for both upstream regulation and quality differentiation are shown in Appendix Table B.21. Again, we generally cannot reject equality of pass-through coefficients across expansionary and contractionary periods.

Third, 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. The results are shown in Appendix Table B.22. However, with current data we cannot make clear comparisons across reform-types of the impact of regulation/quality on pass-through, as any differences 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 across type, as shown in Table 2, 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.[45]

VI. CONCLUSION

This paper investigates the role of market structure in determining VAT pass-through. We extend existing theory by modeling five different settings in which market competitiveness and product differentiation can influence pass-through. We test these relationships empirically using

[45]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.

a consumption 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. Quantitatively, we find that—relative to average baseline pass-through of up to 33%—a one-standard-deviation rise in (i) the competition-friendliness of regulation in upstream markets and (ii) the scope for quality differentiation can increase pass-through by up to 22 and 38 percentage points respectively.

Overall, our theoretical results emphasize the complexity of the interplay between competition and pass-through, which was previously understated or unaddressed. We thus contribute to rationalizing the diversity of pass-through estimates—including some seemingly inconsistent findings, discussed below.

Our primary empirical contribution is that we uncover the substantial roles of regulation and quality differentiation in determining VAT pass-through. A substantial literature exists estimating the effects of specific tax changes.[46] Without either (i) exploiting cross-country and/or cross-product variation in tax changes, or (ii) imposing strong structural assumptions, one cannot isolate the underlying drivers of the varying pass-through observed in such studies. Our findings thus highlight differences in regulation and quality differentiation as important potential factors explaining these studies' varying estimates of pass-through.

In doing so, we add to existing studies that have identified an impact of market structure on pass-through for specific countries and products with mixed results. Such studies include product-specific within-country work on local markets which either find that firm concentration is associated with smaller pass-through (Dimitrakopoulou et al. (2024), Genakos and Pagliero (2022) for gasoline, Galloway and Li (2023) for retail, Cabral et al. (2018) for medical insurance), or that greater brand concentration, lower competition, and market power are associated with larger pass-through rates (Doyle and Samphantharak (2008), Stolper (2018) for gasoline, Miller et al. (2017) for cement). They also include Hong and Li (2017) showing that higher vertical control leads to higher cost pass-through in US retail prices, and Miravete et al. (2018, 2020) demonstrating the importance of heterogeneous preferences and market power in the design of

[46]For instance, Carbonnier (2007) considers the impact of decreasing VAT on cars and housing repairs in France; Benzarti and Carloni (2017) consider a VAT cut for French restaurants, Mariscal and 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 a temporary VAT cut in Germany.

liquor taxes. As with BDKW, who constructed the core dataset of European VAT rates used in this paper, by drawing on a broad range of countries and consumption categories we are able to include tighter controls and produce more general empirical results.

Similarly, to the small number of existing studies that do use cross-country data to examine pass-through, we contribute new empirical findings on the role of market structure. In addition to BDKW, who consider heterogeneity resulting from different types of VAT reform, Benzarti et al. (2020) assess asymmetry in pass-through using data on all VAT changes across EU member states, while Andrade et al. (2015) focus on the impact of VAT changes in destination markets on prices charged by French exporters with varying shares of the destination market. We thus complement these papers by highlighting the importance of upstream regulation and the scope for quality differentiation. In finding a substantial downstream knock-on effect of upstream regulation, our results also draw a new parallel with empirical literatures on the consequences of trade and structural reforms, which similarly find large downstream spillovers of upstream reforms (e.g. Amiti and Konings, 2007; Arnold et al., 2016; Bertrand et al., 2007).[47]

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

[47]For instance, 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, while Bertrand et al. (2007) find similar effects on French manufacturing firms of banking deregulation in the 1980s.

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CONFLICT OF INTEREST DISCLOSURE

The authors have no financial arrangements that might give rise to conflicts of interest with respect to the research reported in this paper.

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TABLES AND FIGURES

Table 1: Summary of VAT reforms by country

	First year in data	Number of reforms	Products affected	Product-months affected
Austria	1998	2	2	2
Belgium	1998	3	3	3
Finland	1998	4	48	61
France	1998	4	36	37
Germany	1998	2	36	71
Greece	2000	4	48	144
Ireland	1998	7	33	148
Italy	1998	2	36	36
Netherlands	1998	1	29	29
Portugal	1998	8	49	194
Slovakia	2008	1	45	45
Slovenia	2006	2	4	4
Spain	1998	2	38	76
Total		42	407	850

Table 2: Summary of observed VAT rates and prices

		Obs	Mean	S.D.	Min	Max
VAT levels	Reduced rate	30,660	0.074	0.033	0.021	0.17
	Standard rate	72,519	0.194	0.02	0.15	0.23
	Zero rate	2,348	0	0	0	0
VAT changes	All	850	0.01	0.022	-0.151	0.17
	Standard	715	0.012	0.011	-0.01	0.03
	Reduced	116	0.005	0.02	-0.05	0.07
	Reclassification	7	-0.038	0.122	-0.151	0.17
	VAT decrease	149	-0.021	0.03	-0.151	-0.005
	VAT increase	701	0.016	0.012	0.005	0.17
Price levels		105,527	102.669	19.877	18.8	527.59

Table 3: Distribution of reforms across regressors

		Mean Change in VAT	Number of Reforms			
			All	Standard	Reduced	Reclassification
$Regimpact_{ikt}$	High	0.01	361	300	54	1
	Low	0.01	489	415	62	6
$QualityLadder_k$	High	0.01	227	204	19	1
	Low	0.01	226	208	17	0

Notes: This table shows the average size of VAT reforms and their distribution across different categories, for groups defined by being above/below the sample median value of $Regimpact_{ikt}$ or $QualityLadder_k$. Each reform is defined as a change in the VAT rate in a given country-product pair ik in a given month t.

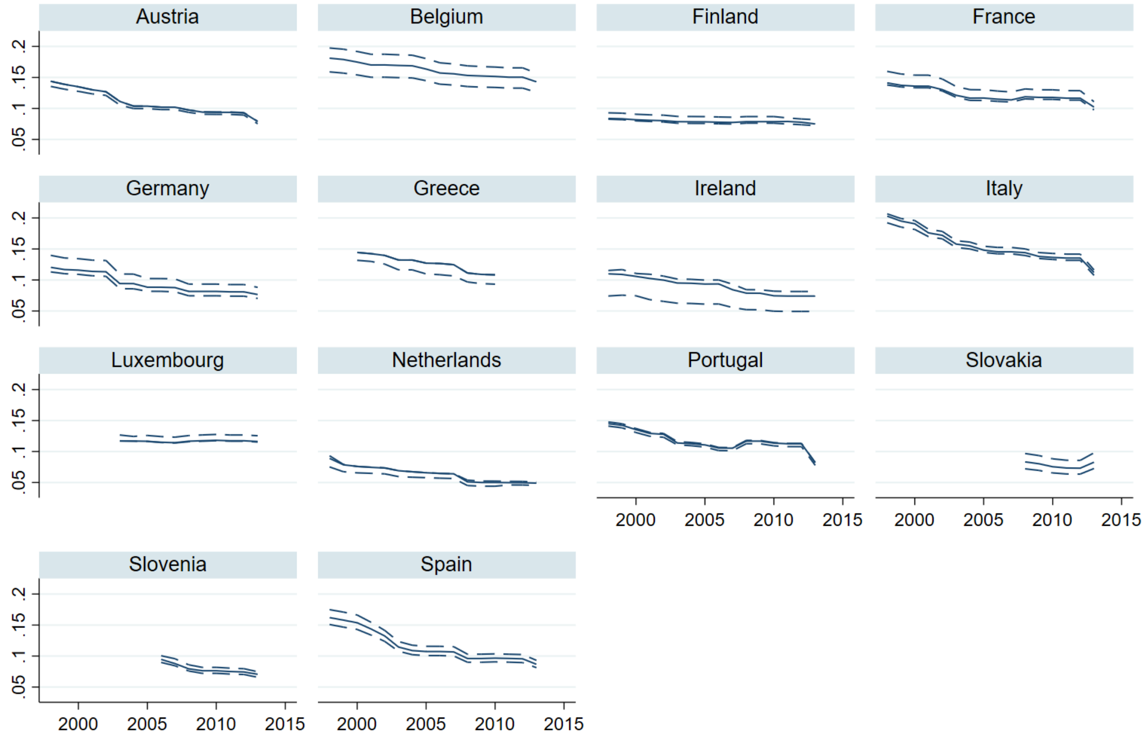
Table 4: Estimates of pass-through heterogeneity

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.074	0.027	0.039	0.098	0.172	0.089
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.070)	(0.054)	(0.058)	(0.121)	(0.167)	(0.122)
	Contemporaneous	0.120	0.259***	0.263***	0.070	-0.283	0.013
	– i.e. β_{10}	(0.111)	(0.080)	(0.078)	(0.116)	(0.198)	(0.112)
	Post-Reform	0.019	0.027	0.032	-0.087	-0.105	-0.119
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.058)	(0.073)	(0.070)	(0.077)	(0.067)	(0.090)
	Total	0.213**	0.312***	0.334***	0.080	-0.217	-0.016
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.104)	(0.101)	(0.101)	(0.182)	(0.170)	(0.190)
Regimpact:	Pre-Reform		0.066	0.062	0.111		0.090
			(0.060)	(0.069)	(0.126)		(0.127)
	Contemporaneous		-0.225***	-0.254***	-0.327**		-0.392***
			(0.070)	(0.079)	(0.136)		(0.124)
	Post-Reform		-0.012	-0.030	0.020		-0.021
			(0.040)	(0.050)	(0.069)		(0.062)
	Total		**-0.171****	**-0.222****	**-0.195**		**-0.323****
			(0.081)	**(0.094)**	**(0.170)**		**(0.160)**
QualityLadder:	Pre-Reform					0.043	-0.001
						(0.123)	(0.097)
	Contemporaneous					0.051	0.244**
						(0.147)	(0.107)
	Post-Reform					0.086	0.140
						(0.083)	(0.099)
	Total					**0.180**	**0.383****
						(0.200)	**(0.188)**
Openness:	Total			-0.195	-0.318		-0.507
				(0.391)	(0.811)		(0.774)
Concentration:	Total			0.183	-0.099		-0.089
				(0.140)	(0.209)		(0.202)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99361	99361	99361	48977	48977	48977

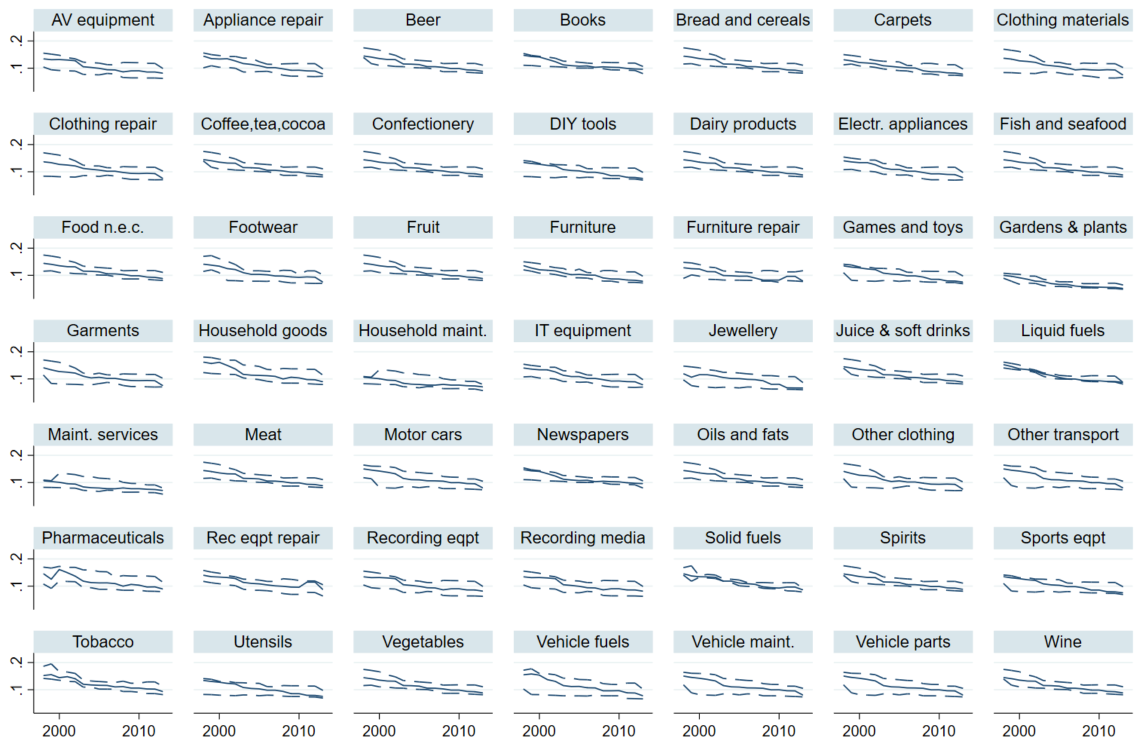
Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, *QualityLadder* 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. Columns (1)-(3) present results on the impact of *Regimpact*: Column (1) repeats the specification in BDKW, Column (2) adds the *Regimpact* variable and its interaction with all reform horizons, and Column (3) shows the full baseline specification, where Openness and Concentration are also included. Columns (4)-(6) present results on the impact of *QualityLadder*: Column (4) validates the smaller quality sample by repeating the specification in Column (3), Column (5) only includes the *QualityLadder* variable and its interaction with all reform horizons, and Column (6) shows the full baseline specification, where *Regimpact*, Openness and Concentration are also included. Pre-Reform, Contemporaneous and Post-Reform effects are also estimated for Openness and Concentration, but are not significant so omitted for conciseness. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

FIGURE 1: Changes in upstream regulation by country and consumption category

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

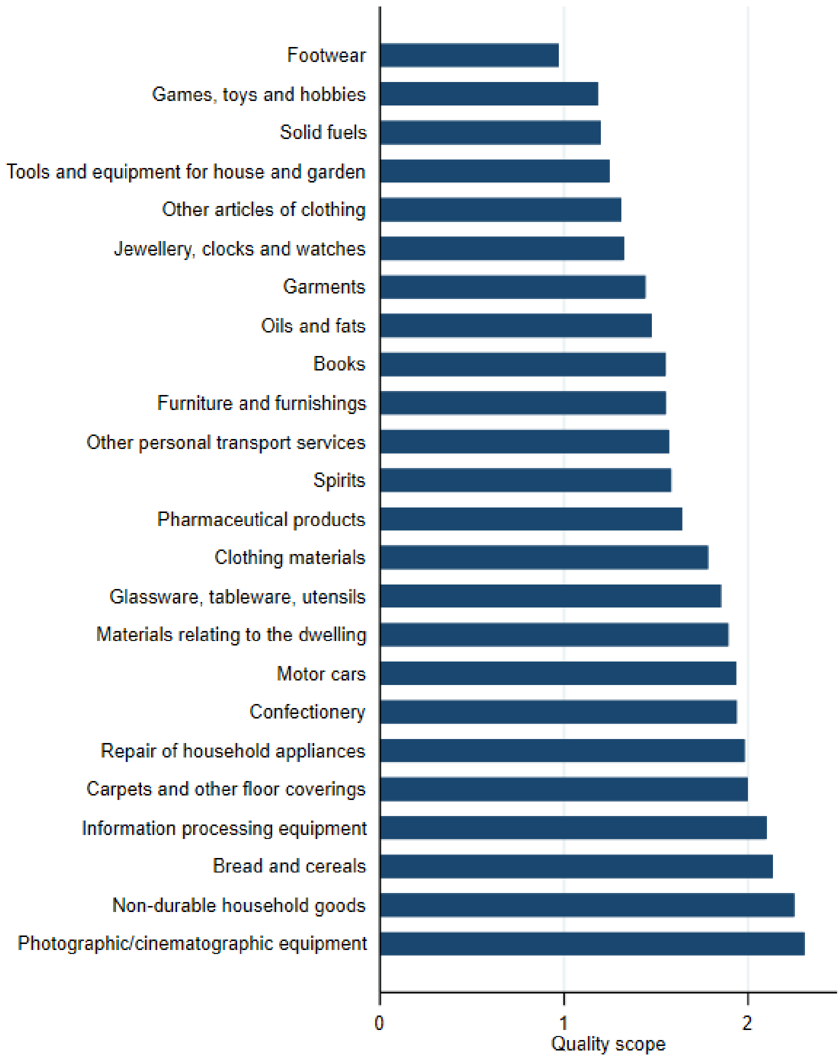


(B) Median *Regimpact* by consumption category over time—25th, 50th and 75th percentiles



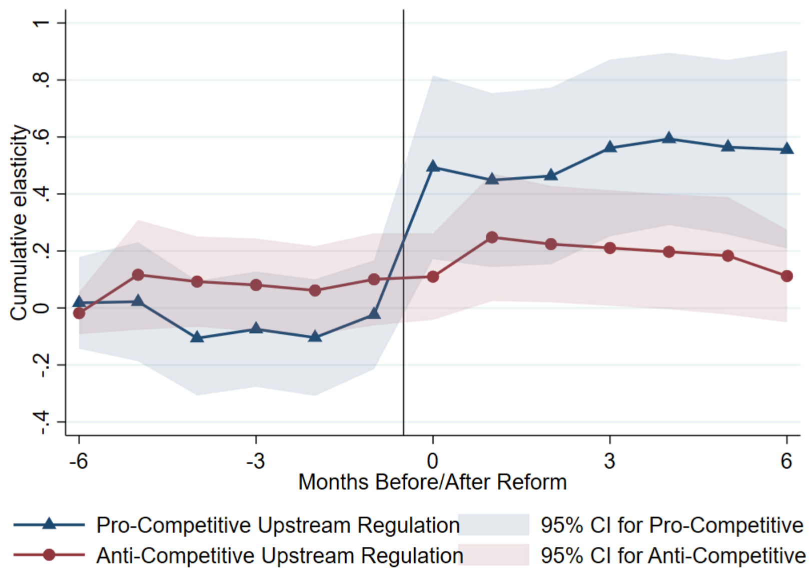
Notes: These plots show the distribution of the *Regimpact* measure across countries and consumption categories over time. A lower value of the indicator reflects a more competition-friendly regulatory stance among input sectors.

Figure 2: 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).

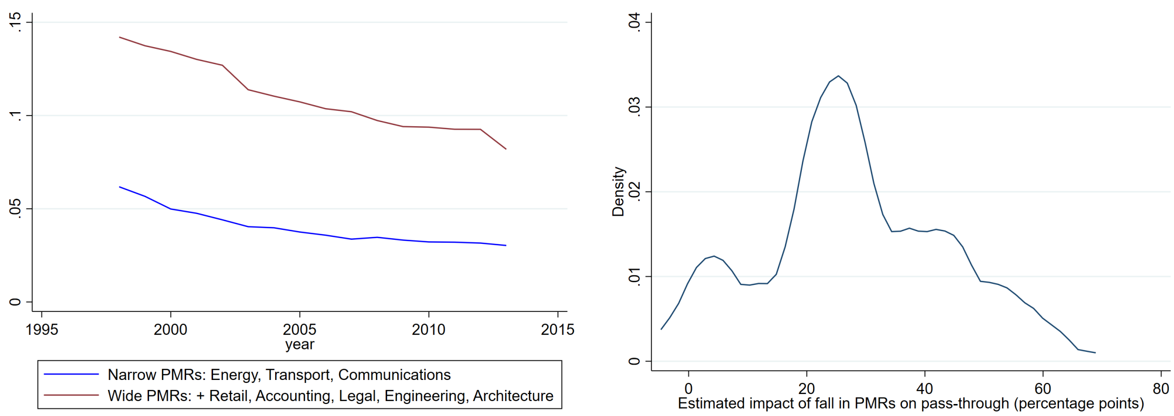
Figure 3: Cumulative effects of upstream regulation on pass-through



Notes: This graph shows cumulative pass-through for country-products with upstream regulation that is relatively supportive or constraining of competition, following our baseline specification (equation 16) with controls for downstream market competitiveness as in Column (3) of Table 4. The blue (red) line shows cumulative pass-through in a country-product pair with regulation that is exactly one standard deviation more (less) competition-friendly than the mean.

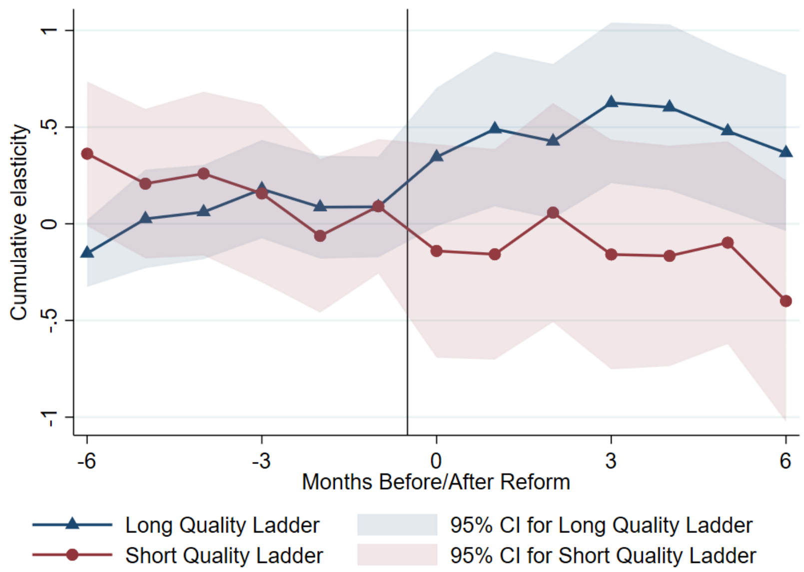
Figure 4: Trends in upstream regulation

(A) Median index of regulation over time (B) Distribution of impact on pass-through



Notes: The left-hand 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 markets. The right-hand 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 4 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.

FIGURE 5: Cumulative effect of longer and shorter quality ladders on pass-through



Notes: This graph shows cumulative pass-through for products with higher or lower scope for quality differentiation, controlling for *Regimpact* and downstream market competitiveness as in Column (6) in Table 4. The blue (red) line shows cumulative pass-through in a country-product pair with a quality ladder that is exactly one standard deviation longer (shorter) than the mean.

Supply and Demand Determinants of Heterogeneous VAT Pass-Through

Matthieu Bellon, Alexander Copestake, Wenzhang Zhang

SUPPLEMENTARY ONLINE APPENDIX

A. THEORETICAL APPENDIX

We examine in turn each of the five cases presented in the main text. In each case, we find it is convenient to use an expression for the degree of pass-through based on producer prices that can be derived from definition (1):

$$\begin{aligned}\gamma - 1 &= \frac{\partial \ln p}{\partial \ln \widetilde{p}} \cdot \frac{\partial \ln \widetilde{p}}{\partial \widetilde{p}} \cdot \frac{\partial \widetilde{p}}{\partial \tau} \cdot \frac{\partial \tau}{\partial \ln (1+\tau)} - 1 \\ &= \frac{\partial \widetilde{p}}{\partial \tau} \cdot \frac{(1+\tau)}{\widetilde{p}} \end{aligned} \tag{21}$$

A. Monopolistic Competition in the Downstream Sector

We focus on a good with horizontal differentiation where each of the N firms 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 $Q = \left(\int_1^N u(q_n) dn \right)$, 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 $\int_1^N p_n q_n dn + P_o Q_o = I$ where I is aggregate income. For tractability, we also assume that $\frac{\partial U}{\partial Q} = 1$.

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

$$u'(q_n) = \eta p_n \tag{22}$$

where η is the Lagrange multiplier associated with the budget constraint. The variable η is related to the marginal utility of income and acts as a demand shifter. It can alternatively be expressed using the budget constraint as $\eta = u'(q(A))/p(A)$, 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 η are assumed to be exogenous. We also assume a constant elasticity of substitution. Therefore, the first order condition (22) 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 σ, 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 ε_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,

$$q = \frac{A}{\widetilde{p}_n(1+\tau)N} \tag{23}$$

All 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

$$\widetilde{p}\left(1 - \frac{1}{\varepsilon_d}\right) = C' \tag{24}$$

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 definition of the demand elasticity 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 substitute price using the FOC (24) and multiply the inequality with the negative term

$-\frac{q\varepsilon_d}{C'(1+\tau)}$ to obtain another inequality that will prove useful in what follows

$$1 - \frac{q\varepsilon_d'}{\varepsilon_d} \frac{1}{\left(1 - \frac{1}{\varepsilon_d}\right)} + \varepsilon_d \frac{C''q}{C'} > 0 \tag{25}$$

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 (24) with respect to the tax 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 (24) 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 and Fabinger (2022).[1]

$$\gamma = \frac{1}{1 - \frac{q\varepsilon_d'}{\varepsilon_d}\frac{1}{\left(1 - \frac{1}{\varepsilon_d}\right)} + \frac{\varepsilon_d}{\varepsilon_s}} \tag{26}$$

In the case of constant marginal costs, this equation simplifies to $\gamma = 1$, which is different from the results presented in Section 3.2 of Adachi and Fabinger (2022) despite the fact that this section also assumes constant-elasticity-of-substitution demand. This difference comes from the fact that they assume $Q = \left(\int_1^N q_n^{\frac{\sigma-1}{\sigma}}\right)^{\xi}$ with $\xi = 0.9$ whereas we assume $\xi = 1$.

Note that the SOC (25) 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

$$\gamma = \frac{1}{1 + \frac{\varepsilon_d}{\varepsilon_s}} = \frac{1}{1 + \frac{\sigma bq}{c+bq}} \tag{27}$$

[1] To see this, note that their ad valorem pass-through semi-elasticity on page 8 simplifies to $\rho_v = \frac{1}{1-v}\frac{\epsilon-\theta}{\epsilon}\frac{1}{1+\frac{\epsilon}{\epsilon_s}-\left(\frac{1}{\epsilon}+\frac{1}{\epsilon_s}\right)\theta+\epsilon q\left(\frac{\theta}{\epsilon}\right)'}$ once we assume no unit tax $(\tau = v)$. Also note that, in our setting, $\epsilon = \epsilon_{own} = \varepsilon_d$, $\theta = 1$ and $\epsilon q\left(\frac{\theta}{\epsilon}\right)' = -\frac{q}{\varepsilon_d}\varepsilon_d'$, and pass-through $\gamma = (1-v)\rho_v$.

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 (23) to substitute prices with quantities in the FOC (24) 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

$$\frac{\partial q}{\partial N}\frac{N}{q} = \frac{1}{\frac{q\varepsilon_d'}{\varepsilon_d}\frac{1}{1-\frac{1}{\varepsilon_d}} - \frac{1}{\varepsilon_s} - 1} \tag{28}$$

Finally, we can take the derivative of the pass-through (equation (26)) with respect to N.

$$\frac{\partial \gamma}{\partial N}\frac{N}{\gamma} = -\frac{(q\varepsilon_d' + q^2\varepsilon_d'')(\varepsilon_d - 1) - (q\varepsilon_d')^2}{(\varepsilon_d-1)^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q} - \frac{q\varepsilon_d'}{\varepsilon_s}\gamma\frac{\partial q}{\partial N}\frac{N}{q} + q\varepsilon_s'\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q} \tag{29}$$

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 (25) 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 marginal costs are convex enough.

Pass-through variation with constant elasticity of substitution. In the case of constant elasticity of substitution (CES case) where $u(q) = q_n^{\frac{\sigma-1}{\sigma}}$, we can also derive how VAT pass-through varies with the parameter σ. In this case we simplify the following equations:

$$\tilde{p} = \frac{\sigma}{\sigma-1}C' \qquad (\textit{simplified equation } 24) \tag{30}$$

$$0 < 1 + \frac{\sigma}{\varepsilon_s} \qquad (\textit{simplified equation } 25) \tag{31}$$

$$\gamma = \frac{1}{1+\frac{\sigma}{\varepsilon_s}} \qquad (\textit{simplified equation } 26) \tag{32}$$

We then derive the variation of equilibrium quantity q with respect to parameter σ using $A\left(\frac{\sigma-1}{\sigma}\right) = C'(1+\tau)qN$ obtained from equations (23) and (30):

$$\frac{A}{\sigma^2} = C''(1+\tau)qN\frac{\partial q}{\partial \sigma} + C'(1+\tau)N\frac{\partial q}{\partial \sigma}$$

We rearrange terms to get

$$\frac{\partial q}{\partial \sigma}\frac{\sigma}{q} = \frac{1}{(\sigma-1)\left(\frac{1}{\varepsilon_s}+1\right)} \tag{33}$$

and we use (31) to obtain $1+\frac{1}{\varepsilon_s} > 1-\frac{1}{\sigma} > 0$, which implies $\frac{\partial q}{\partial \sigma}\frac{\sigma}{q} > 0$. Intuitively, a higher elasticity of substitution reduces the monopoly (market) power of each firms which let prices go down and produces more.

Then, we can take the derivative of the pass-through (equation (32)) with respect to σ.

$$\begin{aligned}\frac{\partial \gamma}{\partial \sigma}\frac{\sigma}{\gamma} &= -\gamma^2\left(\frac{\varepsilon_s - \sigma\varepsilon_s'\frac{\partial q}{\partial \sigma}}{\varepsilon_s^2}\right)\frac{\sigma}{\gamma} \\ &= \frac{\sigma\gamma}{\varepsilon_s^2}\left(\varepsilon_s' q\left[\frac{\partial q}{\partial \sigma}\frac{\sigma}{q}\right] - \varepsilon_s\right)\end{aligned} \tag{34}$$

Therefore, $\frac{\partial \gamma}{\partial \sigma}\frac{\sigma}{\gamma}$ is negative if and only if $\varepsilon_s' q < \varepsilon_s\left[\frac{\partial q}{\partial \sigma}\frac{\sigma}{q}\right]^{-1}$ and equivalently if and only if $\varepsilon_s' q < (\sigma-1)(1+\varepsilon_s)$. This condition is satisfied when the cost function is weakly increasing and convex ($\varepsilon_s \geq 0$ and $\varepsilon_s' \leq 0$ with at least one strict inequality), a case of increasing marginal costs. Conversely, it can be violated with increasing returns to scale when $\varepsilon_s \geq 0$ and ε_s' is positive and large enough.

In the case of linear marginal costs, $\frac{\partial \gamma}{\partial \sigma}\frac{\sigma}{\gamma}$ is negative if and only if $-\frac{c}{bq} < (\sigma-1)\frac{c+2bq}{bq}$ which is equivalent to $-\frac{\sigma c}{bq} < 2(\sigma-1)$, and $\frac{1}{b} > -\frac{2(\sigma-1)q}{\sigma c}$. Put simply, the VAT pass-through increases with the elasticity of substitution if and only if $\frac{1}{b} > \frac{1}{b_0}$ with $b_0 \equiv -\frac{\sigma c}{2(\sigma-1)q}$, which is true when $b > 0$.

The intuition behind this result is as follows. Lower demand resulting from higher taxes induces producers to scale back production. With increasing marginal costs ($\varepsilon_s' > 0$ or $b > 0$), a reduction in scale implies some savings on production costs which, in turn, allows for lower producer prices.[2] In this case, greater competition through a larger elasticity of substitution amplifies producer costs adjustment because each firm is producing more $\left(\frac{\partial q}{\partial \sigma}\frac{\sigma}{q} > 0\right)$. When the elasticity of substitution is high, firms have stretched production capacities and a reduction in scale yields large savings. When the elasticity of substitution is low, firms are small, and savings from scaling down are smaller and producers are less able to lower their prices in compensation for higher VAT. Therefore, a greater elasticity of substitution with increasing marginal costs implies a lower pass-through.

Pass-through variation with N with a variable elasticity of substitution. Moving away from the assumption of a constant elasticity of substitution, this section aims at deriving the variation of pass-through with respect to the number of firms in this alternative demand setting.

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 (22) and all the above calculations based on the unspecified elasticity of demand ε_d are still valid. In this case however, the elasticity of substitution is equal to the inverse of the love for variety $\varepsilon_d = -\frac{\partial q_n}{\partial p_n}\frac{p_n}{q_n} = \frac{1}{r_u(q)}$. Furthermore, its derivative is $\varepsilon_d' = -\frac{r_u'}{r_u^2}$ and second derivative $\varepsilon_d'' = \frac{2r_u'^2 r_u - r_u'' r_u^2}{r_u^4}$.

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 (29) depending on $q\varepsilon_d'$. The SOC (25) 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

[2] This can be seen because $\gamma < 1$ when $\varepsilon_s > 0$.

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

$q\varepsilon'_d$		0	ϵ_3		ϵ_4	**ruled out by SOC**
$\frac{\partial q}{\partial N}\frac{N}{q}$	-		-	+		$\times$
$-\frac{q\varepsilon'_d}{\varepsilon_s}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$	-		+	-		$\times$
$q\varepsilon'_s\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$	sign$(-\varepsilon'_s)$		sign$(-\varepsilon'_s)$	sign(ε'_s)		$\times$
$q\varepsilon'_d$	ϵ_1	0		ϵ_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.

$\epsilon_1 < 0 < \epsilon_3$, 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 only if $-\varepsilon'_s > \frac{\varepsilon_s^2}{q\varepsilon_d}\left(\frac{g[q\varepsilon'_d]}{(\varepsilon_d-1)^2} - \frac{q\varepsilon'_d}{\varepsilon_s}\right)$. 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 ε'_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 (ε'_d small enough) and $-\varepsilon'_s$ 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 (29) depending on $q\varepsilon'_d$. The SOC (25) 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 ε_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 ε'_s is large enough (b negative enough in the case of linear marginal costs) and specifically if and only if $\varepsilon'_s > \frac{\varepsilon_s^2}{q\varepsilon_d}\left(\frac{q\varepsilon'_d}{\varepsilon_s} - \frac{g[q\varepsilon'_d]}{(\varepsilon_d-1)^2}\right)$. To summarize for the case of increasing returns to scale, we obtain that the pass-through increases with the number of firms when ε'_s is large enough.

We can rephrase our conclusions in more generic terms to encompass the two cases

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

$q\varepsilon'_d$	0	ϵ_4	ruled out by SOC
$\frac{\partial q}{\partial N}\frac{N}{q}$	-	-	$\times$
$-\frac{q\varepsilon'_d}{\varepsilon_s}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$ $q\varepsilon'_s\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial q}{\partial N}\frac{N}{q}$	$+$ sign$(-\varepsilon'_s)$	- sign$(-\varepsilon'_s)$	$\times$ $\times$

$q\varepsilon'_d$	ϵ_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.

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 generalizes the results in **proposition 1**.

B. 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.

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

$$U = \left(aQ^{1-\beta} + (1-a)Q_o^{1-\beta}\right)^{\frac{\nu}{1-\beta}} \quad (35)$$

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 η and get the aggregate demand curve introduced in the main text

$$p(Q) = A'Q^{-\beta} \tag{36}$$

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

$$\widetilde{p} + \frac{\partial \widetilde{p}}{\partial q_n} q_n - C_n' = 0 \text{ for all } n \tag{37}$$

Summing (37) across firms, and using the definition of the demand elasticity, we get

$$p\left(N - \frac{1}{\varepsilon_d}\right) = N\bar{C}'(1+\tau) \tag{38}$$

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 ε_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.

$$\begin{aligned}
& \frac{\partial p}{\partial Q} + \frac{\partial^2 p}{\partial Q^2} q_n - \frac{\partial C_n'}{\partial (Q/N)} \frac{(1+\tau)}{N} < 0 \qquad \text{for all } n \\
\Leftrightarrow \quad & \frac{-1}{\varepsilon_d}\frac{p}{Q} + \frac{\varepsilon_d'}{\varepsilon_d^2}\frac{p}{Q} q_n - \frac{1}{\varepsilon_d}\frac{\frac{\partial p}{\partial Q}Q - p}{Q^2} q_n - \frac{\partial C_n'}{\partial (Q/N)}\frac{(1+\tau)}{N} < 0 \\
\Leftrightarrow \quad & p - p\frac{\varepsilon_d'}{\varepsilon_d} q_n - p\frac{\frac{1}{\varepsilon_d}+1}{Q} q_n + \frac{\partial C_n'}{\partial (Q/N)}\frac{(1+\tau)Q\varepsilon_d}{N} > 0
\end{aligned} \tag{39}$$

After summing up the second inequality for all n, the second order condition (39) becomes

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

Dividing the first two terms by the left-hand side of the firm FOC (38) and the third term by the right-hand side of the same FOC yields a useful inequality.

$$1-\left(\frac{\varepsilon_d'}{\varepsilon_d}Q+1\right)\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}>0 \tag{40}$$

To obtain an expression for the pass-through, we take the derivative of the above equation (38) with respect to τ.

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

We then use the definition of the supply elasticity and the firm FOC (37) to obtain

$$\gamma=\frac{1}{1-\frac{Q\varepsilon_d'}{\varepsilon_d}\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}} \tag{41}$$

The firm SOC (40) 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 (38).

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

Using the firm FOC (38), 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

$$\frac{\partial Q}{\partial N}\frac{N}{Q}=\frac{1-\frac{N}{N-\frac{1}{\varepsilon_d}}-\frac{1}{\varepsilon_s}}{-\frac{1}{\varepsilon_d}+\frac{Q\varepsilon'_d}{\varepsilon_d^2}\frac{1}{N-\frac{1}{\varepsilon_d}}-\frac{1}{\varepsilon_s}}=\frac{\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}}{1-\frac{Q\varepsilon'_d}{\varepsilon_d}\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}} \tag{42}$$

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

$$\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)}=\frac{\partial Q}{\partial N}\frac{N}{Q}-1=\frac{\left(\frac{Q\varepsilon'_d}{\varepsilon_d}+1\right)\frac{1}{N-\frac{1}{\varepsilon_d}}-1}{1-\frac{Q\varepsilon'_d}{\varepsilon_d}\frac{1}{N-\frac{1}{\varepsilon_d}}+\frac{\varepsilon_d}{\varepsilon_s}} \tag{43}$$

Finally, we can take the derivative of the pass-through (equation (41)) with respect to N

$$\frac{\partial\gamma}{\partial N}\frac{N}{\gamma}=\frac{Q\varepsilon'_d\varepsilon_d\gamma N}{(N\varepsilon_d-1)^2}-\frac{(Q\varepsilon'_d+Q^2\varepsilon''_d)(N\varepsilon_d-1)-(Q\varepsilon'_d)^2}{(N\varepsilon_d-1)^2}\gamma\frac{\partial Q}{\partial N}\frac{N}{Q}-\frac{Q\varepsilon'_d}{\varepsilon_s}\gamma\frac{\partial Q}{\partial N}\frac{N}{Q}+\frac{Q\varepsilon'_s}{N}\frac{\varepsilon_d}{\varepsilon_s^2}\gamma\frac{\partial(Q/N)}{\partial N}\frac{N}{(Q/N)} \tag{44}$$

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 simplify 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 (39) 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**.[3]

Pass-through variation with constant elasticity of substitution . In the CES case, we again derive how VAT pass-through varies with the substitution elasticity parameter β.

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

We simplify the following equations:

$$
\begin{aligned}
p &= N\bar{C}'\tfrac{(1+\tau)}{(N-\beta)} && (simplified\ equation\ 38) && (45)\\
0 &< 1-\tfrac{1}{N-\beta}+\tfrac{1}{\beta\varepsilon_s} && (simplified\ equation\ 40) && (46)\\
\gamma &= \tfrac{1}{1+\frac{1}{\beta\varepsilon_s}} && (simplified\ equation\ 41) && (47)
\end{aligned}
$$

We then examine the variation of quantities with respect to β by taking the derivative of the firm FOC (45).

$$
\begin{aligned}
& \frac{\partial p}{\partial Q}\frac{\partial Q}{\partial \beta}(N-\beta)-p = N(1+\tau)\bar{C}''\frac{\partial(Q/N)}{\partial\beta}\\
\Leftrightarrow\quad & -\frac{p}{\varepsilon_d Q}\frac{\partial Q}{\partial\beta}(N-\beta)-p=(1+\tau)\frac{\bar{C}'}{\varepsilon_s Q/N}\frac{\partial Q}{\partial\beta}\\
\Leftrightarrow\quad & \frac{\partial Q}{\partial\beta}\frac{\beta}{Q}=\frac{-p}{\frac{(1+\tau)\bar{C}'}{\varepsilon_s Q/N}(Q/\beta)+p(N-\beta)}
\end{aligned}
$$

Using the firm FOC (45), we can simplify the right-hand side of the above. After rearranging terms, we get

$$
\frac{\partial Q}{\partial\beta}\frac{\beta}{Q}=\frac{\partial(Q/N)}{\partial\beta}\frac{\beta}{Q/N}=\frac{-1}{(N-\beta)\left(\frac{1}{\beta\varepsilon_s}+1\right)} \tag{48}
$$

We additionally use inequality (46) and the assumption that $N>\beta$ to obtain that $0<\frac{1}{N-\beta}<\frac{1}{\frac{1}{\beta\varepsilon_s}+1}$ showing that both total quantity Q and average firm quantity Q/N increase when products become closer substitutes (when $\varepsilon_d=1/\beta$ increases).

Finally, we can take the derivative of the pass-through (equation (47)) with respect to $1/\beta$ (we use the inverse of β to facilitate interpretation as the elasticity of substitution increases when it increases).

$$
\begin{aligned}
\frac{\partial\gamma}{\partial(1/\beta)}\frac{(1/\beta)}{\gamma}=\frac{\partial\ln\gamma}{\partial\ln(1/\beta)} &= -\frac{\partial\ln\gamma}{\partial\ln\beta}=-\frac{-1}{1+\frac{1}{\beta^2\varepsilon_s}}\left(-\frac{1}{\beta\varepsilon_s}-\frac{1}{\beta}\frac{\varepsilon_s'}{\varepsilon_s^2}\frac{\partial(Q/N)}{\partial\beta}\right)\beta\\
&= \frac{\gamma}{\beta\varepsilon_s^2}\left((Q/N)\varepsilon_s'\left[-\frac{\partial(Q/N)}{\partial\beta}\frac{\beta}{Q/N}\right]-\varepsilon_s\right)
\end{aligned} \tag{49}
$$

We know from equation (48) that the term in square bracket is positive. Therefore, $\frac{\partial\gamma}{\partial(1/\beta)}\frac{(1/\beta)}{\gamma}$ is negative if and only if $(Q/N)\varepsilon_s' < \varepsilon_s\left[-\frac{\partial(Q/N)}{\partial\beta}\frac{\beta}{Q/N}\right]^{-1}$ or equivalently if and only if $(Q/N)\varepsilon_s' < (N-\beta)(\varepsilon_s + 1/\beta)$. As in the case of monopolistic competition, this condition is satisfied when the cost function is weakly increasing and convex ($\varepsilon_s \geq 0$ and $\varepsilon_s' \leq 0$ with at least one strict inequality), a case of increasing marginal costs. Conversely, it can be violated with increasing returns to scale when $\varepsilon_s \geq 0$ and ε_s' is positive and large enough.

In the case of linear marginal costs, $\frac{\partial\gamma}{\partial(1/\beta)}\frac{(1/\beta)}{\gamma}$ is negative if and only if $-\frac{c}{b(Q/N)} < (N-\beta)\frac{c+b(Q/N)(1+1/\beta)}{b(Q/N)}$ which is equivalent to $-(N+1-\beta)\frac{c}{b(Q/N)} < (N-\beta)(1+1/\beta)$ and $\frac{1}{b} > -\frac{(N-\beta)(1+1/\beta)(Q/N)}{(N+1-\beta)c}$. Put simply, the VAT passs-through increases with the elasticity of substitution if and only if $\frac{1}{b} > \frac{1}{b_0}$ with $b_0 \equiv -\frac{(N+1-\beta)c}{(N-\beta)(1+1/\beta)(Q/N)}$, which is true when $b > 0$.

The intuition behind this result is as before. Lower demand resulting from higher taxes induces producers to scale back production. With increasing marginal costs ($\varepsilon_s' > 0$ or $b > 0$), a reduction in scale implies some savings on production costs which, in turn, allows for lower producer prices.[4] In this case, greater competition via a larger elasticity of substitution amplifies producer costs adjustment because each firm is producing more $\left(\frac{\partial q}{\partial\sigma}\frac{\sigma}{q} > 0\right)$. When the elasticity of substitution is high, firms have stretched production capacities and a reduction in scale yields large savings. When the elasticity of substitution is low, firms are small, and savings from scaling down are smaller and producers are less able to lower their prices in compensation for higher VAT. Therefore, a greater elasticity of substitution with increasing marginal costs implies a lower pass-through.

Pass-through variation with N with a variable elasticity of substitution. In what follows, we do not assume a specific functional form for the utility function any more and assume ε_d' can differ from zero. Nevertheless, the FOC (22) and all the above calculations based on the unspecified elasticity of demand ε_d are still valid. We maintain the assumption that $\varepsilon > 1$.

[4]This can be seen because $\gamma < 1$ when $\varepsilon_s > 0$.

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

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

$\boldsymbol{Q\varepsilon'_d}$	$\boldsymbol{\epsilon_1}$	$\boldsymbol{0}$		$\boldsymbol{\epsilon_2}$		**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 $-\varepsilon'_s\frac{Q\varepsilon_d}{\varepsilon_s^2} > \left(\frac{g[Q\varepsilon'_d]}{(\varepsilon_d-1)^2} - \frac{q\varepsilon'_d}{\varepsilon_s}\right) - \frac{Q\varepsilon'_d\varepsilon_d\gamma N}{(N\varepsilon_d-1)^2}\left(\frac{\frac{N}{(Q/N)}}{\frac{\partial(Q/N)}{\partial N}}\right)$			?		$\times$

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.*

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 (44) depending on $Q\varepsilon'_d$. The SOC (40) 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 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 ε'_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 (44) depending on $Q\varepsilon_d'$. The SOC (40) 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 ε_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 ε_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 generalizes the results in **proposition 1**.

C. 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, 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 (35) 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 (36). 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:

$$\widetilde{p}_F \;=\; p_I\frac{\partial Q_I}{\partial Q_F} = p_I f' = p_I d Q_F^{\frac{\rho}{1-\rho}} \tag{50}$$

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 (50) 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

$$\widetilde{p}_I + \frac{\partial \widetilde{p}_I}{\partial q_{I,n}} q_{I,n} - c_n - b q_{I,n} = 0 \tag{51}$$

Summing (51) across firms and noting that $\widetilde{p}_I = p_I$ yield

$$\left(N - \frac{1}{\varepsilon_{dI}}\right) p_I = \sum_n \left(c_n + b\frac{Q_I}{N}\right) = 0$$
$$\left(N - \frac{1}{\varepsilon_{dI}}\right) \frac{p_F}{f'} = (1+\tau) N \bar{C}' \tag{52}$$

where the function $\bar{C}'(.)$ is defined as before as in equation (38). 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.[5]

$$\varepsilon_{dI} \equiv -\frac{\partial Q_I}{\partial p_I}\frac{p_I}{Q_I} = \varepsilon_f \varepsilon_{sF} \tag{53}$$

where $\varepsilon_f \equiv \left(\frac{\partial Q_F}{\partial Q_I}\frac{Q_I}{Q_F}\right)^{-1} = \frac{Q_F f'}{f}$ is the inverse elasticity of the production function and is always 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.

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

[5]To prove this, it is convenient to obtain the derivative of the input price with respect to quantity using the FOC (50): $\frac{\partial p_I}{\partial Q_I} = \widetilde{p}_F \frac{\partial^2 Q_F}{\partial Q_I^2} = \frac{p_I}{\frac{\partial Q_F}{\partial Q_I}}\frac{\partial^2 Q_F}{\partial Q_I^2}$. 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 $\varepsilon_{dI} \equiv -\left(\frac{\partial p_I}{\partial Q_I}\right)^{-1}\frac{p_I}{Q_I} = -\frac{1}{Q_I}\frac{\partial Q_F}{\partial Q_I}\left(\frac{\partial^2 Q_F}{\partial Q_I^2}\right)^{-1} = \frac{\varepsilon_{sF}}{\frac{\partial Q_F}{\partial Q_I}\frac{Q_I}{Q_F}}$.

We sum across all n and use the same steps as in the single-sector case in equations (39) and (40) to rewrite the SOC into

$$1-\left(\frac{\varepsilon'_{dI}}{\varepsilon_{dI}}Q_I+1\right)\frac{1}{N-\frac{1}{\varepsilon_{dI}}}+\frac{\varepsilon_{dI}}{\varepsilon_{sI}}>0 \tag{54}$$

To obtain an expression for the pass-through, we take the derivative of the above equation (52) with respect to τ and use the notation $\varepsilon'_{dI}=\partial\varepsilon_{dI}/\partial Q_I$. We get

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

We then use the definition of the supply elasticity and the firm FOC (52) to obtain

$$\gamma_F=\frac{1}{1+\frac{Q_Ff''}{f'}\varepsilon_{dF}-\frac{Q_F\varepsilon'_{dI}}{\varepsilon_{dI}^2}\frac{\varepsilon_{dF}f'}{N-\frac{1}{\varepsilon_{dI}}}+\varepsilon_{dF}\frac{Q_Ff'}{Q_I\varepsilon_{sI}}}=\frac{1}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}}{\varepsilon_{dI}^2}\frac{\varepsilon_f}{N-\frac{1}{\varepsilon_{dI}}}\right)} \tag{55}$$

Once again, the firm SOC (54) 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 (52).

$$\frac{\partial p_F}{\partial Q_F}\frac{\partial Q_F}{\partial N}\left(N-\frac{1}{\varepsilon_{dI}}\right)\frac{1}{f'}+\frac{p_F}{f'}-\left(N-\frac{1}{\varepsilon_{dI}}\right)\frac{p_Ff''}{f'^2}\frac{\partial Q_F}{\partial N}+\frac{\varepsilon'_{dI}}{\varepsilon_{dI}}\frac{\partial Q_I}{\partial Q_F}\frac{\partial Q_F}{\partial N}\frac{p_F}{f'}=(1+\tau)\bar{C}'+N(1+\tau)\bar{C}''\frac{\partial(Q_I/N)}{\partial N}$$
$$\Leftrightarrow-\frac{\partial Q_F}{\partial N}\frac{\left(N-\frac{1}{\varepsilon_{dI}}\right)p_F}{f'\varepsilon_{dF}Q_F}+\frac{p_F}{f'}-\left(N-\frac{1}{\varepsilon_{dI}}\right)\frac{p_Ff''}{f'^2}\frac{\partial Q_F}{\partial N}+\frac{\varepsilon'_{dI}}{\varepsilon_{dI}}\frac{\partial Q_F}{\partial N}p_F=(1+\tau)\bar{C}'+(1+\tau)\bar{C}''f'\frac{\partial Q_F}{\partial N}-(1+\tau)\bar{C}''\frac{f}{N}$$
$$\frac{\partial Q_F}{\partial N}\frac{N}{Q_F}=\frac{1-\frac{1}{\varepsilon_{sI}}-\frac{N}{N-\frac{1}{\varepsilon_{dI}}}}{-\frac{1}{\varepsilon_{dF}}-\frac{Q_Ff''}{f'}+\frac{\varepsilon'_{dI}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}Q_Ff'-\frac{\varepsilon_f}{\varepsilon_{sI}}}$$
$$\frac{\partial Q_F}{\partial N}\frac{N}{Q_F}=\frac{\frac{\varepsilon_{dF}}{\varepsilon_{sI}}+\frac{\varepsilon_{dF}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(N-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \tag{56}$$
$$\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)}=\frac{\partial Q_I}{\partial N}\frac{1}{N}\frac{N}{(Q_I/N)}-\frac{Q_I}{N^2}\frac{N}{(Q_I/N)}=\varepsilon_f\frac{\partial Q_F}{\partial N}\frac{N}{Q_F}-1$$
$$\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)}=\frac{\varepsilon_{dF}\left(\frac{\varepsilon_f}{\varepsilon_{sI}}+\frac{1}{\varepsilon_{sF}}\frac{1}{N-\frac{1}{\varepsilon_{dI}}}\right)-1-\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}\varepsilon_f\right)}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}/\varepsilon_{dI}}{N-\frac{1}{\varepsilon_{dI}}}\varepsilon_f\right)}$$
$$\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)}=\frac{-1-\frac{\varepsilon_{dF}}{\varepsilon_{sF}}\left(1-\frac{1+Q_I\varepsilon'_{dI}}{N-\frac{1}{\varepsilon_{dI}}}\right)}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{Q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(N-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \tag{57}$$

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 (55) and (57), and obtain the derivative of the pass-through with respect to N.

$$\frac{\partial(Q_I/N)}{\partial N}\frac{N}{(Q_I/N)} = \frac{-1-\frac{\varepsilon_{dF}}{\varepsilon_{sF}}\left(1-\frac{1}{N-\frac{1}{\varepsilon_{dI}}}\right)}{1+\frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} \tag{58}$$

$$\gamma_F = \frac{1}{1+\frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} \tag{59}$$

$$\frac{\partial\gamma_F}{\partial N}\frac{N}{\gamma_F} = \varepsilon'_{sI}\frac{\partial(Q_I/N)}{\partial N}\frac{\varepsilon_{dF}\varepsilon_f}{\widetilde{\varepsilon}_s^2}\gamma_F N \tag{60}$$

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 ε_f, ε_{sF}, and ε_{dF} are all positive. The SOC (54) additionally implies that $1 + \varepsilon_{dF}/\widetilde{\varepsilon}_s > 0$. 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**.

D. 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 (35) 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 maximizes profits after internalizing their impact on demand from the final good producer and we get the same first order condition

$$p_I \left(1 - \frac{1}{\varepsilon_{dI}}\right) = C' \tag{61}$$

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 (53) 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

$$1 - \frac{q_I \varepsilon'_{dI}}{\varepsilon_{dI}} \frac{1}{\left(1 - \frac{1}{\varepsilon_{dI}}\right)} + \frac{\varepsilon_{dI}}{\varepsilon_{sI}} > 0 \tag{62}$$

To find an expression for the pass-through, we take the derivative of equation (61) with respect to τ 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

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

We then use the definition of the supply elasticity and the firm FOC (61) to obtain

$$\gamma_F = \frac{1}{1 + \varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}} + \frac{\varepsilon_f}{\varepsilon_{sI}} - \frac{q_I \varepsilon'_{dI}}{\varepsilon_{dI}^2}\frac{\varepsilon_f}{1 - \frac{1}{\varepsilon_{dI}}}\right)} \tag{63}$$

This pass-through follows a similar expression as under Cournot competition (equation 55). Once again, the input producer SOC (62) implies that the pass-through is positive.

We obtain the derivative of quantities with respect to N using the FOC (61) and the relation between aggregate input and varieties $\left(q_I = Q_I N^{\frac{-\sigma}{\sigma-1}}\right)$.

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

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

$$\frac{\partial Q_F}{\partial N}\frac{N}{Q_F} = \frac{\frac{\sigma}{\sigma-1}\frac{\varepsilon_{dF}}{\varepsilon_{sI}}+\frac{1}{\sigma-1}}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(1-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \tag{64}$$

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

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

$$\frac{\partial q_I}{\partial N}\frac{N}{q_I} = \frac{\frac{1}{\sigma-1}\varepsilon_f-\frac{\sigma}{\sigma-1}-\frac{\sigma}{\sigma-1}\frac{\varepsilon_{dF}}{\varepsilon_{sF}}\left(1-\frac{q_I\varepsilon'_{dI}}{1-\frac{1}{\varepsilon_{dI}}}\right)}{1+\varepsilon_{dF}\left(\frac{1}{\varepsilon_{sF}}+\frac{\varepsilon_f}{\varepsilon_{sI}}-\frac{q_I\varepsilon'_{dI}}{\varepsilon_{dI}\left(1-\frac{1}{\varepsilon_{dI}}\right)}\varepsilon_f\right)} \tag{65}$$

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 (55) and (57), and obtain the derivative of the pass-through with respect to N.

$$\frac{\partial q_I}{\partial N}\frac{N}{q_I} = \frac{-\frac{\sigma}{\sigma-1}\left(1+\frac{\varepsilon_{dF}}{\varepsilon_{sF}}-\frac{\varepsilon_f}{\sigma}\right)}{1+\frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} = \frac{-\frac{\sigma}{\sigma-1}\left(\frac{\frac{\sigma-1}{\sigma}+\rho\left(\frac{1}{\beta}-1\right)}{1-\rho}\right)}{1+\frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} \tag{66}$$

$$\gamma_F = \frac{1}{1+\frac{\varepsilon_{dF}}{\widetilde{\varepsilon}_s}} \tag{67}$$

$$\frac{\partial\gamma_F}{\partial N}\frac{N}{\gamma_F} = \varepsilon'_{sI}\frac{\partial q_I}{\partial N}\frac{\varepsilon_{dF}\varepsilon_f}{\widetilde{\varepsilon}_s^2}\gamma_F N \tag{68}$$

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 ε_f, ε_{sF}, and ε_{dF} are all positive. The SOC (62) 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**.

E. 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 λ_n that provides her with the highest indirect utility

$$V_{nk} = \delta_n + \xi_{nk}, \qquad \text{with } \delta_n \equiv \left(\theta\lambda_n^{\psi} - p_n^{\psi}\right)^{1/\psi} \qquad \text{and } \psi < 1 \tag{8}$$

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 θ 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 (8) through the consumer-variety-specific term, ξ_{nk}. Following standard practice in the discrete choice literature, ξ_{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 δ_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.

$$\max_{\widetilde{p}_n, \lambda_n} \left[\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right] \frac{e^{\delta_n}}{\sum_m e^{\delta_m}} \tag{69}$$

The two first order conditions are

$$0 = e^{\delta_n} - \left(\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right)(1+\tau)^{\psi}\widetilde{p}_n^{\psi-1}\left(\theta\lambda_n^{\psi} - (\widetilde{p}_n(1+\tau))^{\psi}\right)^{\frac{1-\psi}{\psi}} e^{\delta_n} \tag{70}$$

$$0 = -\frac{1}{Z}e^{\delta_n} + \left(\widetilde{p}_n - w - \frac{\lambda_n}{Z}\right)\theta\lambda_n^{\psi-1}\left(\theta\lambda_n^{\psi} - (\widetilde{p}_n(1+\tau))^{\psi}\right)^{\frac{1-\psi}{\psi}} e^{\delta_n} \tag{71}$$

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

$$\lambda_n^{1-\psi} = \frac{\theta Z}{(1+\tau)^{\psi}}\widetilde{p}_n^{1-\psi} \tag{72}$$

$$\begin{aligned}\delta_n &= \left(\theta\left(\frac{\theta Z}{(1+\tau)^{\psi}}\right)^{\frac{\psi}{1-\psi}}\widetilde{p}_n^{\psi} - (\widetilde{p}_n(1+\tau))^{\psi}\right)^{\frac{1}{\psi}} \\ &= \left(\theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}}(1+\tau)^{\frac{\psi}{\psi-1}} - 1\right)^{\frac{1}{\psi}}(1+\tau)\widetilde{p}_n \end{aligned}\tag{73}$$

We solve for prices by substituting quality and mean valuation using equations (72) and (73) in the first order condition (70).

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

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

$$\widetilde{p}_n = w\left(1 - \theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}}(1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-1} + \frac{1}{(1+\tau)}\left(1 - \theta^{\frac{1}{1-\psi}} Z^{\frac{\psi}{1-\psi}}(1+\tau)^{\frac{\psi}{\psi-1}}\right)^{-\frac{1}{\psi}} \tag{74}$$

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 (74) 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}}} \qquad (10)
\end{aligned}
$$

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

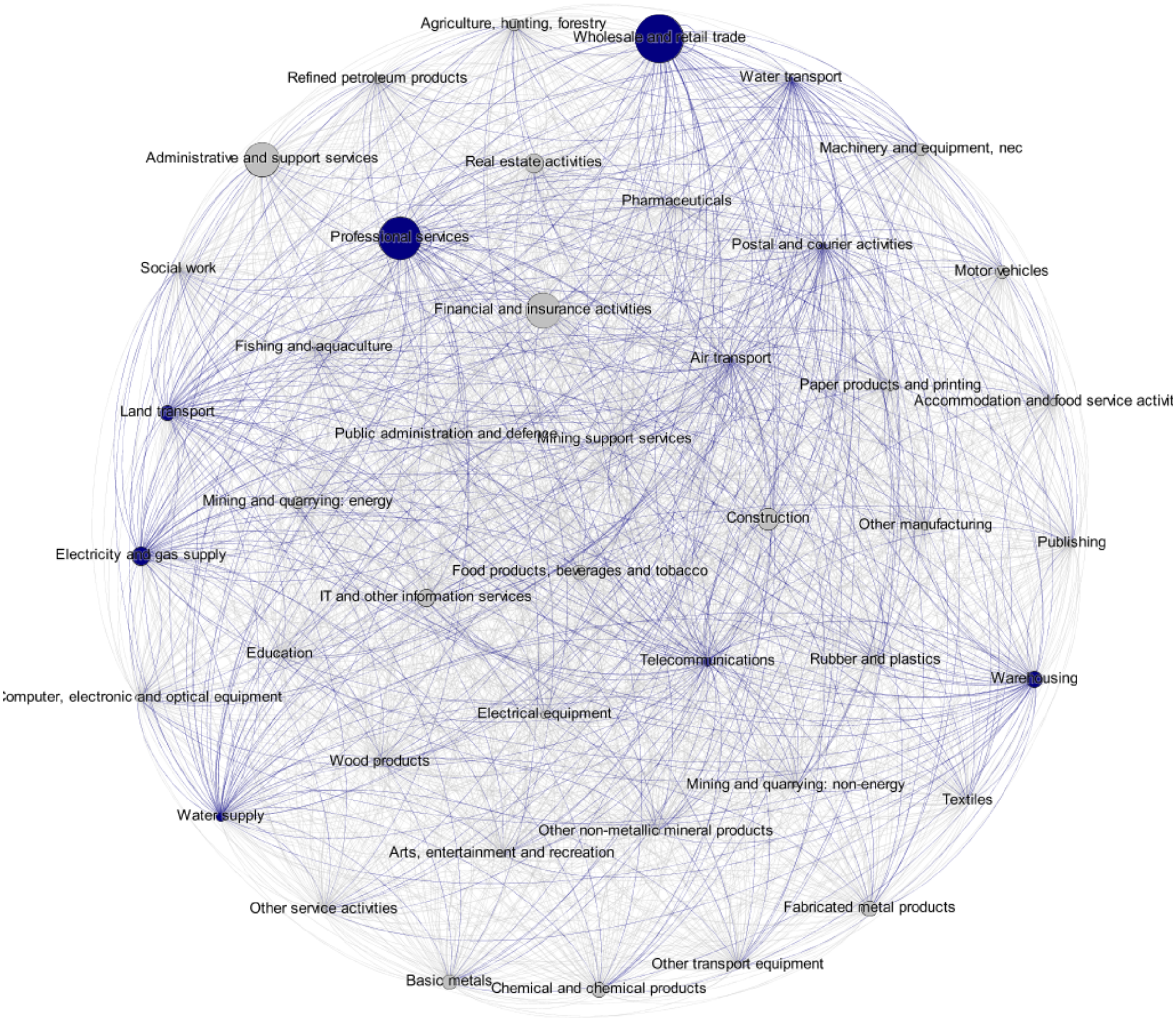
$$
\begin{aligned}
\frac{\partial \gamma}{\partial \theta} = & -\frac{\psi}{(1-\psi)^2} Z^{\frac{\psi}{\psi-1}} \theta^{\frac{1}{1-\psi}-1} (1+\tau)^{\frac{\psi}{1-\psi}} \left(\theta^{\frac{1}{\psi-1}} Z^{\frac{\psi}{\psi-1}} (1+\tau)^{\frac{\psi}{1-\psi}} - 1\right)^{-2} \\
& - \frac{\frac{\theta^{\frac{\psi}{1-\psi}}}{1-\psi} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} \left[1+\frac{w(1+\tau)}{\psi} \left(1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1}{\psi}-1}\right]}{\left[1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}} + w(1+\tau) \left(1-\theta^{\frac{1}{1-\psi}} \left(\frac{Z}{1+\tau}\right)^{\frac{\psi}{1-\psi}}\right)^{\frac{1}{\psi}}\right]^2}
\end{aligned}
\qquad (75)
$$

When $0 < \psi < 1$, the above is negative. When $\psi < 0$, the above is positive when ψ 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.

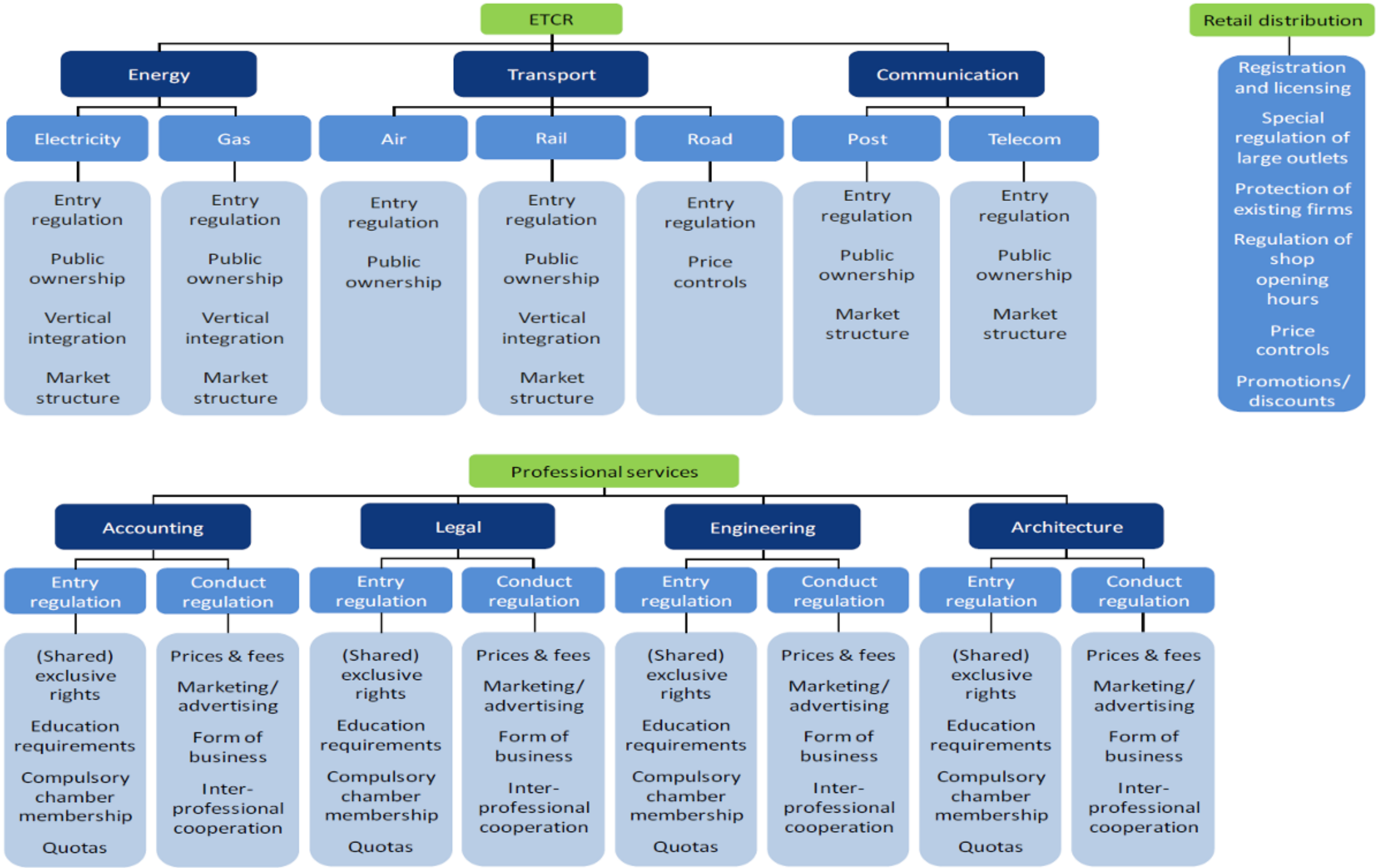
B. EMPIRICAL APPENDIX

FIGURE B.1: Upstream non-manufacturing sectors



Notes: This graph shows, in blue, the key upstream non-manufacturing sectors 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 (2021a).

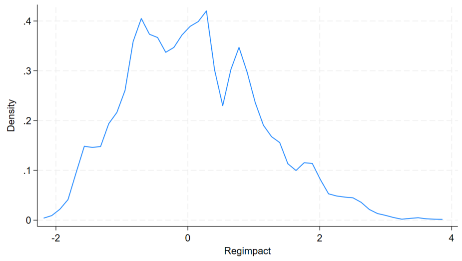
FIGURE B.2: Upstream sectors included in *Regimpact* indicator, and the categories upon which they are scored



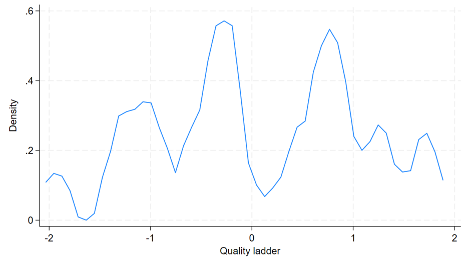
Notes: The *Regimpact* measure is the average score of the pro-competitiveness of regulation in the upstream services sectors (shown above), weighted by the proportions in which they are used in a given market (from input-output tables). For example, one question used for 'entry regulation' in the electricity sector is: "What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier?" (Conway and 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 and Wanner (2016)

Figure B.3: Distribution of main explanatory variables

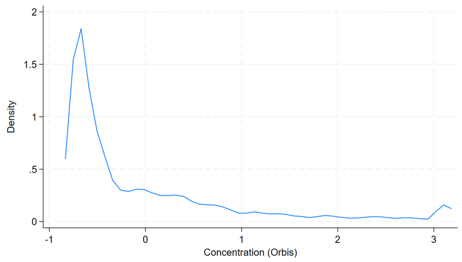
(a) *Regimpact*



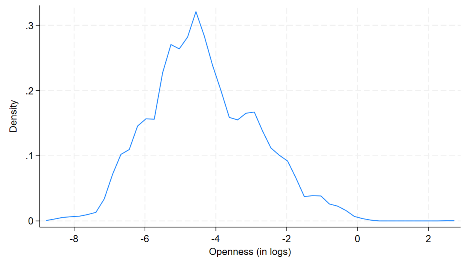
(b) Quality ladder



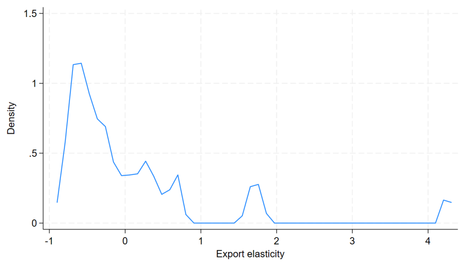
(c) Concentration



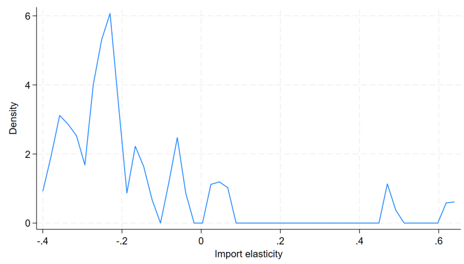
(d) Openness (in logs)



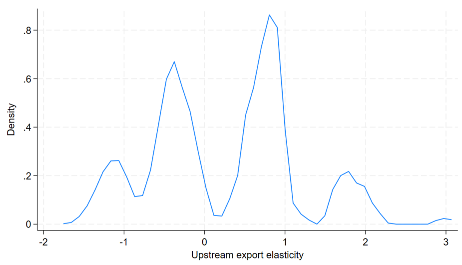
(e) Export elasticity



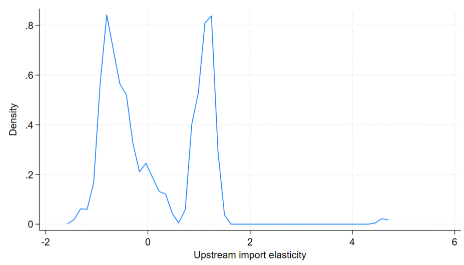
(f) Import elasticity



(g) Upstream export elasticity



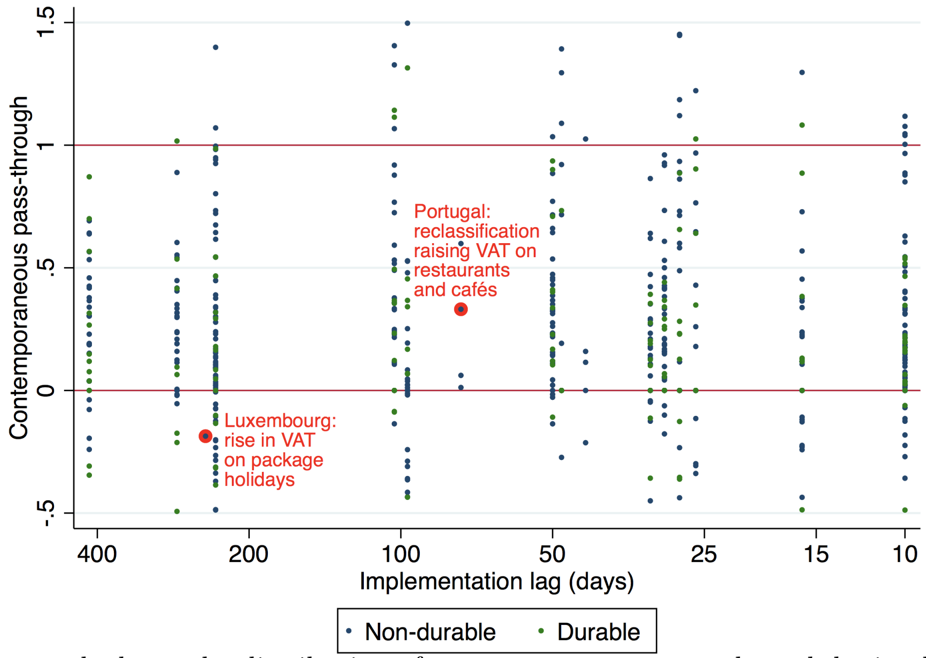
(h) Upstream import elasticity



Notes: These graphs show the kernel densities of the main explanatory variables used in the paper (from left to right, and top to bottom): *Regimpact*, quality ladder, concentration (HHIs from Orbis), openness (in logs), export elasticity, import elasticity, upstream export elasticity, and upstream import elasticity. The openness variable is log-tranformed and standardized to show variation (around 25 percent are zeros). We drop one outlier product category (meat, constituting approximately 3 percent of the sample) from the import elasticity measure.

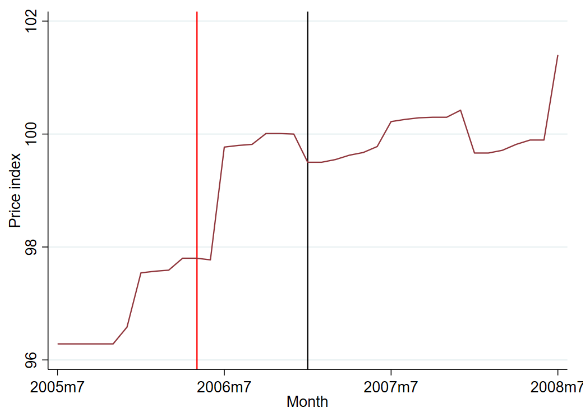
Figure B.4: Heterogeneity in announcement effects

(a) Heterogeneity of pass-through by implementation lag

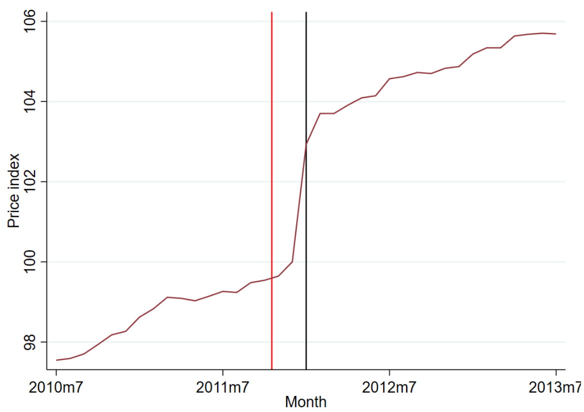


Notes: This graph shows the distribution of contemporaneous pass-through by implementation lag, across reforms for which announcement date data is available. The vertical spread illustrates the substantial heterogeneity in pass-through, even after controlling for implementation lags. The two reform episodes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

(b) Possible announcement effect: Package holidays in Luxembourg

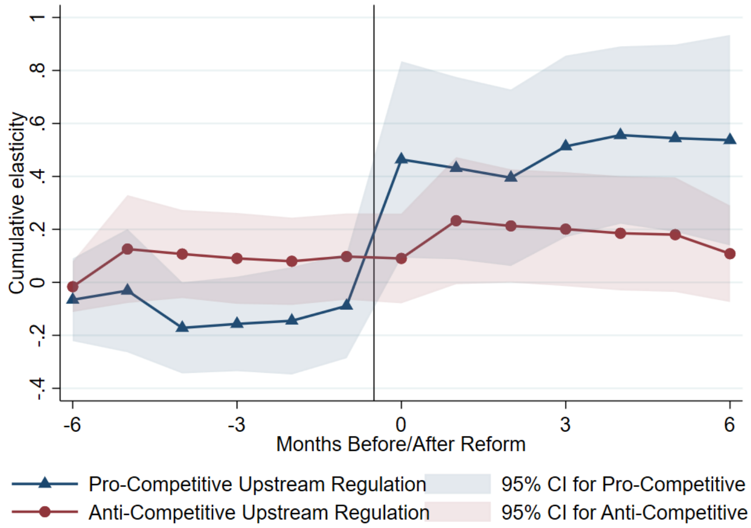


(c) No announcement effect: Restaurants and cafés in Portugal



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.

FIGURE B.5: Cumulative effects of upstream regulation on pass-through (non-early announced)

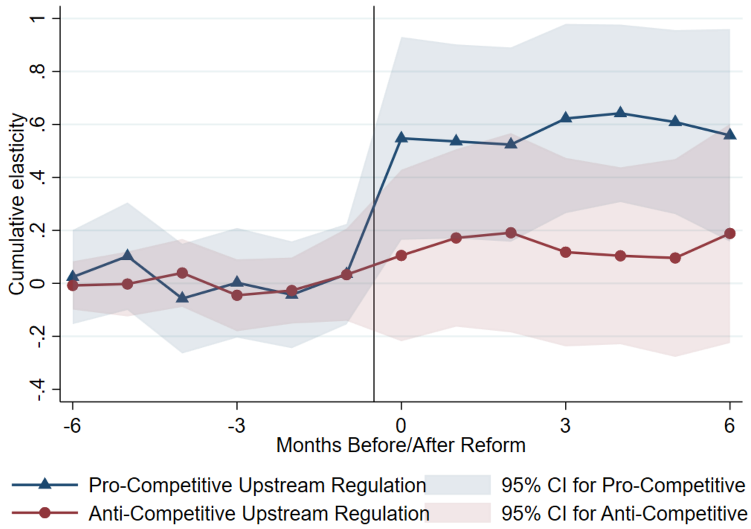


Notes: This graph shows cumulative pass-through for country-products with upstream regulation that is relatively supportive or constraining of competition, following our baseline specification (equation 16) with controls for downstream market competitiveness. The blue (red) line shows cumulative pass-through in a country-product pair with regulation that is exactly one standard deviation more (less) competition-friendly. Reforms that were announced more than a month in advance are excluded.

FIGURE B.6: Cumulative effect of longer and shorter quality ladders on pass-through (non-early announced)

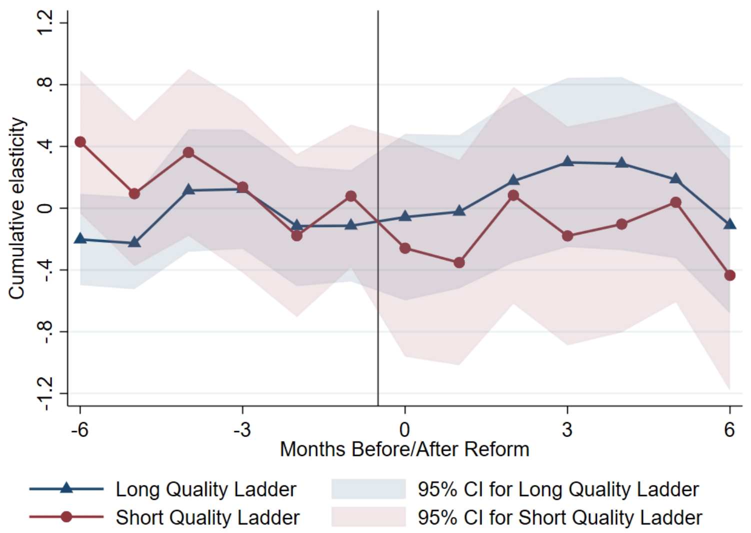
Notes: This graph shows cumulative pass-through for products with higher or lower scope for quality differentiation, controlling for downstream market competitiveness as in Column (6) in Table 4. The blue (red) line shows cumulative pass-through in a country-product pair with a quality ladder that is exactly one standard deviation longer (shorter) than the mean. Reforms that were announced more than a month in advance are excluded.

FIGURE B.7: Cumulative effects of upstream regulation on pass-through (non-durable products only)



Notes: This graph shows cumulative pass-through for country-products with upstream regulation that is relatively supportive or constraining of competition, following our baseline specification (equation 16) with controls for downstream market competitiveness. The blue (red) line shows cumulative pass-through in a country-product pair with regulation that is exactly one standard deviation more (less) competition-friendly.

FIGURE B.8: Cumulative effect of longer and shorter quality ladders on pass-through (non-durable products only)



Notes: This graph shows cumulative pass-through for products with higher or lower scope for quality differentiation, controlling for downstream market competitiveness as in Column (6) in Table 4. The blue (red) line shows 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.1: 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.2: Summary statistics for main variables

Variable	Obs	Mean	S.D.	Min	Max
Δ ln(Price)	105,527	.001	.024	-.414	.415
Δ ln(1 + 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

Table B.3: VAT changes for which announcement dates are observed

		Obs	Mean	S.D.	Min	Max
VAT changes	All	561	0.01	0.02	-0.15	0.17
	Standard	485	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	100	-0.01	0.02	-0.15	-0.01
	VAT increase	461	0.02	0.01	0.01	0.17

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

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.074	0.027	0.051	0.105	0.172	0.121
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.070)	(0.054)	(0.065)	(0.102)	(0.167)	(0.103)
	Contemporaneous	0.120	0.259***	0.283***	0.095	-0.283	0.029
	– i.e. β_{10}	(0.111)	(0.080)	(0.083)	(0.107)	(0.198)	(0.109)
	Post-Reform	0.019	0.027	0.034	-0.050	-0.105	-0.076
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.058)	(0.073)	(0.073)	(0.080)	(0.067)	(0.086)
	Total	0.213**	0.312***	0.367***	0.150	-0.217	0.074
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.104)	(0.101)	(0.121)	(0.170)	(0.170)	(0.175)
Regimpact:	Pre-Reform		0.066	0.082	0.124		0.122
			(0.060)	(0.066)	(0.130)		(0.132)
	Contemporaneous		-0.225***	-0.252***	-0.349***		-0.412***
			(0.070)	(0.072)	(0.127)		(0.117)
	Post-Reform		-0.012	-0.024	-0.017		-0.043
			(0.040)	(0.048)	(0.057)		(0.055)
	Total		-0.171**	-0.193**	-0.241		-0.334**
			(0.081)	(0.091)	(0.162)		(0.154)
QualityLadder:	Pre-Reform					0.043	-0.058
						(0.123)	(0.101)
	Contemporaneous					0.051	0.253**
						(0.147)	(0.115)
	Post-Reform					0.086	0.095
						(0.083)	(0.094)
	Total					0.180	0.291
						(0.200)	(0.181)
Openness:	Total			-0.292	-0.801		-0.822
				(0.405)	(0.751)		(0.740)
Concentration:	Total			0.228	0.345		0.265
				(0.157)	(0.214)		(0.203)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99361	99361	99361	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. 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. * p <0.10, ** p <0.05, *** p <0.01.

Table B.5: Using alternative measure of horizontal concentration

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.074	0.027	0.030	0.008	0.172	0.001
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.070)	(0.054)	(0.053)	(0.118)	(0.167)	(0.123)
	Contemporaneous	0.120	0.259***	0.261***	0.097	-0.283	0.039
	– i.e. β_{10}	(0.111)	(0.080)	(0.076)	(0.130)	(0.198)	(0.123)
	Post-Reform	0.019	0.027	0.031	0.023	-0.105	-0.005
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.058)	(0.073)	(0.072)	(0.082)	(0.067)	(0.092)
	Total	0.213**	0.312***	0.322***	0.128	-0.217	0.035
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.104)	(0.101)	(0.096)	(0.205)	(0.170)	(0.212)
Regimpact:	Pre-Reform		0.066	0.066	0.117		0.097
			(0.060)	(0.061)	(0.120)		(0.120)
	Contemporaneous		-0.225***	-0.229***	-0.347***		-0.412***
			(0.070)	(0.073)	(0.129)		(0.116)
	Post-Reform		-0.012	-0.012	-0.000		-0.036
			(0.040)	(0.044)	(0.058)		(0.059)
	Total		-0.171**	-0.174*	-0.231		-0.351**
			(0.081)	(0.091)	(0.163)		(0.156)
QualityLadder:	Pre-Reform					0.043	-0.009
						(0.123)	(0.108)
	Contemporaneous					0.051	0.250**
						(0.147)	(0.107)
	Post-Reform					0.086	0.119
						(0.083)	(0.091)
	Total					0.180	0.360*
						(0.200)	(0.184)
Openness:	Total			-0.058	-0.469		-0.648
				(0.393)	(0.801)		(0.755)
Concentration:	Total			-0.033	-0.030		-0.030
				(0.114)	(0.204)		(0.175)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99361	99361	99361	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. 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. * p <0.10, ** p <0.05, *** p <0.01.

Table B.6: 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	0.162*	0.176*	0.070	0.186*	0.022
		(0.095)	(0.098)	(0.076)	(0.109)	(0.058)
	Contemporaneous	0.250**	0.220*	0.087	0.369***	0.274***
		(0.106)	(0.117)	(0.134)	(0.102)	(0.104)
	Post-Reform	0.062	0.078	-0.028	0.103	-0.031
		(0.087)	(0.076)	(0.049)	(0.093)	(0.074)
	Total	0.475***	0.474**	0.128	0.659***	0.265**
		(0.165)	(0.209)	(0.114)	(0.195)	(0.117)
Implementation lag:	Pre-Reform	-0.060	-0.063	-0.026	-0.017	0.045
		(0.341)	(0.158)	(0.151)	(0.157)	(0.161)
	Contemporaneous	0.055	0.080	0.135	0.014	0.039
		(0.184)	(0.146)	(0.161)	(0.140)	(0.158)
	Post-Reform	0.241	0.120	0.202	0.171	0.230
		(0.251)	(0.226)	(0.147)	(0.255)	(0.165)
	Total	0.235	0.137	0.311*	0.168	0.314
		(0.452)	(0.350)	(0.178)	(0.318)	(0.194)
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: Standard errors are shown in parentheses. 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. * p <0.10, ** p <0.05, *** p <0.01.

Table B.7: Estimates for reforms announced less than a month in advance

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.036	-0.008	0.004	0.041	0.117	0.015
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.069)	(0.049)	(0.057)	(0.087)	(0.155)	(0.092)
	Contemporaneous	0.097	0.269***	0.273***	0.129	-0.243	0.016
	– i.e. β_{10}	(0.121)	(0.095)	(0.093)	(0.153)	(0.211)	(0.156)
	Post-Reform	0.026	0.039	0.045	0.033	0.010	0.073
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.062)	(0.083)	(0.078)	(0.067)	(0.059)	(0.073)
	Total	0.159	0.299***	0.322***	0.203	-0.115	0.104
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.115)	(0.114)	(0.115)	(0.193)	(0.182)	(0.212)
Regimpact:	Pre-Reform		0.062	0.093	0.045		0.026
			(0.060)	(0.073)	(0.116)		(0.114)
	Contemporaneous		-0.235***	-0.280***	-0.384***		-0.447***
			(0.075)	(0.088)	(0.147)		(0.127)
	Post-Reform		-0.017	-0.028	-0.104*		-0.100*
			(0.044)	(0.054)	(0.057)		(0.059)
	Total		-0.190**	-0.214**	-0.443**		-0.521***
			(0.086)	(0.108)	(0.188)		(0.173)
QualityLadder:	Pre-Reform					0.132	0.102
						(0.152)	(0.131)
	Contemporaneous					-0.029	0.368**
						(0.211)	(0.145)
	Post-Reform					-0.094	-0.092
						(0.084)	(0.100)
	Total					0.009	0.378
						(0.255)	(0.241)
Openness:	Total			-0.208	-1.073		-1.064
				(0.433)	(0.816)		(0.825)
Concentration:	Total			0.103	-0.204		-0.297
				(0.177)	(0.339)		(0.311)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		95670	95670	95670	47006	47006	47006

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

Table B.8: Estimates for non-durable products only

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.005	0.005	0.034	-0.021	0.024	-0.018
	– i.e. $\sum_{j=1}^{6}\beta_{1j}$	(0.057)	(0.058)	(0.066)	(0.182)	(0.129)	(0.182)
	Contemporaneous	0.295***	0.299***	0.293***	-0.141	0.055	-0.141
	– i.e. β_{10}	(0.081)	(0.084)	(0.084)	(0.175)	(0.205)	(0.163)
	Post-Reform	0.062	0.061	0.047	-0.114	-0.040	-0.114
	– i.e. $\sum_{j=-6}^{-1}\beta_{1j}$	(0.081)	(0.084)	(0.078)	(0.177)	(0.099)	(0.178)
	Total	0.362***	0.365***	0.374***	-0.276	0.039	-0.272
	– i.e. $\sum_{j=-6}^{6}\beta_{1j}$	(0.109)	(0.104)	(0.113)	(0.290)	(0.268)	(0.286)
Regimpact:	Pre-Reform		0.012	-0.001	-0.007		-0.005
			(0.053)	(0.065)	(0.084)		(0.082)
	Contemporaneous		-0.175*	-0.220*	-0.536***		-0.544***
			(0.106)	(0.125)	(0.153)		(0.143)
	Post-Reform		0.061	0.036	0.057		0.045
			(0.057)	(0.074)	(0.101)		(0.096)
	Total		-0.101	-0.185	-0.487**		-0.504**
			(0.148)	(0.174)	(0.233)		(0.220)
QualityLadder:	Pre-Reform					-0.116	-0.096
						(0.107)	(0.106)
	Contemporaneous					0.181	0.197*
						(0.120)	(0.115)
	Post-Reform					0.079	0.062
						(0.102)	(0.113)
	Total					0.144	0.163
						(0.166)	(0.180)
Openness:	Total			0.102	0.155		0.164
				(0.615)	(0.323)		(0.326)
Concentration:	Total			0.179	-0.398*		-0.383
				(0.155)	(0.231)		(0.233)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		82328	82328	82328	34192	34192	34192

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

Table B.9: Main results excluding subsequent reforms

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.056	0.015	0.033	0.052	0.157	0.052
	– i.e. $\sum_{j=1}^{6}\beta_{1j}$	(0.077)	(0.058)	(0.061)	(0.129)	(0.172)	(0.131)
	Contemporaneous	0.072	0.247***	0.236**	0.043	-0.386*	-0.166
	– i.e. β_{10}	(0.119)	(0.095)	(0.099)	(0.175)	(0.227)	(0.154)
	Post-Reform	0.035	0.065	0.050	-0.019	0.022	0.016
	– i.e. $\sum_{j=-6}^{-1}\beta_{1j}$	(0.066)	(0.090)	(0.083)	(0.077)	(0.066)	(0.096)
	Total	0.163	0.327***	0.319**	0.076	-0.207	-0.098
	– i.e. $\sum_{j=-6}^{6}\beta_{1j}$	(0.113)	(0.126)	(0.133)	(0.214)	(0.189)	(0.222)
Regimpact:	Pre-Reform		0.068	0.072	0.160		0.161
			(0.061)	(0.073)	(0.129)		(0.129)
	Contemporaneous		-0.225***	-0.248**	-0.293		-0.389***
			(0.075)	(0.101)	(0.180)		(0.140)
	Post-Reform		-0.037	-0.015	-0.054		-0.035
			(0.047)	(0.063)	(0.057)		(0.058)
	Total		-0.194**	-0.191*	-0.186		-0.262
			(0.083)	(0.114)	(0.209)		(0.193)
QualityLadder:	Pre-Reform					-0.003	-0.059
						(0.127)	(0.096)
	Contemporaneous					0.214	0.646***
						(0.257)	(0.152)
	Post-Reform					-0.133	-0.117
						(0.094)	(0.114)
	Total					0.078	0.470**
						(0.257)	(0.227)
Openness:	Total			0.067	-0.453		-0.272
				(0.374)	(0.868)		(0.842)
Concentration:	Total			-0.027	-0.541		-0.650*
				(0.152)	(0.408)		(0.340)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		88851	88851	88851	43385	43385	43385

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. All subsequent reforms are removed (a country-product is restricted to experience at most one VAT reform). * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table B.10: Main results for BCHK specification plus additional fixed effects

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.234**	0.228*	0.239*	0.248	0.242	0.244
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.113)	(0.128)	(0.134)	(0.163)	(0.178)	(0.170)
	Contemporaneous	0.370***	0.450***	0.467***	0.519**	0.305	0.448*
	– i.e. β_{10}	(0.115)	(0.112)	(0.109)	(0.224)	(0.236)	(0.239)
	Post-Reform	0.168*	0.195*	0.231**	0.144	0.108	0.084
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.099)	(0.107)	(0.109)	(0.140)	(0.114)	(0.184)
	Total	0.772***	0.873***	0.938***	0.912***	0.655*	0.776**
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.223)	(0.217)	(0.233)	(0.331)	(0.370)	(0.357)
Regimpact:	Pre-Reform		0.003	-0.032	0.094		0.072
			(0.081)	(0.112)	(0.129)		(0.114)
	Contemporaneous		-0.186***	-0.202**	-0.227		-0.349***
			(0.070)	(0.079)	(0.171)		(0.131)
	Post-Reform		-0.066	-0.094	-0.064		-0.097
			(0.054)	(0.070)	(0.115)		(0.082)
	Total		-0.250*	-0.327**	-0.196		-0.374*
			(0.128)	(0.160)	(0.248)		(0.197)
QualityLadder:	Pre-Reform					0.104	0.026
						(0.171)	(0.144)
	Contemporaneous					0.150	0.416*
						(0.270)	(0.219)
	Post-Reform					-0.012	0.191
						(0.155)	(0.215)
	Total					0.242	0.633*
						(0.389)	(0.380)
Openness:	Total			0.464	0.060		-0.219
				(0.660)	(1.241)		(1.101)
Concentration:	Total			0.513	-0.159		-0.206
				(0.336)	(0.500)		(0.483)
Controls		✓	✓	✓	✓	✓	✓
Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		97998	97998	97998	48281	48281	48281

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Observations are weighted by their share of national consumption. *Regimpact*, openness, market concentration and *QualityLadder* 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. Following BCHK, all specifications include time fixed effects and country-time economic controls (unemployment rates, nominal interest rates, and real GDP growth); we also include country-product fixed effects. Estonia is excluded from the sample as the monthly nominal interest rate (obtained from OECD) is unavailable. * p <0.10, ** p <0.05, *** p <0.01.

Table B.11: Estimates using discrete PMR and Quality variable

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.074	0.040	0.052	0.187	0.284	0.192
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.070)	(0.058)	(0.064)	(0.158)	(0.202)	(0.158)
	Contemporaneous	0.120	0.238***	0.240***	0.037	-0.267	0.038
	– i.e. β_{10}	(0.111)	(0.077)	(0.075)	(0.109)	(0.215)	(0.103)
	Post-Reform	0.019	0.038	0.041	-0.072	-0.068	-0.069
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.058)	(0.073)	(0.071)	(0.082)	(0.042)	(0.082)
	Total	0.213**	0.316***	0.333***	0.151	-0.051	0.161
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.104)	(0.105)	(0.109)	(0.211)	(0.117)	(0.211)
Regimpact:	Pre-Reform		0.063	0.051	0.065		0.088
			(0.106)	(0.119)	(0.238)		(0.243)
	Contemporaneous		-0.351***	-0.378**	-0.517**		-0.532**
			(0.135)	(0.150)	(0.260)		(0.257)
	Post-Reform		-0.052	-0.086	-0.003		-0.011
			(0.074)	(0.096)	(0.141)		(0.142)
	Total		-0.340**	-0.414**	-0.455		-0.456
			(0.158)	(0.187)	(0.326)		(0.323)
QualityLadder:	Pre-Reform					-0.109	-0.081
						(0.133)	(0.127)
	Contemporaneous					0.311	0.329*
						(0.212)	(0.175)
	Post-Reform					0.112	0.057
						(0.116)	(0.136)
	Total					0.314	0.304
						(0.220)	(0.212)
Openness:	Total			-0.195	-0.555		-0.606
				(0.385)	(0.780)		(0.773)
Concentration:	Total			0.163	-0.108		-0.093
				(0.141)	(0.213)		(0.219)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99361	99361	99361	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *RegimpactHML* (*QladdHML*) is a discrete variable taking value 1 if the observation is in the top quartile of the *Regimpact* (*QualityLadder*) 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE B.12: Main results with fixed X_{ikt} using first available observations

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.074	-0.016	-0.005	-0.044	0.172	-0.042
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.070)	(0.059)	(0.058)	(0.101)	(0.167)	(0.102)
	Contemporaneous	0.120	0.374***	0.407***	0.332**	-0.283	0.307***
	– i.e. β_{10}	(0.111)	(0.112)	(0.113)	(0.134)	(0.198)	(0.118)
	Post-Reform	0.019	0.033	0.059	0.000	-0.105	-0.010
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.058)	(0.102)	(0.106)	(0.094)	(0.067)	(0.093)
	Total	0.213**	0.390***	0.461***	0.288	-0.217	0.255
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.104)	(0.133)	(0.143)	(0.227)	(0.170)	(0.210)
Regimpact:	Pre-Reform		0.088	0.077	0.190		0.149
			(0.061)	(0.063)	(0.141)		(0.135)
	Contemporaneous		-0.230***	-0.271***	-0.449***		-0.492***
			(0.079)	(0.082)	(0.130)		(0.116)
	Post-Reform		-0.011	-0.035	-0.043		-0.073
			(0.052)	(0.058)	(0.053)		(0.055)
	Total		-0.153*	-0.228**	-0.303*		-0.416***
			(0.091)	(0.098)	(0.165)		(0.146)
QualityLadder:	Pre-Reform					0.043	0.002
						(0.123)	(0.107)
	Contemporaneous					0.051	0.190*
						(0.147)	(0.111)
	Post-Reform					0.086	0.113
						(0.083)	(0.086)
	Total					0.180	0.304*
						(0.200)	(0.165)
Openness:	Total			-0.274	-0.766*		-0.743*
				(0.191)	(0.445)		(0.443)
Concentration:	Total			0.334**	0.371**		0.341**
				(0.147)	(0.169)		(0.137)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99361	99361	99361	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. Different from our baseline specification, we use the first available values of the standardized *Regimpact*, openness and market concentration variables such that they are not affected by subsequent VAT changes. Pre-Reform, Contemporaneous and Post-Reform effects are also estimated for Openness and Concentration, but are omitted for conciseness. * p <0.10, ** p <0.05, *** p <0.01.

Table B.13: Main results with one-year lagged X_{ikt}

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.074	0.017	0.030	0.028	0.041	0.036
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.070)	(0.054)	(0.057)	(0.112)	(0.120)	(0.118)
	Contemporaneous	0.120	0.282***	0.291***	0.111	0.038	0.075
	– i.e. β_{10}	(0.111)	(0.085)	(0.082)	(0.129)	(0.148)	(0.116)
	Post-Reform	0.019	0.024	0.024	-0.110	-0.135*	-0.144
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.058)	(0.075)	(0.073)	(0.083)	(0.069)	(0.092)
	Total	0.213**	0.323***	0.345***	0.029	-0.055	-0.034
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.104)	(0.106)	(0.106)	(0.187)	(0.209)	(0.188)
Regimpact:	Pre-Reform		0.004	-0.046	0.107		0.120
			(0.055)	(0.084)	(0.158)		(0.149)
	Contemporaneous		-0.231***	-0.262***	-0.373***		-0.414***
			(0.070)	(0.076)	(0.136)		(0.107)
	Post-Reform		-0.016	-0.027	0.029		-0.018
			(0.037)	(0.048)	(0.067)		(0.061)
	Total		-0.244**	-0.336***	-0.237		-0.313*
			(0.097)	(0.120)	(0.219)		(0.186)
QualityLadder:	Pre-Reform					-0.004	-0.029
						(0.114)	(0.103)
	Contemporaneous					0.173	0.239**
						(0.111)	(0.104)
	Post-Reform					0.115	0.173*
						(0.082)	(0.096)
	Total					0.284	0.383**
						(0.189)	(0.179)
Openness:	Total			-0.221	0.170		-0.023
				(0.246)	(0.572)		(0.542)
Concentration:	Total			0.240*	-0.102		-0.091
				(0.146)	(0.175)		(0.171)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99361	95713	95089	46829	46829	46829

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. Different from our baseline specification, we use one-year lags of the standardized *Regimpact*, openness and market concentration variables such that they are not affected by subsequent VAT changes. Pre-Reform, Contemporaneous and Post-Reform effects are also estimated for Openness and Concentration, but are not significant so omitted for conciseness. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.14: Main results with raw price, detrended and de-seasonalized with FEs

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.109	0.055	0.064	0.093	0.147	0.080
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.133)	(0.371)	(0.331)	(0.510)	(0.391)	(0.584)
	Contemporaneous	0.128	0.289***	0.290***	0.091	-0.291	0.044
	– i.e. β_{10}	(0.301)	(0.001)	(0.000)	(0.479)	(0.188)	(0.726)
	Post-Reform	0.052	0.062	0.064	-0.053	-0.057	-0.075
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.418)	(0.447)	(0.411)	(0.497)	(0.432)	(0.409)
	Total	0.289**	0.407***	0.418***	0.130	-0.201	0.049
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.021)	(0.001)	(0.001)	(0.557)	(0.346)	(0.833)
Regimpact:	Pre-Reform		0.068	0.060	0.122		0.086
			(0.270)	(0.415)	(0.352)		(0.501)
	Contemporaneous		-0.254***	-0.292***	-0.386**		-0.435***
			(0.001)	(0.001)	(0.012)		(0.002)
	Post-Reform		-0.022	-0.047	-0.003		-0.042
			(0.599)	(0.395)	(0.966)		(0.537)
	Total		-0.208**	-0.279**	-0.267		-0.390**
			(0.021)	(0.012)	(0.159)		(0.028)
QualityLadder:	Pre-Reform					0.067	0.033
						(0.620)	(0.766)
	Contemporaneous					-0.015	0.191*
						(0.923)	(0.081)
	Post-Reform					0.057	0.117
						(0.531)	(0.273)
	Total					0.109	0.340*
						(0.631)	(0.100)
Openness:	Total			-0.413	-0.476		-0.643
				(0.297)	(0.580)		(0.429)
Concentration:	Total			0.185	-0.096		-0.088
				(0.210)	(0.681)		(0.706)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99360	99360	99360	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Observations are weighted by their share of national consumption. *Regimpact*, openness, market concentration and *QualityLadder* 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. Country-product-trend and country-product-calendar-month FEs are also included, to de-trend and de-seasonalise raw prices. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.15: Main results with raw prices

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.105*	0.072	0.088	0.036	-0.076	0.007
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.056)	(0.064)	(0.067)	(0.136)	(0.139)	(0.146)
	Contemporaneous	0.205**	0.325***	0.311***	0.186	0.066	0.206
	– i.e. β_{10}	(0.092)	(0.093)	(0.091)	(0.153)	(0.128)	(0.170)
	Post-Reform	0.083	0.095	0.102	0.016	0.058	0.028
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.061)	(0.075)	(0.073)	(0.071)	(0.063)	(0.081)
	Total	0.393***	0.492***	0.501***	0.239	0.049	0.241
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.124)	(0.129)	(0.124)	(0.246)	(0.235)	(0.269)
Regimpact:	Pre-Reform		0.036	0.034	0.035		-0.028
			(0.055)	(0.067)	(0.113)		(0.118)
	Contemporaneous		-0.195***	-0.244***	-0.322**		-0.287**
			(0.062)	(0.074)	(0.128)		(0.132)
	Post-Reform		-0.018	-0.051	-0.012		-0.023
			(0.039)	(0.048)	(0.070)		(0.067)
	Total		-0.177*	-0.261**	-0.300		-0.338
			(0.101)	(0.115)	(0.216)		(0.233)
QualityLadder:	Pre-Reform					0.018	0.041
						(0.138)	(0.125)
	Contemporaneous					-0.240	-0.111
						(0.166)	(0.167)
	Post-Reform					-0.060	-0.011
						(0.094)	(0.111)
	Total					-0.282	-0.082
						(0.246)	(0.242)
Openness:	Total			-0.655	-1.552		-1.475
				(0.435)	(1.128)		(1.074)
Concentration:	Total			0.262	0.085		0.110
				(0.171)	(0.276)		(0.273)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		99361	99361	99361	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Observations are weighted by their share of national consumption. *Regimpact*, openness, market concentration and *QualityLadder* 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.16: Including export elasticity as additional measure of downstream competition

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.261**	0.184*	0.162	0.073	0.172	0.065
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.130)	(0.107)	(0.110)	(0.120)	(0.167)	(0.121)
	Contemporaneous	-0.054	0.291**	0.271**	0.096	-0.283	0.048
	– i.e. β_{10}	(0.182)	(0.129)	(0.118)	(0.120)	(0.198)	(0.112)
	Post-Reform	-0.034	-0.027	0.038	-0.065	-0.105	-0.093
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.067)	(0.117)	(0.130)	(0.082)	(0.067)	(0.092)
	Total	0.174	0.448**	0.470**	0.103	-0.217	0.020
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.157)	(0.182)	(0.189)	(0.185)	(0.170)	(0.187)
Regimpact:	Pre-Reform		0.009	-0.027	0.100		0.079
			(0.113)	(0.113)	(0.128)		(0.129)
	Contemporaneous		-0.354***	-0.366***	-0.318**		-0.382***
			(0.114)	(0.126)	(0.137)		(0.124)
	Post-Reform		-0.006	-0.006	0.028		-0.013
			(0.062)	(0.101)	(0.070)		(0.062)
	Total		-0.352***	-0.399***	-0.190		-0.316**
			(0.131)	(0.152)	(0.171)		(0.161)
QualityLadder:	Pre-Reform					0.043	-0.007
						(0.123)	(0.098)
	Contemporaneous					0.051	0.251**
						(0.147)	(0.108)
	Post-Reform					0.086	0.145
						(0.083)	(0.101)
	Total					0.180	0.390**
						(0.200)	(0.190)
Openness:	Total			-0.566	-0.285		-0.462
				(0.523)	(0.814)		(0.778)
Concentration:	Total			0.250	-0.097		-0.086
				(0.264)	(0.208)		(0.201)
ExportElast:	Total			-0.020	0.080		0.135
				(0.154)	(0.160)		(0.162)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		63144	63144	63144	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. Export elasticity is obtained from Broda et al. (2008). *Regimpact*, openness, market concentration, *ExportElast*, and *QualityLadder* are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. * p <0.10, ** p <0.05, *** p <0.01.

Table B.17: Adding import elasticity as additional measure of downstream competition

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.322**	0.220*	0.306**	-0.051	0.172	-0.057
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.149)	(0.122)	(0.149)	(0.163)	(0.167)	(0.162)
	Contemporaneous	-0.096	0.284**	0.238	0.038	-0.283	0.029
	– i.e. β_{10}	(0.202)	(0.144)	(0.145)	(0.130)	(0.198)	(0.132)
	Post-Reform	-0.090	-0.118	-0.072	0.045	-0.105	0.039
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.068)	(0.129)	(0.142)	(0.104)	(0.067)	(0.101)
	Total	0.135	0.386**	0.472**	0.032	-0.217	0.011
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.144)	(0.183)	(0.217)	(0.249)	(0.170)	(0.254)
Regimpact:	Pre-Reform		0.019	0.009	0.128		0.126
			(0.120)	(0.117)	(0.130)		(0.131)
	Contemporaneous		-0.372***	-0.388***	-0.325**		-0.393***
			(0.126)	(0.134)	(0.135)		(0.123)
	Post-Reform		0.029	0.025	0.012		-0.042
			(0.069)	(0.102)	(0.069)		(0.061)
	Total		-0.324**	-0.355**	-0.185		-0.309*
			(0.132)	(0.151)	(0.170)		(0.160)
QualityLadder:	Pre-Reform					0.043	-0.032
						(0.123)	(0.094)
	Contemporaneous					0.051	0.248**
						(0.147)	(0.110)
	Post-Reform					0.086	0.182*
						(0.083)	(0.107)
	Total					0.180	0.398**
						(0.200)	(0.198)
Openness:	Total			-0.557	-0.328		-0.590
				(0.526)	(0.804)		(0.763)
Concentration:	Total			0.237	-0.111		-0.097
				(0.269)	(0.211)		(0.206)
ImportElast:	Total			0.478	0.042		-0.022
				(0.877)	(0.140)		(0.134)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		61010	61010	61010	48977	48977	48977

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. Import elasticity is obtained from Broda and Weinstein (2006). *Regimpact*, openness, market concentration, *ImportElast*, and *QualityLadder* are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. One outlier product category (meat, constituting approximately 3 percent of the sample) is excluded. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.18: Using downstream and IOT-based upstream export elasticity as additional measures of competition

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.341**	0.236**	0.194*	0.050	0.302	0.101
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.157)	(0.116)	(0.111)	(0.098)	(0.225)	(0.112)
	Contemporaneous	-0.068	0.286*	0.242*	0.043	-0.339	-0.008
	– i.e. β_{10}	(0.217)	(0.149)	(0.123)	(0.131)	(0.244)	(0.115)
	Post-Reform	-0.031	-0.012	0.052	-0.084	-0.140*	-0.124
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.075)	(0.134)	(0.148)	(0.103)	(0.083)	(0.109)
	Total	0.242	0.510**	0.488**	0.010	-0.177	-0.031
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.191)	(0.207)	(0.191)	(0.202)	(0.177)	(0.191)
Regimpact:	Pre-Reform		-0.009	-0.072	0.067		0.195
			(0.188)	(0.219)	(0.219)		(0.214)
	Contemporaneous		-0.345***	-0.315**	-0.314*		-0.378**
			(0.129)	(0.146)	(0.166)		(0.160)
	Post-Reform		-0.020	0.003	0.048		-0.012
			(0.071)	(0.105)	(0.080)		(0.072)
	Total		-0.375*	-0.383	-0.199		-0.195
			(0.207)	(0.251)	(0.236)		(0.210)
UpExpElast	Pre-Reform			0.013	-0.197		-0.162
				(0.180)	(0.158)		(0.154)
	Contemporaneous			0.154	-0.009		-0.006
				(0.173)	(0.131)		(0.109)
	Post-Reform			0.067	-0.092		-0.090
				(0.228)	(0.129)		(0.126)
	Total			0.235	-0.297		-0.257
				(0.319)	(0.268)		(0.247)
QualityLadder:	Pre-Reform					0.025	-0.062
						(0.128)	(0.108)
	Contemporaneous					0.026	0.220*
						(0.140)	(0.113)
	Post-Reform					0.111	0.183
						(0.096)	(0.114)
	Total					0.162	0.341
						(0.208)	(0.215)
Openness:	Total			-0.105	-0.272		-0.714
				(0.580)	(0.933)		(0.867)
Concentration:	Total			0.191	-0.181		-0.160
				(0.263)	(0.194)		(0.209)
ExportElast:	Total			-0.152	0.242		0.315*
				(0.201)	(0.173)		(0.188)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		52677	52677	52677	38612	38612	38612

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. Similar to the construction of *Regimpact* in baseline, upstream export elasticity (*UpExpElast*) is calculated using product-level elasticities obtained from Broda et al. (2008), weighted by the degree to which they contribute to production of the output product from the OECD country-specific IOTs in 1995. *Regimpact*, openness, market concentration, *ExportElast*, *UpExpElast* and *QualityLadder* are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.19: Using downstream and IOT-based upstream import elasticity as additional measures of competition

		Dependent variable: change in log prices					
		Full Sample			Quality Sample		
		(1)	(2)	(3)	(4)	(5)	(6)
Baseline β_1	Pre-Reform	0.425**	0.279**	0.315**	-0.137	0.302	-0.102
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.181)	(0.137)	(0.159)	(0.165)	(0.225)	(0.174)
	Contemporaneous	-0.119	0.283*	0.135	0.179	-0.339	0.122
	– i.e. β_{10}	(0.246)	(0.168)	(0.145)	(0.151)	(0.244)	(0.157)
	Post-Reform	-0.096	-0.117	-0.095	0.217	-0.140*	0.165
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.077)	(0.153)	(0.159)	(0.175)	(0.083)	(0.173)
	Total	0.210	0.445**	0.355	0.259	-0.177	0.185
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.177)	(0.208)	(0.220)	(0.304)	(0.177)	(0.309)
Regimpact:	Pre-Reform		0.009	-0.010	0.107		0.218
			(0.196)	(0.200)	(0.196)		(0.199)
	Contemporaneous		-0.374**	-0.372**	-0.350**		-0.402***
			(0.147)	(0.146)	(0.151)		(0.150)
	Post-Reform		0.019	0.017	0.019		-0.034
			(0.082)	(0.115)	(0.073)		(0.072)
	Total		-0.346*	-0.366*	-0.225		-0.218
			(0.206)	(0.214)	(0.195)		(0.185)
UpImpElast	Pre-Reform			0.026	-0.129		-0.089
				(0.167)	(0.167)		(0.165)
	Contemporaneous			0.296*	0.341*		0.286*
				(0.173)	(0.180)		(0.168)
	Post-Reform			0.163	0.208		0.154
				(0.255)	(0.216)		(0.208)
	Total			0.485	0.420		0.351
				(0.327)	(0.391)		(0.365)
QualityLadder:	Pre-Reform					0.025	-0.041
						(0.128)	(0.100)
	Contemporaneous					0.026	0.173*
						(0.140)	(0.102)
	Post-Reform					0.111	0.162
						(0.096)	(0.105)
	Total					0.162	0.294
						(0.208)	(0.194)
Openness:	Total			-0.033	0.133		-0.328
				(0.583)	(0.962)		(0.889)
Concentration:	Total			0.235	-0.171		-0.167
				(0.264)	(0.202)		(0.212)
ImportElast:	Total			-0.263	-0.172		-0.158
				(1.079)	(0.195)		(0.188)
Country-Time FEs		✓	✓	✓	✓	✓	✓
Product-Time FEs		✓	✓	✓	✓	✓	✓
Country-Product FEs		✓	✓	✓	✓	✓	✓
N		50543	50543	50543	38612	38612	38612

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. One outlier product category (meat, constituting approximately 3 percent of the sample) is excluded. Similar to the construction of *Regimpact* in baseline, upstream import elasticity (*UpImpElast*) is calculated using product-level elasticities obtained from Broda and Weinstein (2006), weighted by the degree to which they contribute to production of the output product using OECD country-specific IOTs in 1995. *Regimpact*, openness, market concentration, *ImportElast*, *UpImpElast* and *QualityLadder* are standardized so the coefficients can be interpreted as the impact on pass-through of a one-standard-deviation rise in the regressor. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.20: Estimates by direction of VAT change

		Dependent variable: change in log prices					
		Increase	Decrease	Coeff.s Equal	Increase	Decrease	Coeff.s Equal
Baseline β_1	Pre-Reform	0.045	-0.058	0.435	0.003	0.000	0.992
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.121)	(0.051)		(0.252)	(0.137)	
	Contemporaneous	0.246**	0.284	0.808	-0.129	0.594	0.001
	– i.e. β_{10}	(0.116)	(0.104)		(0.165)	(0.184)	
	Post-Reform	-0.001	0.055	0.609	-0.205	0.207	0.102
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.088)	(0.067)		(0.142)	(0.202)	
	Total	0.290	0.281	0.973	-0.331	0.801	0.009
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.206)	(0.129)		(0.375)	(0.263)	
Regimpact:	Pre-Reform	0.016	0.009	0.953	0.112	0.159	0.874
		(0.078)	(0.073)		(0.182)	(0.229)	
	Contemporaneous	-0.258**	-0.145	0.588	-0.308**	0.201	0.084
		(0.101)	(0.182)		(0.153)	(0.237)	
	Post-Reform	-0.016	0.162	0.132	0.007	0.043	0.918
		(0.057)	(0.104)		(0.091)	(0.347)	
	Total	-0.258*	0.026	0.327	-0.189	0.404	0.251
		(0.152)	(0.251)		(0.260)	(0.428)	
QualityLadder:	Pre-Reform				0.004	0.081	0.662
					(0.113)	(0.158)	
	Contemporaneous				0.216*	0.378*	0.530
					(0.131)	(0.200)	
	Post-Reform				0.204	-0.298	0.039
					(0.126)	(0.184)	
	Total				0.425*	0.161	0.514
					(0.237)	(0.288)	
Openness:	Total	0.166	-1.131*	0.125	-0.461	-1.743	0.446
		(0.514)	(0.670)		(1.034)	(1.155)	
Concentration:	Total	0.355*	-0.196	0.067	-0.054	0.159	0.678
		(0.209)	(0.202)		(0.246)	(0.454)	
Number of VAT changes:		701	149		373	80	
Country-Time FEs		✓			✓		
Product-Time FEs		✓			✓		
Country-Product FEs		✓			✓		
N		103924			48977		

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. 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'. * p <0.10, ** p <0.05, *** p <0.01.

Table B.21: Estimates across the business cycle

		Dependent variable: change in log prices					
		Expansions	Contractions	Coeff.s Equal	Expansions	Contractions	Coeff.s Equal
Baseline β_1	Pre-Reform	-0.031	0.096	0.318	-0.079	0.037	0.714
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.072)	(0.110)		(0.221)	(0.250)	
	Contemporaneous	0.299**	0.190	0.566	-0.134	-0.005	0.688
	– i.e. β_{10}	(0.124)	(0.135)		(0.212)	(0.197)	
	Post-Reform	0.168	-0.052	0.093	-0.097	-0.104	0.974
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.106)	(0.079)		(0.132)	(0.161)	
	Total	0.436***	0.234	0.443	-0.310	-0.072	0.688
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.157)	(0.196)		(0.379)	(0.422)	
Regimpact:	Pre-Reform	0.174*	0.089	0.508	-0.144	0.051	0.612
		(0.099)	(0.083)		(0.325)	(0.171)	
	Contemporaneous	-0.291***	-0.188	0.611	-0.351**	-0.450**	0.705
		(0.103)	(0.176)		(0.167)	(0.201)	
	Post-Reform	-0.083	0.100	0.049	0.022	-0.015	0.802
		(0.069)	(0.062)		(0.087)	(0.116)	
	Total	-0.200	0.001	0.463	-0.473	-0.415	0.903
		(0.129)	(0.243)		(0.321)	(0.330)	
QualityLadder:	Pre-Reform				-0.114	0.071	0.169
					(0.079)	(0.125)	
	Contemporaneous				0.458***	0.025	0.082
					(0.136)	(0.167)	
	Post-Reform				0.076	0.030	0.792
					(0.144)	(0.110)	
	Total				0.420*	0.127	0.423
					(0.240)	(0.280)	
Openness:	Total	-0.387	-0.374	0.986	-0.444	-0.162	0.889
		(0.484)	(0.570)		(1.158)	(1.586)	
Concentration:	Total	-0.086	0.489*	0.096	-0.577	0.237	0.185
		(0.152)	(0.268)		(0.428)	(0.341)	
Number of VAT changes:		298	552		149	304	
Average size of VAT change (pp):		0.54	1.21		0.80	1.25	
Country-Time FEs		✓			✓		
Product-Time FEs		✓			✓		
Country-Product FEs		✓			✓		
N		99361			48977		

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, *QualityLadder*, 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'. * p <0.10, ** p <0.05, *** p <0.01.

Table B.22: Estimates across VAT Types

		Dependent variable: change in log prices							
		Standard	Reduced	Reclass	Coeff.s Equal	Standard	Reduced	Reclass	Coeff.s Equal
Baseline β_1	Pre-Reform	0.534***	-0.425	-0.086	0.000	0.369	-0.372	0.108	0.371
	– i.e. $\sum_{j=1}^{6} \beta_{1j}$	(0.194)	(0.130)	(0.052)		(0.368)	(0.463)	(0.076)	
	Contemporaneous	0.406***	0.646	2.069	0.000	0.076	0.245	0.502	0.095
	– i.e. β_{10}	(0.117)	(0.166)	(0.295)		(0.189)	(0.493)	(0.059)	
	Post-Reform	0.062	-0.279	-3.358	0.014	-0.206	-0.966	-0.113	0.411
	– i.e. $\sum_{j=-6}^{-1} \beta_{1j}$	(0.172)	(0.464)	(1.170)		(0.278)	(0.644)	(0.104)	
	Total	1.002***	-0.058	-1.375	0.034	0.239	-1.094	0.497	0.221
	– i.e. $\sum_{j=-6}^{6} \beta_{1j}$	(0.260)	(0.470)	(1.078)		(0.529)	(0.924)	(0.130)	
Regimpact:	Pre-Reform	0.596**	0.104	0.021	0.120	0.503	0.015	0.000	0.241
		(0.254)	(0.072)	(0.121)		(0.305)	(0.166)	(0.000)	
	Contemporaneous	-0.148	-0.797***	-0.115	0.000	-0.041	-0.945***	0.000	0.000
		(0.184)	(0.089)	(0.099)		(0.239)	(0.165)	(0.000)	
	Post-Reform	0.294	0.077	1.018**	0.189	-0.017	-0.370	0.000	0.570
		(0.183)	(0.178)	(0.504)		(0.230)	(0.353)	(0.000)	
	Total	0.742*	-0.616***	0.924	0.000	0.445	-1.300***	0.000	0.001
		(0.403)	(0.162)	(0.577)		(0.519)	(0.367)	(0.000)	
QualityLadder:	Pre-Reform					-0.010	0.016	0.000	0.993
						(0.120)	(0.210)	(0.000)	
	Contemporaneous					0.104	-0.187	0.000	0.427
						(0.104)	(0.224)	(0.000)	
	Post-Reform					0.178	-0.827	0.000	0.111
						(0.115)	(0.583)	(0.000)	
	Total					0.272	-0.999**	0.000	0.023
						(0.204)	(0.423)	(0.000)	
Openness:	Total	0.229	-5.247*	3.110	0.071	0.207	-4.842	0.000	0.775
		(0.403)	(2.976)	(1.968)		(0.930)	(7.118)	(0.000)	
Concentration:	Total	0.244	0.255	-3.393*	0.197	-0.165	-2.951	0.000	0.166
		(0.227)	(0.161)	(2.014)		(0.219)	(1.873)	(0.000)	
Number of VAT changes:		715	116	7		412	36	1	
Country-Time FEs			✓				✓		
Product-Time FEs			✓				✓		
Country-Product FEs			✓				✓		
N			99361				48977		

Notes: Estimates are the sum of the price elasticity coefficients with respect to tax changes over each period. Standard errors are clustered at the country-product level and shown in parentheses. Prices are de-trended and de-seasonalized, and observations are weighted by their share of national consumption. *Regimpact*, *QualityLadder*, 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 VAT types. * p <0.10, ** p <0.05, *** p <0.01.