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THE BREXIT VOTE, INFLATION AND U.K. LIVING STANDARDS*

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This article studies how voting for Brexit affected living standards in the United Kingdom. Using heterogeneity in exposure to import costs across product groups, we analyze how the depreciation of sterling caused by the referendum affected consumer prices. We find that the Brexit depreciation led to higher inflation in product groups with greater import shares in consumer expenditure. Our results are consistent with complete pass-through of import costs to consumer prices and imply aggregate exchange rate pass-through of 0.29. We estimate the Brexit depreciation increased consumer prices by 2.9%, costing the average household £870 per year.

1. INTRODUCTION

In June 2016, the United Kingdom voted to leave the European Union. Together with the election of President Trump later the same year, the Brexit vote signaled a major shift in international economic policy. For seven decades after World War II, industrialized economies generally favored policies to dismantle barriers to economic integration. Brexit and the U.S.–China trade war mark, at least temporarily, a reversal of that trend. Protectionism is back.

Understanding the economic consequences of Brexit is important not only to inform debate and decision making in an area of great public interest, but also because Brexit provides a rare opportunity to learn how a modern economy adjusts to the decision to increase trade barriers with its most important trading partner. With notable exceptions, such as Irwin's (2011) work on interwar protectionism, most evidence on trade policy has come from liberalization episodes. The return to protectionism provides fresh impetus to study the impact of rising trade costs (Evenett, 2019).

This article contributes to that objective by analyzing the impact of the Brexit vote on living costs during the period before the United Kingdom left the European Union (EU) in January 2020. Prior to the referendum, most research predicted that leaving the EU would reduce the United Kingdom's income per capita in the long run (Aichele and Felbermayr, 2015; Dhingra et al., 2017; Sampson, 2017). These forecasts cannot yet be evaluated. However, even before any new policies were implemented, the referendum led to changes in economic behavior

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due to both anticipation of future trade policy changes and uncertainty over what form those changes would take.[1] Most immediately, the leave vote led to a substantial depreciation of sterling, which fell around 10% on a trade-weighted basis.

The Brexit depreciation offers an attractive setting for isolating the price consequences of a policy shock. The fall in sterling was unanticipated, sharp, and persistent. Moreover, it was not caused by a shock to contemporaneous economic conditions that could directly affect consumer prices holding the exchange rate fixed. Instead, it resulted from a political event that caused currency investors to change their expectations about future economic policy. Our objective in this article is to measure how the Brexit depreciation affected U.K. living standards by estimating its impact on consumer prices.

Building on Goldberg and Campa (2010), our empirical strategy uses product-level differences in exposure to import costs to identify price variation caused by the exchange rate decline. We motivate our import cost exposure measure by developing a model of consumer prices that allows for both direct import consumption and indirect expenditure on imports used as intermediate inputs in domestic production. Our framework takes into account input–output linkages across sectors as well as distribution margins that drive a wedge between basic prices and purchaser prices. The model shows that exchange rate movements lead to larger price changes in product groups with higher import shares, where the import share is defined as the cost share of directly and indirectly consumed imports in consumer expenditure.

Guided by the model, we use U.K. input–output tables for 2013 to calculate the import share for each of the product groups that comprise the consumer expenditure basket. The share of imports in aggregate U.K. consumer expenditure is 0.29, of which 16 percentage points is directly consumed imports, while the remainder is imported intermediates used in domestic production. The aggregate import share masks substantial heterogeneity across product groups with tradable products mostly having higher import shares than services. For example, the import share of New cars is 0.64, whereas that of Education is 0.05.

Using the import share variable, we estimate the consumer price effects of the Brexit depreciation from two alternative specifications. First, we consider an event study specification that regresses the log difference of consumer prices by product group on the import share interacted with a treatment dummy that switches on after the Brexit referendum. Our estimates control for oil price changes and inflation in the Euro area. We find that following the referendum the increase in inflation was higher for product groups with larger import shares and that this differential impact persisted for at least two years. The estimates imply that, for each 10 percentage point increase in the import share, inflation in the two years following the referendum was 2.1 percentage points higher.

We also estimate that changes in producer price index (PPI) inflation after the vote were higher in sectors with larger shares of imported intermediates in production costs. It follows that failing to account for indirect imports would underestimate import cost exposure. Thus, our results not only imply that the Brexit depreciation led to higher consumer prices. They also show that accounting for the share of imported intermediate inputs in consumer expenditure is necessary to explain heterogeneity in price changes across product groups and to quantify the price effects of the Brexit depreciation.

The event study specification does not control for exchange rate changes, meaning we cannot rule out the possibility that it conflates the impact of the Brexit depreciation with exchange rate variation in the periods before and after the referendum that is unrelated to Brexit. Therefore, we also estimate a second specification where we interact the import share with the log difference of the exchange rate and its lags. We estimate this specification on a window around the Brexit vote using quarterly data from 2011 to 2018 and including between four and eight exchange rate lags.

[1] See, for example, Born et al. (2019) on GDP, Costa et al. (2019) on nominal wages, Bloom et al. (2019) on investment and productivity, Breinlich et al. (2020) on foreign direct investment, and Crowley et al. (2018) on the extensive margin of trade.

Consistent with the event study estimates, we find that a decline in the exchange rate increases inflation more in product groups with greater import shares. Summing the estimated coefficients on the exchange rate–import share interactions gives a measure of long-run pass-through from the exchange rate to consumer prices conditional on import shares, which we refer to as *import cost pass-through*.[2] We cannot reject the hypothesis of complete import cost pass-through, meaning that a 10% depreciation increases product group prices by 1% more for each 10 percentage point rise in the product group's import share.

Our import cost pass-through estimates are not directly comparable to conventional pass-through estimates because our differences-in-differences identification strategy exploits import share variation across product groups. However, we can map import cost pass-through to aggregate consumer price pass-through by aggregating across product groups. For this purpose, we assume that exchange rate movements do not affect the price index of a product group with zero import share, which pins down the level of the price effect. Given this assumption, complete import cost pass-through implies that aggregate pass-through to consumer prices equals the aggregate import share, which is 0.29.

Since the Brexit vote led sterling to depreciate by around 10%, our aggregate pass-through estimate implies that the depreciation caused by the Brexit vote raised consumer prices by 2.9% by June 2018. By design, this estimate only incorporates price changes resulting from the impact of the sterling depreciation on import costs and does not capture any price effects of Brexit that are uncorrelated with import share variation across product groups. A 2.9% consumer price rise is equivalent to an increase in the cost of living for the average U.K. household of £870 per year. As there is no evidence of a countervailing increase in nominal incomes, our findings imply the Brexit depreciation had a sizeable negative effect on real wages and living standards in the United Kingdom.

In related work, Born et al. (2019) use the synthetic control method to estimate that the Brexit vote had reduced U.K. GDP at the end of 2018 by between 1.7% and 2.5%. Interestingly, they find that most of this effect is driven by lower consumption growth. Our results suggest that the Brexit depreciation contributed to the reduction in GDP growth documented by Born et al. by driving up consumer prices leading to lower consumption growth.

To quantify the distributional consequences of the Brexit depreciation, we calculate how the increase in the cost of living varies across households with different expenditure patterns. Households that spend more on product groups with higher import shares are harder hit. We find that a household at the 75th percentile of the distribution of cost of living increases experienced a 1 percentage point larger increase in inflation from the Brexit depreciation than a household at the 25th percentile.

Comparing households in different deciles of the income distribution shows that the costs are evenly shared across income levels because there is no systematic correlation between income and the share of imports in household expenditure. However, the inflation impact differs considerably across regions. Households in Northern Ireland and Wales fared worst since they spend a relatively higher fraction of income on high import share products such as food and drink, clothing, and fuel. By contrast, households in London were least affected due to their relatively larger expenditure on rent, which has a low import share. These differences reinforce existing regional inequalities within the United Kingdom.

Collectively, our results provide robust evidence that the Brexit depreciation caused a substantial increase in U.K. living costs. We also show that failing to account for import share heterogeneity across product groups leads to downward bias in pass-through estimates. Using our estimation specification and data, but not interacting the exchange rate terms with the import share, delivers an estimate of pass-through to consumer prices around 0.15. This estimate

[2] To avoid possible confusion, note that our definition of import cost pass-through is not the same as pass-through to import prices at the border. Instead, it equals the elasticity of consumer prices to the interaction of the exchange rate with the share of imports in consumer expenditure. Consequently, it depends upon both pass-through at the border and how border prices feed through to consumer prices. See Subsection 3.4 for a detailed discussion of this distinction.

is biased downwards because, without including the interactions terms, we cannot control for quarter fixed effects to capture other time-varying inflationary pressures that may be correlated with exchange rate movements.

Although the pass-through literature often estimates incomplete short-run pass-through to border prices and import costs (Burstein and Gopinath, 2014), our results are consistent with evidence that large, salient shocks such as the Brexit vote are associated with greater pass-through. Burstein et al. (2005) find evidence of high pass-through to import costs following several large devaluation episodes and show that price changes following large devaluations are driven by tradable products, whereas smaller exchange rate fluctuations lead to incomplete pass-through for traded goods. In addition, studies of recent U.S. tariff increases have found evidence of complete pass-through to import prices (Amiti et al., 2019; Fajgelbaum et al., 2020) and, in the case of washing machines, a consumer price elasticity to tariffs in excess of 100% (Flaaen et al., 2020).

Our finding of complete import cost pass-through is also consistent with evidence from transaction-level U.K. customs data. Corsetti et al. (2020) estimate that there was complete pass-through from the Brexit depreciation to import prices by 36 weeks after the referendum. However, they do not study consumer prices.[3] Hobijn et al. (2021) do analyze consumer price changes following the vote. But they use the depreciation as a quasi-experiment to investigate the relative success of state-dependent versus time-dependent pricing models in explaining the dynamics of price adjustments caused by the Brexit depreciation.

The remainder of the article is organized as follows. The next section provides more background on the Brexit referendum and the subsequent depreciation of sterling. Section 3 develops a simple model of how import costs affect consumer prices, which we use to define our import share measure. Section 4 then introduces our data and explains how the import share is calculated from input–output tables. Section 5 presents results from the event study estimates, and Section 6 covers the pass-through specification. Section 7 then uses the results to quantify how the Brexit depreciation affected the cost of living in the United Kingdom. Finally, Section 8 offers some concluding remarks. An online appendix provides further details on our data as well as additional results. For reference, it also reports the import share of each product group in our data.

2. THE BREXIT VOTE AND STERLING

Prior to the Brexit referendum, opinion polls predicted a close vote. By contrast, betting markets implied around an 85% probability that the United Kingdom would choose to remain in the EU (The Economist, 2016), reflecting the conventional wisdom that undecided voters would opt for the status quo. However, on June 23, 2016, 52% of U.K. voters supported leaving the EU.

The Brexit vote did not lead to any immediate changes in the United Kingdom's economic relationships with the EU or the rest of the world. The United Kingdom only officially notified the EU of its intention to leave the union in March 2017. Brexit did not take place until January 31, 2020, and the United Kingdom's economic relationship with the EU did not change until the start of 2021. However, the leave vote did immediately affect expectations about the United Kingdom's economic future. The shift in expectations had two components. First, there was an increase in uncertainty over the future of U.K. economic policy and trade agreements (Bloom et al., 2018). Second, the referendum led to a decline in the expected future openness of the United Kingdom to trade and immigration with the EU.

Because economic behavior is forward looking, these changes in expectations had an immediate impact on financial markets. On June 24, 2016, after the result was known, the FTSE 100 stock market index fell by 3.8% and sterling depreciated by 8.1% against the U.S. dollar and

[3] See also Chen et al. (forthcoming) for transaction-level evidence on pass-through to U.K. border prices.



NOTES: Import-weighted effective exchange rate index calculated using daily data from January 2016 to July 2017 and normalized to 100 on the day of the referendum (June 23, 2016, indicated by the vertical line). An increase in the exchange rate corresponds to a depreciation of sterling.

FIGURE 1

THE DEPRECIATION OF STERLING AFTER THE 2016 REFERENDUM
[COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

5.8% against the euro.[4] Stock prices soon recovered, supported by the Bank of England's decision in August 2016 to cut interest rates by 25 basis points and undertake renewed quantitative easing. But the fall in sterling proved to be persistent. Figure 1 shows the import-weighted effective U.K. exchange rate at daily frequency from the start of 2016 until the middle of 2017.[5] In the week after the referendum, the effective exchange rate depreciated by 9.2%, and it fluctuated around 10% below its pre-referendum value over the following two years.

We study the impact of the Brexit depreciation on consumer prices and living standards. The Brexit depreciation is a rare example of an unanticipated, large, persistent shock to a major currency. Moreover, the depreciation was caused by the United Kingdom's decision to change future policy, not by a shock to domestic or foreign economic conditions. These features simplify, though do not eliminate, the problem of separating the price effects of exchange rate movements from the impact of supply and demand shocks that directly affect both the exchange rate and consumer prices.

To overcome challenges to identification, we use the share of imports in consumer expenditure to measure products' exposure to exchange rate movements, as explained in detail below. The identifying assumption is that, conditional on exchange rate changes, shocks to consumer prices following the leave vote are uncorrelated with pre-referendum import share variation across products. Consequently, our estimates isolate the impact of the depreciation from other channels whose price effects are not correlated with import shares.

3. IMPORT COSTS AND CONSUMER PRICES

To implement our empirical strategy, we measure the import share of consumer expenditure for different product groups. Consumers purchase imports both directly and indirectly via

[4] Breinlich et al. (2018) and Davies and Studnicka (2018) analyze share price movements in the days after the referendum.

[5] See Subsection 4.2 for a description of how the exchange rate index is constructed.

consumption of domestic goods produced using imported inputs. To capture both these channels in the import share measure, we develop a simple model of how variation in import costs affects consumer prices. The model builds upon elements from Burstein et al. (2005), Goldberg and Campa (2010), and Berlingieri et al. (2018). We assume consumers buy both domestic and foreign goods, which come bundled with locally produced distribution services that capture the cost of bringing goods to market. Producers use both domestic and imported inputs and we take input–output linkages between sectors into account when modeling intermediate input use.

3.1. *Consumption and Production.* Suppose consumers purchase a basket of G product groups indexed by g. Within each product group, consumers purchase a domestic good D_g, an imported good M_g, and distribution services S_g. The consumption aggregate C_g for group g is given by

$$C_g = \left(M_g^{\gamma_g} D_g^{1-\gamma_g}\right)^{1-\lambda_g} S_g^{\lambda_g}, \tag{1}$$

where λ_g gives the share of distribution services in expenditure on group g and γ_g gives the share of imports in expenditure net of distribution costs.[6]

Production of domestic good g uses a bundle v_g of primary factors (e.g., labor and capital) together with aggregates of domestic and imported intermediate inputs. Output Y_g is given by

$$Y_g = \phi_g\left(X_{Mg}^{\delta_g} X_{Dg}^{1-\delta_g}\right)^{\alpha_g} v_g^{1-\alpha_g}, \tag{2}$$

where ϕ_g denotes the productivity of sector g, X_{Mg} denotes imported intermediate usage, and X_{Dg} denotes domestic intermediate usage. Here, α_g is the share of intermediate inputs in production costs and δ_g is the share of imports in intermediate input costs.

The imported intermediate bundle used by domestic producers in sector g is an aggregate of imports of all G product groups:

$$X_{Mg} = \prod_{j=1}^{G} x_{Mgj}^{\mu_{gj}}, \tag{3}$$

where x_{Mgj} denotes the quantity of imported good j used to produce the sector g imported intermediate input and μ_{gj} gives the cost share of j in imported intermediate expenditure by sector g. Likewise, the domestic intermediate bundle is an aggregate of all G domestic goods:

$$X_{Dg} = \prod_{j=1}^{G} x_{Dgj}^{\psi_{gj}}, \tag{4}$$

where x_{Dgj} denotes the quantity of domestic good j used to produce the sector g domestic intermediate input and ψ_{gj} gives the cost share of j in domestic intermediate expenditure by sector g.

Finally, we assume that distribution services are produced by the domestic wholesale and retail sectors according to

$$S_g = X_{Wg}^{\xi} X_{Rg}^{1-\xi}, \tag{5}$$

[6] Corsetti and Dedola (2005) consider an alternative specification of distribution services in which distribution costs are additive.

where X_{Wg} denotes wholesale output used in sector g and X_{Rg} is retail output. The share of distribution services expenditure spent on wholesale is ξ, while the expenditure share of retail is $1-\xi$. Since ξ does not vary with g, distribution services are homogeneous and the price of distribution services will be constant across product groups.[7] The production technologies for wholesale and retail goods have the same structure as for all other goods and are given by Equations (2)–(4) with $g = W$ for wholesale and $g = R$ for retail.

3.2. *Prices.* We solve for consumption and intermediate good prices under the assumption that all markets are competitive. Let p^S be the price of distribution services, p_g^M be the price of imported good g, and p_g^D be the price of domestic good g. Cost minimization using Equation (1) implies that the consumption price index p_g^C for product group g is

$$p_g^C = \left[\frac{1}{1-\lambda_g}\left(\frac{p_g^M}{\gamma_g}\right)^{\gamma_g}\left(\frac{p_g^D}{1-\gamma_g}\right)^{1-\gamma_g}\right]^{1-\lambda_g}\left(\frac{p^S}{\lambda_g}\right)^{\lambda_g}.$$

Distribution services introduce a wedge between basic prices (obtained by letting $\lambda_g \to 0$ in the expression above) and the purchasers' prices paid by consumers. Purchasers' prices may also depend upon the level of taxes and subsidies on products. Although we do not model taxes and subsidies explicitly, we adjust for their presence when mapping the model to consumer expenditure data.

We are interested in how consumer prices change over time following an exchange rate movement. For any variable z, let $\hat{z}$ be the log difference of z between period t and the previous period: $\hat{z} \equiv \log z_t - \log z_{t-1}$. Then we can write the change in the group g price index as

$$\hat{p}_g^C = (1-\lambda_g)\gamma_g\hat{p}_g^M + (1-\lambda_g)(1-\gamma_g)\hat{p}_g^D + \lambda_g\hat{p}^S. \tag{6}$$

This expression allows us to decompose the impact of a change in import costs on consumer prices into direct and indirect effects. The *direct effect* is given by the first term on the right-hand side of (6), which shows that higher import prices feed into consumer prices directly through consumer expenditure on imported goods. The magnitude of the direct effect is determined by the share of imports in consumer expenditure $(1-\lambda_g)\gamma_g$.

In addition, import costs may affect consumer prices indirectly through their impact on the domestic good price p_g^D and the price of distribution services p^S. The second and third terms on the right-hand side of (6) capture this *indirect effect*. The magnitude of the indirect effect depends upon the extent to which imports are used in domestic production and the share of domestic production in consumer expenditure.

To calculate the indirect effect, we use (2)–(4) to analyze how changes in import costs affect domestic prices. From (2), assuming constant productivity and factor prices, cost minimization by domestic producers yields

$$\hat{p}_g^D = \alpha_g\delta_g\hat{p}_{Mg}^X + \alpha_g(1-\delta_g)\hat{p}_{Dg}^X, \tag{7}$$

[7] In principle, ξ could vary by product group, but in our data we do not observe wholesale and retail expenditure shares at the product group level.

where p^X_{Mg} and p^X_{Dg} denote the prices of the imported and domestic intermediate input bundles, respectively. Using (3) and (4), we can write changes in the prices of these intermediate bundles as

$$\hat{p}^X_{Mg} = \sum_{j=1}^{G} \mu_{gj} \hat{p}^M_j, \qquad \hat{p}^X_{Dg} = \sum_{j=1}^{G} \psi_{gj} \hat{p}^D_j,$$

and substituting these expressions into (7) yields

$$\hat{p}^D_g = \alpha_g \delta_g \sum_{j=1}^{G} \mu_{gj} \hat{p}^M_j + \alpha_g (1 - \delta_g) \sum_{j=1}^{G} \psi_{gj} \hat{p}^D_j.$$

Since we have G such equations (one per product group), we can solve the linear system to obtain domestic price changes in terms of import cost variation. This gives

$$\hat{P}^D = (I - \Omega^D)^{-1} \Omega^M \hat{P}^M, \tag{8}$$

where $\hat{P}^D$ is the $G \times 1$ vector of domestic price changes $\hat{p}^D_g$, $\hat{P}^M$ is the vector of import price changes $\hat{p}^M_g$, Ω^D is a $G \times G$ matrix with elements $\omega^D_{gj} = \alpha_g(1 - \delta_g)\psi_{gj}$ where g denotes the row and j the column, Ω^M is a $G \times G$ matrix with elements $\omega^M_{gj} = \alpha_g \delta_g \mu_{gj}$, and I is the $G \times G$ identity matrix.

Recall that Equations (2)–(4) with $g = W$ and $g = R$ define the production technologies for wholesale and retail, respectively. Consequently, we also obtain from (8) the effect of import prices on domestic wholesale and retail prices. Using (5) we can then write the change in the price of distribution services as

$$\hat{p}^S = \xi \hat{p}^D_W + (1 - \xi)\hat{p}^D_R, \tag{9}$$

where p^D_W denotes the price of wholesale services and p^D_R the retail price. Finally, substituting (8) and (9) back into Equation (6) allows us to express the indirect effect in terms of changes in import costs.

3.3. *Import Share.* We are interested in how consumer prices respond to changes in import costs. Suppose an exchange rate depreciation causes all import prices to increase by the same proportion $\hat{p}^M_g = \hat{p}^M$ for all $g = 1, \ldots, G$. In this case, combining Equations (6), (8), and (9) implies that the change in the group g price index is

$$\hat{p}^C_g = \left[(1 - \lambda_g)\gamma_g + (1 - \lambda_g)(1 - \gamma_g) \sum_{j=1}^{G} \theta_{gj} + \lambda_g \left(\xi \sum_{j=1}^{G} \theta_{Wj} + (1 - \xi) \sum_{j=1}^{G} \theta_{Rj} \right) \right] \hat{p}^M, \tag{10}$$

where θ_{gj} denotes the element in row g and column j of the $G \times G$ matrix $(I - \Omega^D)^{-1}\Omega^M$ that appears in Equation (8).

The term in square brackets on the right-hand side of (10) gives the elasticity of consumer prices to import prices. We will call this elasticity the *import share* of group g (denoted as $ImportShare_g$) since it equals the cost share of imports in domestic consumer expenditure on product group g, accounting for both direct import consumption and indirect consumption of imports embodied in domestically produced goods and distribution services. The expenditure share of directly consumed imports equals $(1 - \lambda_g)\gamma_g$, which we label the *direct import share*, while the remaining terms represent the *indirect import share*. Of course, the total import share is the sum of the direct and indirect shares.

The import share is determined by the consumption and production function parameters defined in Equations (1)–(5). Because these parameters govern consumers' expenditure shares and producers' cost shares, they can be calculated from input–output tables, which implies that the import share is observable for each product group g. Consequently, we use Equation (10) to construct the import share measure used in our empirical analysis. We expect that products with larger import shares will experience higher inflation following an increase in import costs due to an exchange rate depreciation. In Section 5, we test this prediction in an event study framework by regressing changes in inflation rates following the Brexit referendum on import shares at the product group level. In Section 6, we use the import share measure to estimate exchange rate pass-through.

3.4. *Discussion.* Our model provides a simple measure of the share of imports in consumer expenditure. Like any model it involves a number of useful abstractions. Two are worth highlighting at this stage.

First, we assume that the elasticity of substitution between the domestic and imported good within each product group, and between alternative inputs to production, is unity. This implies that the expenditure and cost shares are fixed by the model's technological parameters and are insensitive to price changes. For example, the share of distribution services in consumer expenditure is always λ_g. Relaxing this assumption by allowing for constant elasticity of substitution consumption and production functions with an elasticity other than one would not change how we measure the import share.

To see why, note that the price change equations (6)–(10) would continue to hold locally in the generalized model provided the coefficients, such as λ_g and γ_g, were interpreted as equilibrium cost and expenditure shares instead of underlying technology parameters. It follows that the local elasticity of consumer prices to import prices would still be given by the import share in Equation (10). Since our empirical import share measure does not vary over time (see Subsection 4.1 for details), this implies that the mapping we use to calculate the import share from observable input–output data would be unchanged in the generalized model.

Allowing for non-unitary elasticities of substitution would affect how prices are aggregated into product group price indices. However, because we observe prices at the product group level we do not undertake any such aggregation. We do aggregate across product groups to calculate aggregate exchange rate pass-through in Section 7. Subsection 5.5 provides evidence that supports using constant expenditure shares to aggregate across product groups.

The second point to highlight is that the model assumes perfect competition, implying one-to-one pass-through of import costs to consumer prices. Departing from perfect competition by allowing producers to charge a constant mark-up over marginal costs would affect price levels, but with constant mark-ups there would still be one-to-one pass-through and the price change equations (6)–(10) would not be affected. However, one-to-one pass-through does not hold in an environment with variable mark-ups. Suppose, for example, that producers face downward sloping demand elasticities as found by Berman, Martin and Mayer (2012). In this case, an increase in import costs would lead to a reduction in mark-ups implying less than complete pass-through. Similarly, if there are nominal price rigidities, then pass-through may depend upon the currency in which prices are set and the frequency of price adjustment (Gopinath et al., 2010).

However, it is straightforward to generalize the model to allow for incomplete pass-through. Incomplete pass-through from exchange rate movements to consumer prices may occur either at the border or in the transmission of import costs to consumer prices. Let β^M denote pass-through into import prices at the border, implying that $\hat{p}^M = \beta^M \hat{e}$ where $\hat{e}$ denotes the exchange rate depreciation.[8] Pass-through at the border is incomplete if $\beta^M < 1$.

[8] Estimates of import price pass-through typically employ specifications based on this expression.

In addition, suppose that instead of Equation (6), the change in consumer prices is given by

$$\hat{p}_g^C = \beta^D\Big[(1-\lambda_g)\gamma_g\hat{p}_g^M + (1-\lambda_g)(1-\gamma_g)\hat{p}_g^D + \lambda_g\hat{p}^S\Big],$$

where β^D denotes pass-through of import costs and domestic production costs to consumer prices, which we refer to as domestic pass-through. Modeling domestic pass-through in this way imposes two convenient simplifications: there is no heterogeneity in pass-through across product groups, and within product groups domestic pass-through is the same for both imported and domestically produced goods.[9] Incomplete domestic pass-through may occur if, for example, retailers and wholesalers adjust mark-ups following price shocks. Equation (10) can now be written as

$$\hat{p}_g^C = \beta^D\beta^M ImportShare_g\hat{e}. \tag{11}$$

When estimating exchange rate pass-through in Section 6, we regress $\hat{p}_g^C$ on $ImportShare_g$ interacted with the exchange rate change $\hat{e}$. Consequently, we estimate the elasticity of product group prices to the exchange rate conditional on import shares. We will refer to this elasticity as *import cost pass-through*, since it gives the pass-through of exchange rate movements to consumer prices conditional on import shares. Equation (11) shows that import cost pass-through equals $\beta^D\beta^M$, that is, the product of pass-through at the border and pass-through in the domestic economy. Using Equation (10) to measure each product group's import share allows us to estimate import cost pass-through in our data.

4. DATA

This section describes the data used in the empirical analysis, focusing on the calculation of import shares. Details are provided in Appendix A (online).

4.1. *Import Share Measure.* Consumer prices are reported using the Classification of Individual Consumption According to Purpose (COICOP). We work with product groups defined at the level of COICOP classes, which is the most disaggregated level for which import shares can be calculated using U.K. input–output tables. The full list of COICOP classes we use is given in Appendix A. Examples include Bread and cereals, Wine, Electricity, Pharmaceutical products, and Restaurants and cafes.

The import share of class g is defined in Equation (10). Other than the share of expenditure on distribution services, λ_g, all the parameters needed to calculate import shares can be inferred from the U.K. Input–Output Analytical Tables published by the Office for National Statistics (ONS). We use the 2013 tables and take advantage of the fact that the ONS publishes separate tables for domestically produced and imported products. Using 2013 data means that the import shares are time-invariant and pre-determined with respect to the Brexit referendum, which ensures our estimates do not suffer from endogeneity bias that could arise if inflation rates are correlated with changes in import shares.

The share of imports in expenditure net of distribution costs, γ_g, is computed as the ratio of household expenditure on imports of good g to total household expenditure (domestic and imported) on good g at basic prices. The share of distribution services expenditure spent on wholesale, ξ, is computed as the ratio of household expenditure on the wholesale sector to household expenditure on the wholesale and retail sectors at basic prices.

To calculate θ_{gj}, we need to know α_g, δ_g, ψ_{gj}, and μ_{gj} for $g, j = 1, \ldots, G$. We compute the share of intermediate inputs in production costs, α_g, as total intermediate consumption

[9] These simplifications are motivated by data limitations, which prevent us from estimating heterogeneity in pass-through across or within product groups.

TABLE 1
IMPORT SHARES BY COICOP DIVISION

COICOP Division	(1) Direct	(2) Indirect	(3) Total
	%	%	%
Food and non-alcoholic beverages	29	14	43
Alcoholic beverages and tobacco	11	13	24
Clothing and footwear	41	8	49
Housing, water, electricity, gas and other fuels	1	17	18
Furniture, household equipment and maintenance	25	9	34
Health	27	6	33
Transport	22	18	40
Communication	17	17	34
Recreation and culture	15	12	27
Education	1	4	5
Restaurants and hotels	0	17	17
Miscellaneous goods and services	14	12	25
Aggregate	16	14	29
Standard deviation	0.17	0.07	0.17

NOTES: The sum of direct and indirect import shares might not equal the total import share due to rounding errors. The aggregate import share is a weighted average across COICOP classes using 2016 CPI expenditure weights. The standard deviation is unweighted and calculated across COICOP classes.

(domestic and imported) by domestic producers of product g over total domestic output of product g. The share of imports in intermediate input costs, δ_g, is computed as the share of imported intermediates in total intermediate consumption by domestic producers of product g. Finally, ψ_{gj} is given by the share of expenditure on product j in domestic intermediate expenditure by domestic producers of product g from the Domestic Use Table. Similarly, μ_{gj} is the share of expenditure on product j in imported intermediate expenditure by domestic producers of product g from the Imports Use Table. All these parameters are calculated using basic price data.

The parameter λ_g is given by the expenditure share of distribution services. To calculate λ_g, we need to adjust consumer expenditure at purchasers' prices reported in the input–output tables to account for net product taxes. We do this using the U.K. Supply and Use Tables for 2013 from the ONS, which include product-level data on expenditure on taxes less subsidies. See Appendix A.1 for details of this calculation. The Input–Output Analytical Tables and the Supply and Use Tables report data using the Classification of Products by Activity (CPA) for 105 products. Consequently, we first compute import shares for the 105 CPA products and then use a concordance provided by the ONS to map CPA products to COICOP classes. This enables us to calculate import shares for 84 COICOP classes.[10]

Table 1 provides summary statistics for the import share variable. We report the average import share for classes in each of the 12 divisions of the COICOP classification. Column (1) gives the direct import share, column (2) the indirect import share, and column (3) the total import share. There is substantial variation in import shares across divisions. Total import shares range from 5% in Education to 49% in Clothing and footwear. Unsurprisingly, tradable goods such as food and drink have higher import shares than services such as restaurants and utilities. But even services have positive total import shares because services firms use imported intermediate inputs. For example, the Restaurants and hotels division has a zero direct import share but an indirect import share of 17%.[11]

[10] The ONS publishes consumer price data for 85 COICOP classes. Our method does not produce an import share for Second-hand cars, which we drop from the empirical analysis.

[11] Table A1 lists the import share for each of the 84 COICOP classes and shows that there is considerable variation in import shares within divisions.

The import share of aggregate consumption equals the weighted average of the class-level import shares, where the weight of each class g is given by its share in consumer expenditure η_g. We use expenditure shares for the year 2016 reported by the ONS. Table 1 reports that the aggregate import share is 29%, which is fairly evenly divided between direct and indirect imports with 16% and 14%, respectively. This illustrates the importance of accounting for indirect import consumption when measuring exposure to import costs.

4.2. *Other Variables.* To measure inflation, we use U.K. consumer price indices (CPIs) at the level of 84 COICOP classes from the ONS (data set MM23). Price indices for COICOP classes are constructed using price data on around 700 individual products and services, together with expenditure share weights based on the allocation of household final consumption expenditure. Appendix A.2 provides further details on the methodology used to construct U.K. CPIs, which is based on EU regulations for consumer price measurement.

The ONS data provide the most comprehensive information available on overall changes in living costs in the United Kingdom, but it is not without limitations. In particular, if there is product exit, then missing prices are inferred based on prices for similar products, which may result in measurement error. Moreover, there are lags in updating the items included in the consumption basket. Consequently, extensive margin changes in the composition of consumer expenditure are imperfectly observed.

As additional price outcomes, we also collect from the ONS PPIs that we match to 42 CPA sectors (mainly manufacturing industries) and an import price index for intermediate inputs (data set MM22). For data on household expenditure patterns, we use the ONS Living Costs and Food Survey. We also obtain wage growth data from the ONS Average Weekly Earnings data set.

To estimate exchange rate pass-through, we construct an effective exchange rate index for the United Kingdom. The index e is calculated as a weighted average of log differences in bilateral exchange rates. An increase in e corresponds to a depreciation of sterling. The weights are given by the share of U.K. imports by trading partner calculated using UN Comtrade data for 2013. We obtain period average bilateral exchange rates for 169 countries from the International Monetary Fund's (IMF) International Financial Statistics database and Thomson Reuters. We calculate effective exchange rate indices at daily, monthly, and quarterly frequencies.

Finally, there are two additional variables that will be used as controls in our empirical analysis. The first is inflation in the Euro area. We obtain the CPI for each COICOP class in the Euro area from the Harmonized Index of Consumer Prices (HICP) provided by Eurostat. This cross-country aggregate is computed from the HICP of the 19 Euro area countries. For the United Kingdom, the HICP is the same as the CPI produced by the ONS. We also obtain Euro area PPIs from Eurostat for NACE Revision 2 sectors, which map directly into CPA sectors.

Second, we use data on oil prices in U.S. dollars from the IMF Commodity Prices database, together with the U.K. Input–Output Analytical Tables for 2013, to construct a variable Oil_{gt} that captures the effect of oil price changes on intermediate input costs by COICOP class in the United Kingdom. The oil price variable is an interaction of the share of consumer expenditure on class g that is (indirectly) spent on imported oil with changes in the U.S. dollar price of oil (see Appendix A.3 for details). Conditional on the oil price change, classes where production is more oil intensive have a higher value of Oil_{gt}.

5. EVENT STUDY

This section undertakes an event study analysis of how the sterling depreciation following the Brexit referendum affected prices in the United Kingdom. Section 6 then uses the period around the Brexit vote to estimate exchange rate pass-through to consumer prices.



NOTES: Monthly data. The indices are normalized to 100 at the time of the referendum (June 2016, indicated by the vertical line). An increase in the exchange rate index corresponds to a depreciation of sterling.

FIGURE 2

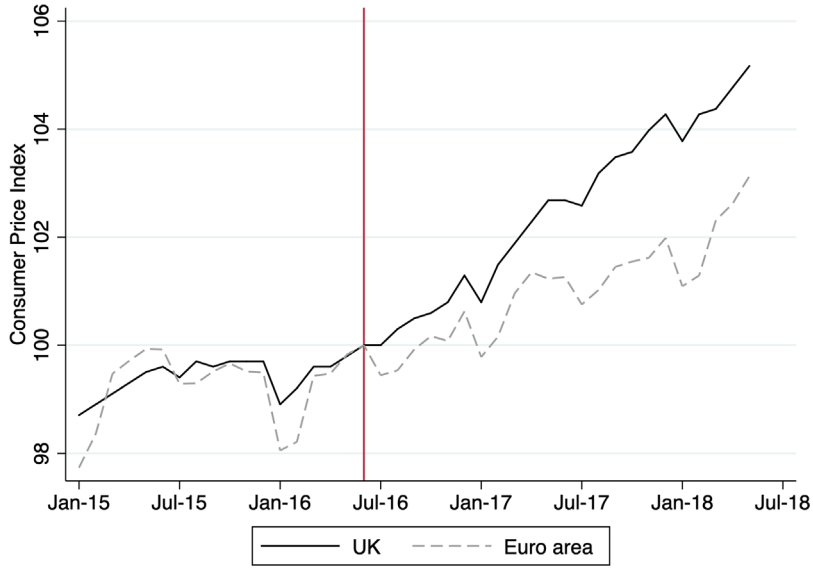
INTERMEDIATE INPUT IMPORT PRICES AND THE VALUE OF STERLING, 2015–18
[COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

5.1. *Descriptive Evidence.* Before turning to regressions, we present some descriptive evidence on how the post-Brexit depreciation affected U.K. prices. Figure 2 plots the evolution of intermediate input import prices and our effective exchange rate index from 2015 to 2018. Import prices at the border rose sharply following the referendum and by mid-2017 the import price index was approximately 10% higher than at the time of the vote, while sterling depreciated by around 10% over the same period. These movements are consistent with complete pass-through from the post-referendum depreciation to import prices.

Further evidence of complete pass-through from the Brexit depreciation into import prices (i.e., $\beta^M = 1$ in our notation) is provided by Corsetti et al. (2020). Using transaction-level U.K. customs data they estimate that import prices at the border had fully adjusted to the depreciation of sterling by 36 weeks after the referendum. Moreover, they find that complete adjustment holds regardless of the currency in which import transactions are invoiced, which is consistent with exchange rate pass-through into border prices being homogeneous across products. Chen et al. (forthcoming) also use heterogeneity in currency of invoicing to estimate pass-through into U.K. import prices. They find no evidence that pass-through differs significantly across 1-digit Standard International Trade Classification (SITC) industries.

Looking at consumer prices, Figure 3 shows the aggregate CPI in the United Kingdom and the Euro area from 2015 to the middle of 2018. Both indices are normalized to 100 at the time of the referendum in June 2016. We see that following the vote prices rose more quickly in the United Kingdom than the Euro area, which is suggestive evidence that the depreciation of sterling increased U.K. inflation. Between June 2016 and June 2018 U.K. prices increased by 1.9 percentage points more than prices in the Euro area.

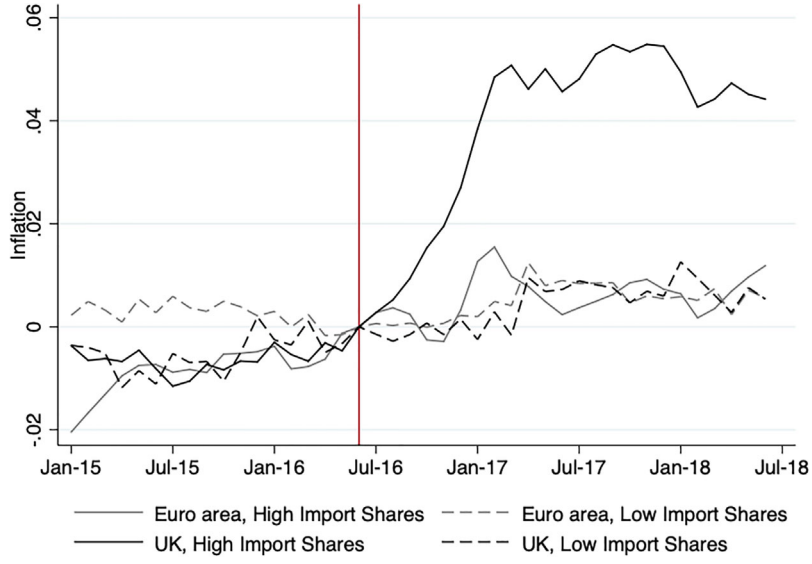
Figure 4 provides a more detailed look at what drove these price changes. For both the United Kingdom and the Euro area, the figure shows how inflation changed following the referendum for high import share COICOP classes compared to low import share classes. Classes are divided into high and low import share groups depending on whether their import share is above or below the median import share. The dark solid line is the average inflation rate in the United Kingdom for high import share classes, while the dark dashed line is



Notes: Monthly data. The indices are normalized to 100 at the time of the referendum (June 2016, indicated by the vertical line).

Figure 3

consumer prices in the united kingdom and the euro area, 2015–18
[color figure can be viewed at wileyonlinelibrary.com]



Notes: COICOP classes with above-median import shares are allocated to the high import share group and those with below-median import shares to the low import share group. For each of the four groups, inflation is expressed as the average log consumer price difference over the previous 12 months relative to the average group inflation rate in June 2016. Monthly data. The vertical line indicates the referendum date (June 2016).

Figure 4

inflation rates in the united kingdom and euro area by import shares, 2015–18
[color figure can be viewed at wileyonlinelibrary.com]

average U.K. inflation for low import share classes. The gray lines provide the same data for the Euro area. Inflation is defined as the log difference in prices over the previous year and is normalized to zero in June 2016 for all groups.

We see that following the referendum there is a sharp increase in U.K. inflation among high import share classes and that inflation remains high throughout 2017 before starting to decline in 2018. However, there is no comparable trend for low import share classes in the United Kingdom or for either group in the Euro area. This suggests that the referendum increased inflation in the United Kingdom by raising the cost of products with high import shares. To formally test this hypothesis, we now introduce our empirical model.

5.2. *Event Study Specification.* We estimate an event study model that, motivated by our theoretical framework, exploits variation in import shares across COICOP classes. The baseline specification is

$$Inflation_{gt} = \chi Post_t \times ImportShare_g + Z_{gt} + \nu_g + \nu_t + \varepsilon_{gt}. \tag{12}$$

The dependent variable $Inflation_{gt}$ is the inflation rate (i.e., the log change in the price index from the previous period) for a given COICOP class g in period t. $Post_t$ is a dummy variable that takes the value one for all periods after the referendum and zero otherwise. $ImportShare_g$ is our measure of the cost share of imports in consumer expenditure on class g as described in Subsections 3.3 and 4.1.

Z_{gt} is a vector of additional variables that may affect inflation at the class level. Specifically, we include in Z_{gt} Euro area inflation for class g in period t and the oil price exposure variable Oil_{gt} described in Subsection 4.2. Euro area inflation is a proxy for inflationary pressures that differ across classes but are not U.K. specific, while Oil_{gt} controls for the effect of changes in oil prices. We also include COICOP class fixed effects and period fixed effects. The former control for time-invariant differences in inflation across classes, while the latter capture changes in aggregate inflationary pressures over time. Any price effects of the leave vote that are uncorrelated with $ImportShare_g$ will be captured by the period fixed effects. Finally, the error term is ε_{gt}.

The coefficient of interest is the $Post_t \times ImportShare_g$ interaction effect χ, which is a differences-in-differences estimate of how inflation changes after the referendum varied across classes with different import shares. A positive estimate of χ implies that the increase in inflation following the referendum was greater for classes where the cost share of imports in consumer expenditure $ImportShare_g$ is higher.

We estimate specification (12) using a sample from June 2014 to June 2018, and we define a period to be either one year or two years long. Since the referendum occurred on June 23, 2016, we define the two-year periods to be June 2014 to June 2016 and June 2016 to June 2018, while the one-year periods are defined to end in June of each year. We choose the sample to include a two-year window after the referendum because the exchange rate pass-through literature usually allows up to two years for exchange rate movements to feed through to consumer prices (Burstein and Gopinath, 2014), a finding we confirm in our pass-through estimates in Section 6. Table 2 shows descriptive statistics for the time-varying estimation variables. The statistics in panel A are calculated using two-year periods, and those in panel B use one-year periods.

5.3. *Consumer Prices.* We start by estimating specification (12) using two-year periods with CPI inflation as the dependent variable. Table 3 presents the results. All columns include COICOP class and period fixed effects, although in column (1) we do not use any other controls. The estimated import share interaction effect is positive and significant at the 10% level. In column (2) we add Oil_{gt} to control for oil price changes. The oil price effect is positive though imprecisely estimated. More importantly, controlling for Oil_{gt} reduces the estimate of

TABLE 2
DESCRIPTIVE STATISTICS

	Mean	Median	Standard Deviation	Min	Max
Panel A: Two-year periods					
CPI inflation	0.021	0.027	0.080	−0.459	0.427
PPI inflation	0.026	0.032	0.096	−0.445	0.396
Oil	−0.005	0.000	0.041	−0.262	0.120
CPI Euro area inflation	0.018	0.019	0.056	−0.426	0.264
PPI Euro area inflation	0.010	0.009	0.063	−0.352	0.259
Panel B: Annual					
CPI inflation	0.011	0.014	0.045	−0.296	0.325
Oil	−0.002	0.000	0.024	−0.181	0.130
CPI Euro area inflation	0.009	0.010	0.032	−0.219	0.256
Panel C: Quarterly					
CPI inflation	0.004	0.003	0.033	−0.428	0.266
Oil	0.000	0.000	0.009	−0.116	0.100
CPI Euro area inflation	0.003	0.003	0.024	−0.329	0.272
Exchange rate index	−0.001	−0.009	0.025	−0.028	0.084

NOTES: Panel A reports summary statistics for the two-year period sample using periods from June 2014 to June 2016 and June 2016 to June 2018. Panel B reports summary statistics for the annual sample using data from 2015–18 for years ending in June. Panel C reports summary statistics for the quarterly sample from 2011Q1 to 2018Q2. CPI inflation, Oil, and CPI Euro area inflation are computed at the level of 84 COICOP classes. PPI inflation and PPI Euro area inflation are computed at the level of 42 CPA sectors.

TABLE 3
CONSUMER PRICE EVENT STUDY ESTIMATES WITH TWO-YEAR PERIODS

	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation Difference
Post × Import Share	0.384*	0.248***	0.211***	0.194***
	(0.207)	(0.090)	(0.066)	(0.061)
Oil		0.792	0.212	−0.041
		(0.519)	(0.278)	(0.175)
Euro area inflation			0.696*	
			(0.391)	
Observations	168	168	168	168
R^2	0.642	0.755	0.828	0.665
Number of classes	84	84	84	84
Class fixed effects	YES	YES	YES	YES
Period fixed effects	YES	YES	YES	YES

NOTES: The dependent variable in columns (1)–(3) is the U.K. inflation rate at the COICOP class level. The dependent variable in column (4) is the difference between the U.K. and Euro area inflation rates. Post is a dummy variable for the two-year post-referendum period (June 2016–June 2018). The pre-referendum period also covers two years (June 2014–June 2016). OLS estimation. Standard errors in parentheses are clustered by COICOP class. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

χ. However, the standard error of the estimate also falls and its statistical significance actually increases.

Our preferred specification is in column (3) where we also control for Euro area inflation, which, as expected, has a positive association with U.K. inflation. The estimated coefficient on the import share interaction in column (3) is 0.211 and is significant at the 1% level. This confirms that, following the referendum, classes with higher import shares experienced larger rises in inflation. The magnitude of the estimate implies that for each 10 percentage point rise in the import share, prices in the two years following the referendum increased by 2.1%.[12]

[12] We have also experimented with controlling for inflation in France, Germany and the United States instead of Euro area inflation. We obtain very similar estimates.

TABLE 4
CONSUMER PRICE EVENT STUDY ESTIMATES WITH TWO-YEAR PERIODS AND BINARY IMPORT SHARE MEASURE

	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation Difference
Post × Import dummy	0.078**	0.048**	0.058***	0.060***
	(0.034)	(0.019)	(0.020)	(0.022)
Oil		0.939	0.211	0.039
		(0.614)	(0.301)	(0.198)
Euro area inflation			0.809**	
			(0.407)	
Observations	168	168	168	168
R^2	0.541	0.720	0.818	0.663
Number of classes	84	84	84	84
Class fixed effects	YES	YES	YES	YES
Period fixed effects	YES	YES	YES	YES

NOTES: The dependent variable in columns (1)–(3) is the U.K. inflation rate at the COICOP class level. The dependent variable in column (4) is the difference between the U.K. and Euro area inflation rates. Post is a dummy variable for the two-year post-referendum period (June 2016–June 2018). The pre-referendum period also covers two years (June 2014–June 2016). The Import dummy variable equals one for COICOP classes with above-median import shares and zero otherwise. OLS estimation. Standard errors in parentheses are clustered by COICOP class. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

It is possible that the depreciation of sterling following the Brexit vote directly affected Euro area inflation. Therefore, in column (4) we include the difference between U.K. and Euro area inflation by COICOP class as our dependent variable. The estimated import share interaction effect is statistically indistinguishable from column (3). In sum, products with higher exposure to import costs saw greater increases in consumer prices following the referendum.

In Table 4, we replace the continuous import share variable used in Table 3 with a binary measure that takes the value one for classes with above-median import shares and zero otherwise. Except for this change, the two tables report the same specifications. Consistent with the graphical evidence in Figure 4, we find that after the referendum inflation increased by more for classes with above-median import shares. In unreported results, we have also estimated specifications with four bins corresponding to the quartiles of the import share distribution. These results confirm that price rises were concentrated in classes in the top two quartiles. However, compared to the continuous variable, the binary and quartile-based measures contain coarser information on how the import share varies across classes since they ignore import share variation *within* bins. Therefore, we revert to using the continuous import share variable $ImportShare_g$ for the remainder of the article.

Table 5 reports the results of estimating equation (12) using one-year periods. The specifications in columns (1)–(4) are the same as those in the corresponding columns of Table 3. Our preferred specification is again in column (3) where we control for both oil price changes and Euro area inflation. The coefficient on the import share interaction term stands at 0.110. Since this is roughly half the value estimated using two-year periods, it is both qualitatively and quantitatively consistent with our earlier results.

In column (5) of Table 5, we interact the import share measure with annual dummies as opposed to the post-referendum indicator. The 2016 dummy takes the value one for the year ending in June 2016, and the 2017 and 2018 dummies are analogously defined (the reference period is the year up to June 2015). This specification allows us to estimate how the post-referendum effect varies over time and to test for pre-trends in the year before the referendum. We estimate positive import share interaction effects for both 2017 and 2018, and the estimated coefficients have similar magnitudes. This implies that the increase in inflation among classes with higher import shares that occurred after the referendum did not subside after the first year but continued through June 2018. This finding is consistent with the literature on

TABLE 5
CONSUMER PRICE EVENT STUDY ESTIMATES WITH ONE-YEAR PERIODS

	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation Difference	(5) Inflation	(6) Inflation
Post × Import Share	0.192**	0.128***	0.110***	0.088***		
	(0.073)	(0.033)	(0.023)	(0.020)		
2012 × Import Share						−0.022
						(0.035)
2013 × Import Share						0.031
						(0.024)
2014 × Import Share						0.033
						(0.028)
2016 × Import Share					0.001	−0.007
					(0.024)	(0.024)
2017 × Import Share					0.116***	0.099***
					(0.027)	(0.025)
2018 × Import Share					0.105***	0.073***
					(0.030)	(0.027)
2019 × Import Share						0.056**
						(0.024)
2020 × Import Share						0.001
						(0.039)
Oil		0.739**	0.438**	0.067	0.442**	0.567**
		(0.344)	(0.201)	(0.115)	(0.204)	(0.228)
Euro area inflation			0.447*		0.449*	0.536***
			(0.239)		(0.243)	(0.162)
Observations	336	336	336	336	336	756
R^2	0.335	0.492	0.559	0.191	0.560	0.426
Number of classes	84	84	84	84	84	84
Class fixed effects	YES	YES	YES	YES	YES	YES
Period fixed effects	YES	YES	YES	YES	YES	YES

NOTES: The dependent variable in columns (1)–(3), (5) and (6) is the U.K. inflation rate at the COICOP class level. The dependent variable in column (4) is the difference between the U.K. and Euro area inflation rates. In columns (1)–(5), the sample runs from the year to June 2015 to the year to June 2018. In column (6), the sample runs from the year to June 2012 to the year to June 2020. Post is a dummy variable for post-referendum periods (the years up to June 2017 and June 2018). OLS estimation. Standard errors in parentheses are clustered by COICOP class. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

the timing of exchange rate pass-through into import and consumer prices (see Burstein and Gopinath, 2014). Reassuringly, we also find no evidence of pre-trends in the data. The estimated import share interaction effect for 2016 is close to zero and statistically insignificant, implying that classes with higher import shares did not witness greater inflation increases in the year before the vote.

In column (6), we extend the sample to run from the year ending June 2012 until the year ending June 2020. As in column (5), we interact the import share with annual dummies and use the year to June 2015 as the reference period. The estimates in column (6) show no evidence of pre-trends before the referendum. After the referendum, the import share interaction effect is positive and significant in 2017, 2018 and 2019 but close to zero in 2020. It is uncertain whether the 2019 effect, which is smaller than for the previous two years, reflects the lingering effects of the Brexit depreciation or other unrelated shocks.

A potential concern with our results is that correlation between the import share and changes in productivity and factor costs could lead to omitted variable bias. Unfortunately, we do not have data on productivity and factor costs at the same frequency and aggregation that we measure inflation. However, we have performed a crude test of this hypothesis using more aggregated ONS data on wage growth for 22 sectors and multi-factor productivity (MFP) growth for 10 sectors. We use data from June 2014 to June 2018 and estimate the event study specification in Equation (12) with sector and period fixed effects as controls.

TABLE 6
CONSUMER PRICE EVENT STUDY ESTIMATES WITH TWO-YEAR PERIODS USING BASIC PRICE IMPORT SHARES

	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation Difference
Post × Import Share	0.143**	0.125***	0.116***	0.113***
	(0.061)	(0.037)	(0.031)	(0.030)
Oil		0.967*	0.329	0.091
		(0.565)	(0.295)	(0.179)
Euro area inflation			0.728*	
			(0.393)	
Observations	168	168	168	168
R^2	0.562	0.760	0.840	0.692
Number of classes	84	84	84	84
Class fixed effects	YES	YES	YES	YES
Period fixed effects	YES	YES	YES	YES

NOTES: The dependent variable in columns (1)–(3) is the U.K. inflation rate at the COICOP class level. The dependent variable in column (4) is the difference between the U.K. and Euro area inflation rates. Import shares are measured in terms of basic prices. Post is a dummy variable for the two-year post-referendum period (June 2016–June 2018). The pre-referendum period also covers two years (June 2014–June 2016). OLS estimation. Standard errors in parentheses are clustered by COICOP class. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

Using either two-year or one-year periods, we find there is no significant change in wage or MFP growth after the referendum and that variation in changes across sectors is not significantly correlated with the import share (results available upon request).

The import share variable measures the import cost share at purchasers' prices. As discussed in Subsection 4.1, the expenditure share on distribution services λ_g is not reported in the U.K. input–output tables, and to calculate import shares at purchasers' prices we estimate λ_g indirectly using the U.K. Supply and Use Tables. Therefore, as an additional robustness check, we also report results when import shares are measured at basic prices. Basic prices do not include distribution services nor net product taxes. In our theory, this corresponds to letting $\lambda_g \to 0$.

Table 6 presents the same set of two-year period specifications estimated in Table 3, except that $ImportShare_g$ is defined as the share of imports in consumer expenditure at basic prices. Again, we find that classes with higher import shares experienced greater increases in inflation after the Brexit vote. However, the import share interaction coefficient is smaller when the basic price measure is used because not including distribution services overestimates variation in import shares across classes.[13] This difference highlights the importance of accounting for distribution costs when measuring exposure to exchange rate changes, as stressed by Burstein et al. (2003).

5.4. *Producer Prices.* To shed further light on the price effects of the Brexit referendum, we also analyze producer prices. We have PPI data for 42 CPA sectors. The producer price of sector g corresponds to the domestic good price p_g^D in our model, meaning that producer price inflation is given by Equation (8). Therefore, if we define $ProducerImportShare_g = \sum_{j=1}^{J} \theta_{gj}$ to be the share of imported inputs in domestic production costs for sector g, we have

$$\hat{p}_g^D = ProducerImportShare_g \times \hat{p}^M.$$

Motivated by this expression, we estimate the event study specification (12) with PPI inflation as the dependent variable and the $Post_t$ dummy interacted with $ProducerImportShare_g$ on

[13] The overestimation results from the expenditure share of distribution services being relatively high (average $\lambda_g = 0.28$) and positively correlated with the basic price import share (a correlation of 0.83), together with distribution services having a low import share of 0.13.

TABLE 7
PRODUCER PRICE EVENT STUDY ESTIMATES WITH TWO-YEAR PERIODS

	(1) PPI Inflation	(2) PPI Inflation	(3) PPI Inflation
Post × Producer Import Share	1.044***	0.534**	0.459**
	(0.355)	(0.202)	(0.210)
Oil		0.746***	0.544
		(0.145)	(0.369)
PPI Euro area inflation			0.330
			(0.488)
Observations	84	84	84
R^2	0.762	0.870	0.880
Number of sectors	42	42	42
Sector fixed effects	YES	YES	YES
Period fixed effects	YES	YES	YES

NOTES: The dependent variable is the U.K. PPI inflation rate for 42 CPA sectors. Post is a dummy variable for the two-year post-referendum period (June 2016–June 2018). The pre-referendum period also covers two years (June 2014–June 2016). OLS estimation. Standard errors in parentheses are clustered by CPA sector. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

the right-hand side. In this case, the oil price exposure variable is measured at the CPA sector level, and we control for PPI inflation in the Euro area.

Table 7 presents the producer price regression results using two-year periods. Although the estimates are less precise than for consumer prices, we find strong evidence that the producer import share interaction effect is positive. This implies that sectors where imported intermediate inputs account for a greater share of production costs experienced larger increases in inflation following the referendum. These estimates support Goldberg and Campa's (2010) argument that the effect of exchange rate movements on consumer prices depends not only on the direct import share of consumer expenditure, but also on indirect import consumption through consumer purchases of goods produced domestically using imported inputs. Recall from Table 1 that the import share of aggregate U.K. consumer expenditure is almost evenly divided between direct and indirect imports. It follows that failing to account for indirect import consumption would severely understate the exposure of consumer prices to import costs.

We also use the producer price specification to look for evidence of strategic complementarities in domestic price setting. In our motivating framework, domestic producer prices p_g^D are unaffected by the price of sector g imports p_g^M after controlling for indirect import use. However, in models with strategic complementarities in price setting, producer prices also depend on the prices of competing goods, such as imports of the same product group.[14] Since imports became more expensive following the referendum, strategic complementarity in pricing would lead domestic producer prices to rise by more in sectors where the share of imports in expenditure at basic prices γ_g is higher. Auer et al. (2021) find evidence consistent with such behavior following the 2015 appreciation of the Swiss franc.

To test for strategic complementarities, we estimate producer price regressions analogous to those reported in Table 7, but we also include the interaction of the $Post_t$ dummy with the direct import share at basic prices γ_g on the right-hand side. This interaction is a proxy for the change in competitors' prices following the referendum and, if there are strategic complementarities in pricing, we expect the interaction to have a positive effect on domestic producer prices. The results are shown in Table 8. In columns (1)–(3), we also control for the $Post_t \times ProducerImportShare_g$ interaction used in Table 7, while in columns (4)–(6) we drop this interaction.[15] In all cases, the estimated effect of the direct import share interaction term

[14] See Amiti et al. (2019) for firm-level evidence of strategic complementarities in Belgian manufacturing.

[15] Note that any impacts on producer prices of the producer import share and the direct import share at basic prices are absorbed by the sector fixed effects in Table 8.

TABLE 8
PRODUCER PRICE EVENT STUDY ESTIMATES WITH TWO-YEAR PERIODS — STRATEGIC COMPLEMENTARITIES

	(1) PPI Inflation	(2) PPI Inflation	(3) PPI Inflation	(4) PPI Inflation	(5) PPI Inflation	(6) PPI Inflation
Post × Producer Import Share	1.023**	0.515***	0.448**			
	(0.379)	(0.189)	(0.199)			
Post × Direct Import Share at basic prices	−0.032	−0.031	−0.024	−0.097	−0.047	−0.034
	(0.056)	(0.044)	(0.049)	(0.069)	(0.057)	(0.058)
Oil		0.745***	0.555		1.095***	0.719
		(0.135)	(0.360)		(0.088)	(0.465)
PPI Euro area inflation			0.311			0.496
			(0.492)			(0.532)
Observations	84	84	84	84	84	84
R^2	0.766	0.873	0.882	0.391	0.822	0.847
Number of sectors	42	42	42	42	42	42
Sector fixed effects	YES	YES	YES	YES	YES	YES
Period fixed effects	YES	YES	YES	YES	YES	YES

NOTES: The dependent variable is the U.K. PPI inflation rate for 42 CPA sectors. Post is a dummy variable for the two-year post-referendum period (June 2016–June 2018). The pre-referendum period also covers two years (June 2014–June 2016). OLS estimation. Standard errors in parentheses are clustered by CPA sector. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

TABLE 9
CONSUMER EXPENDITURE SHARE EVENT STUDY ESTIMATES WITH TWO-YEAR PERIODS

	(1) Consumer Expenditure Share	(2) Consumer Expenditure Share	(3) Consumer Expenditure Share
Post × Import Share	0.058	−0.098	−0.194
	(0.519)	(0.544)	(0.564)
Observations	150	150	150
R^2	0.380	0.390	0.396
Oil	NO	YES	YES
Euro area inflation	NO	NO	YES
Number of classes	75	75	75
Class fixed effects	YES	YES	YES
Period fixed effects	NO	NO	NO

NOTES: The dependent variable is the consumer expenditure share at the COICOP class level. Post is a dummy variable for the two-year post-referendum period. OLS estimation. Standard errors in parentheses are clustered by COICOP class. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

is close to zero and statistically insignificant. Therefore, we do not find evidence of strategic complementarities in price setting following the Brexit referendum. However, we caution that our results do not rule out the existence of strategic complementarities at more disaggregated levels.

5.5. *Consumer Expenditure.* How did the increase in prices following the referendum affect consumer expenditure patterns? To address this question, we estimate the event study specification (12) using data on the share of consumer expenditure by COICOP class. We obtain consumer expenditure for 75 COICOP classes from the Living Costs and Food Survey and use the log difference of expenditure shares over two-year periods as the dependent variable.[16]

The results of estimating the consumer expenditure regressions are shown in Table 9. Regardless of whether or not the Oil and Euro area inflation controls are included, we estimate that the import share interaction term is uncorrelated with changes in consumer expenditure. These estimates are consistent with consumer demand having a unit elasticity of substitution between COICOP classes. Consequently, they provide a rationale for using constant expenditure shares to aggregate price changes across classes when estimating the aggregate impact of the Brexit depreciation on consumer prices, as we do in Subsection 7.1. They also imply that real consumer expenditure growth in the two years after the referendum was lower for classes with higher import shares, suggesting that the Brexit depreciation reduced real consumption growth.

6. EXCHANGE RATE PASS-THROUGH

We have shown that the Brexit vote led to faster price increases for products with higher import shares. However, we cannot infer exchange rate pass-through from the event study specification because it does not account for exchange rate variation around the time of the referendum. Therefore, to estimate pass-through we now modify our estimation equation to

[16] During our sample, the Living Costs and Food Survey switched from collecting data on a calendar year basis to using the U.K. financial year, which ends in March (e.g., the 2015 survey covers April 2015 to March 2016). For the pre-period, we use the difference between the 2013 calendar year survey and the 2015 financial year survey, while for the post-period we use the difference between the 2015 and 2017 financial year surveys.

TABLE 10
IMPORT COST PASS-THROUGH ESTIMATES

	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation	(5) Inflation
Import cost pass-through	0.819***	0.972***	1.111***	1.412***	1.209***
	(0.236)	(0.281)	(0.365)	(0.434)	(0.350)
Test: Import cost pass-through = 1					
F-stat	0.57	0.01	0.09	0.90	0.36
p-value	0.45	0.92	0.76	0.34	0.55
Number of lags	4	5	6	7	8
Observations	2250	2250	2250	2250	2250
R^2	0.601	0.601	0.601	0.603	0.603
Class×season fixed effects	YES	YES	YES	YES	YES
Quarter fixed effects	YES	YES	YES	YES	YES

NOTES: The dependent variable is the quarterly U.K. inflation rate at the COICOP class level. The sample covers 2011Q1 to 2018Q2. The main regressor is the exchange rate change, contemporaneous and including lags as specified, interacted with import shares by COICOP class. Import cost pass-through is the sum of the coefficients on all import share interaction terms. Euro area inflation rates by COICOP class and exposure to oil price changes are included as controls (coefficients not reported). Season fixed effects refer to the same quarter every year. OLS estimation. Standard errors in parentheses are clustered by COICOP class. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

control for observed exchange rate movements both before and after the referendum. Specifically, we estimate a distributed lag version of Equation (11) given by

$$Inflation_{gt} = \sum_{s=0}^{T} \beta_s ImportShare_g \times \hat{e}_{t-s} + Z_{gt} + \nu_{gq} + \nu_t + \varepsilon_{gt}, \tag{13}$$

where $\hat{e}$ is the log difference in the sterling effective exchange rate index. This specification allows for the effect of exchange rate movements on consumer prices to take up to T quarters and, consistent with the theoretical model, assumes the elasticity of consumer prices to the exchange rate varies across classes with different import shares. Consequently, estimating this equation gives what we defined in Subsection 3.4 as import cost pass-through. Our estimate of import cost pass-through β in the long run equals the sum of the coefficients of all the $ImportShare_g$ times exchange rate interaction terms, $\beta = \sum_{s=0}^{T} \beta_s$. Recall that if there is complete import cost pass-through then $\beta = 1$, and that Equation (11) implies β can be interpreted as the product of pass-through at the border β^M and domestic pass-through β^D.

We estimate Equation (13) using quarterly data from 2011Q1 to 2018Q2 with CPI inflation by COICOP class as the dependent variable. As in the event study, we control for Euro area inflation and exposure to oil price changes. We also include quarter fixed effects ν_t and class-season fixed effects ν_{gq}, where the seasons q are the four quarters of the year. That is, we include four fixed effects per COICOP class, each of which turns on in a different quarter. The class-season effects control for seasonal variation in product-specific inflation rates. The identifying assumption is that changes in inflation captured by the error term ε_{gt} that are correlated with the timing of exchange rate movements are uncorrelated with import share variation across classes.

Panel C of Table 2 shows descriptive statistics for the estimation variables at quarterly frequency and Table 10 presents the regression results. For each regression, we show estimated import cost pass-through $\beta = \sum_{s=0}^{T} \beta_s$. The full set of coefficient estimates β_s for each of the exchange rate lags is reported in Appendix B (online). In column (1), we include four exchange rate lags and estimate that import cost pass-through equals 0.819. This estimate is statistically different from zero, confirming that exchange rate depreciations lead to higher inflation in classes with higher import shares. However, it is insignificantly different from one, implying that we cannot reject the hypothesis of complete import cost pass-through.

TABLE 11
EXCHANGE RATE PASS-THROUGH ESTIMATES WITHOUT IMPORT SHARE INTERACTIONS

	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation	(5) Inflation
Exchange rate pass-through	0.120***	0.150***	0.158***	0.150***	0.138***
	(0.032)	(0.033)	(0.036)	(0.038)	(0.041)
Number of lags	4	5	6	7	8
Observations	2250	2250	2250	2250	2250
R^2	0.591	0.592	0.592	0.592	0.592
Class × season fixed effects	YES	YES	YES	YES	YES
Quarter fixed effects	NO	NO	NO	NO	NO

NOTES: The dependent variable is the quarterly U.K. inflation rate at the COICOP class level. The sample covers 2011Q1 to 2018Q2. The main regressor is the exchange rate change, both contemporaneous and including lags as specified. Exchange rate pass-through is the sum of the coefficients on all exchange rate terms. Euro area inflation rates by COICOP class and exposure to oil price changes are included as controls (coefficients not reported). Season fixed effects refer to the same quarter every year. OLS estimation. Standard errors in parentheses are clustered by COICOP class. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

Complete import cost pass-through implies that a 1% exchange rate depreciation causes a 0.1% greater increase in class-level prices for each 10% increase in the import share.

In columns (2)–(5), we add additional exchange rate lags going from five lags in column (2) up to eight lags in column (5). Although the point estimate of import cost pass-through varies somewhat across specifications, it is always positive and significant but not statistically different from one. Therefore, the evidence in Table 10 is consistent with complete import cost pass-through to consumer prices in the period around the Brexit referendum. However, neither can we rule out the possibility that import cost pass-through is high but below 100%.

Because import cost pass-through is defined conditional on the import share, it is conceptually distinct from aggregate exchange rate pass-through, which is given by the elasticity of the overall CPI p^C to the exchange rate. But having estimated β, we can aggregate across COICOP classes to obtain aggregate exchange rate pass-through. Since our pass-through specification uses a differences-in-differences identification strategy, aggregation requires making one additional assumption to pin down the level effect of the depreciation on prices, which is absorbed by the period fixed effects in Table 10. We make the assumption that the Brexit depreciation did not affect the price index of a hypothetical class with an import share of zero. This assumption is consistent with the evidence in Figure 4 showing that there was only a small increase in average inflation following the referendum among classes with below-median import shares.

Let η_g be the share of class g in consumer expenditure. Then using $\hat{p}^C = \sum_{g=1}^{G} \eta_g \hat{p}_g^C$ and Equation (11) gives that aggregate pass-through $\hat{p}^C/\hat{e}$ satisfies

$$\frac{\hat{p}^C}{\hat{e}} = \beta \sum_{g=1}^{G} \eta_g \times ImportShare_g. \tag{14}$$

Substituting $\beta = 1$ and using Equation (14) to weight import shares across classes implies that pass-through to the aggregate CPI equals 0.29, which is the import share of aggregate consumption reported in Table 1. This is our preferred estimate of long-run exchange rate pass-through in our sample.

We have estimated pass-through from a two-step process that accounts for heterogeneity in import shares across classes. By contrast, pass-through is usually estimated by regressing price changes on exchange rate movements (and marginal cost controls) without including import share interactions. For comparison, Table 11 reports the results from estimating a conventional pass-through specification on our sample. In particular, we estimate a modified version of Equation (13) where the exchange rate terms are not interacted with import shares.

We also drop the quarter fixed effects as they are collinear with the exchange rate movements. In this case, estimated exchange rate pass-through to consumer prices is around 0.15 and is not sensitive to the number of lags included (see Appendix B for the estimated coefficients on all exchange rate lags).

This finding is consistent with existing estimates of pass-through in the United Kingdom that do not control for import share heterogeneity. Goldberg and Campa (2010) report that using this approach actually delivers a negative pass-through estimate for the United Kingdom after four quarters, while Burstein and Gopinath (2014) estimate pass-through of 0.14 after eight quarters for a consumer price measure that excludes services. Forbes et al. (2018) estimate pass-through for the United Kingdom using a structural vector autoregression framework. They find that pass-through varies depending on the source of the exchange rate shock, but the average pass-through to consumer prices in their sample after eight quarters is 0.13.

Our preferred pass-through estimate is roughly twice as large as the estimates reported in Table 11. This difference illustrates the importance of allowing for exchange rate exposure to vary across product groups when estimating consumer price pass-through. Formally, not including the import share interaction terms in specification (13) can generate heterogeneity bias if import shares are correlated with consumer expenditure shares, and omitted variable bias from not including time fixed effects. In our data, the correlation between import shares and expenditures shares is −0.09, which generates a negligible heterogeneity bias. Instead, a negative correlation between the quarter fixed effects and exchange rate changes is responsible for the downward bias evident in Table 11.

7. COST OF LIVING

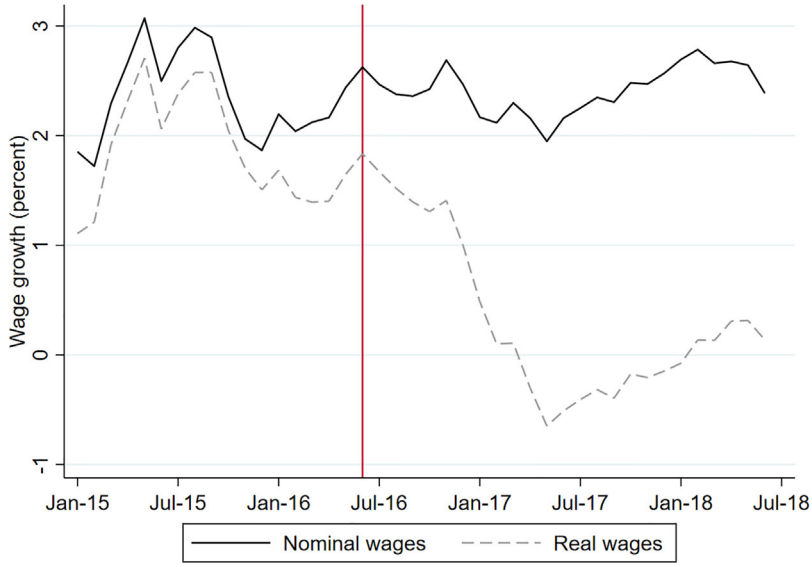
In this section, we use the empirical results reported above to provide indicative estimates of how the Brexit vote has affected the cost of living and real wages in the United Kingdom. We consider both aggregate effects and distributional consequences across households with different expenditure patterns. The analysis sheds light on the welfare effects of exchange rate movements and on how the referendum has affected U.K. living standards prior to Brexit occurring.

Throughout this section, we assume that, consistent with the estimates in Table 10, there is complete import cost pass-through. We also assume that the referendum led to a 10% depreciation of sterling since the effective exchange rate depreciated by around 10% immediately following the vote and then fluctuated in a band roughly 10% below its pre-referendum value over the next year. Sterling also experienced a more modest and gradual depreciation in the first half of 2016, as shown in Figure 1. To avoid conflating the inflation effects of the pre-referendum depreciation with Brexit, we do not use the event study estimates from Section 5 to compute cost of living effects. However, to the extent that this depreciation was driven by uncertainty regarding the outcome of the vote, our results will underestimate the magnitude of the Brexit depreciation and the consequent price rises.

The magnitude of the Brexit depreciation measures how changes in foreign exchange traders' expectations regarding future U.K. economic performance affected the value of sterling. The analysis below seeks to estimate the impact of this depreciation on living costs, while remaining agnostic about why the vote caused a 10% depreciation. Consequently, although our results provide a summary estimate of the price effects of the Brexit depreciation, our approach does not speak to why the leave vote caused sterling to depreciate.

7.1. *Aggregate Effects.*

To infer aggregate changes in inflation from our estimates, we need to know the level effect of the depreciation on prices. Consequently, we maintain the assumption introduced in Section 6 that the Brexit depreciation did not impact the price index of a class with zero import share. This assumption implies that the results reported below only include referendum effects that operate through the impact of the sterling depreciation on import costs. For example, any impact of the depreciation on productivity is not accounted for.



NOTES: Wage growth is the percentage change year on year in the three-month average of Average Weekly Earnings - Total Pay. Series KAC3 for nominal wages, A3WW for real wages. The vertical line indicates the referendum date (June 2016).

FIGURE 5

WAGE GROWTH IN THE UNITED KINGDOM, 2015–18
[COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

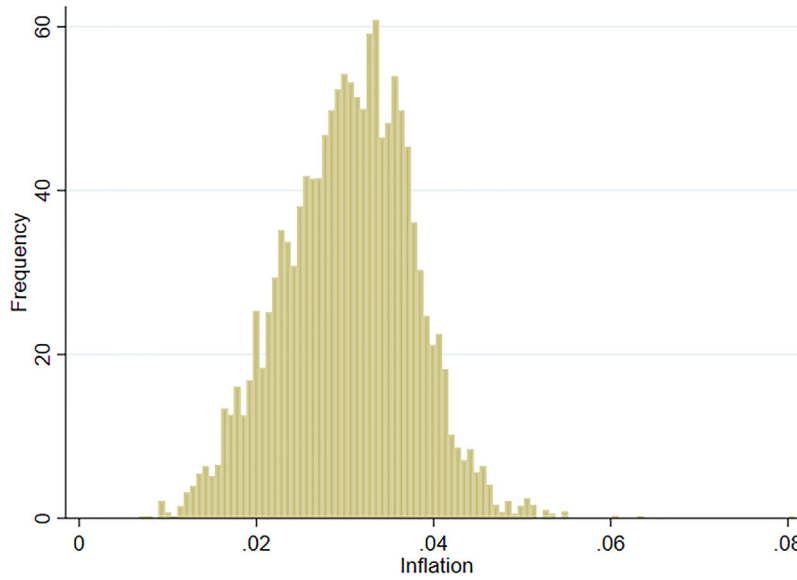
Similarly, any effects of Brexit on prices that are uncorrelated with variation in import shares, for example, due to monetary policy easing by the Bank of England following the referendum or domestic demand and supply shocks caused by anticipation of Brexit, are not captured by our estimates.

Our findings imply that the 10% depreciation due to the Brexit vote increased prices for a class g by $10 \times ImportShare_g$ percent. Aggregating across classes using consumer expenditure shares, it follows that the Brexit depreciation increased the U.K. CPI by around 2.9% by June 2018. This calculation holds the expenditure weight for each COICOP class fixed at 2016 levels. However, using 2018 weights instead also delivers an estimated effect of 2.9%, as the weights vary little over time and the correlation between the 2016 and 2018 weights is 0.99. Comparing our estimate to the approximately 2 percentage point gap between U.K. and Euro area inflation in the two years after the referendum shown in Figure 3 implies that inflationary pressures not linked to the exchange rate were more muted in the United Kingdom than the Euro area following the referendum.

A 2.9% price rise is equivalent to a £870 per year increase in the cost of living for the average household. In aggregate, this corresponds to £23.5 billion per year additional expenditure for the United Kingdom, or £450 million per week.[17]

Figure 5 shows nominal and real wage growth before and after the referendum. There is no evidence of a trend break in nominal wage growth around the time of the referendum, while real wage growth declined sharply and became negative in 2017. Costa et al. (2019) estimate that, if anything, the depreciation of sterling following the referendum reduced nominal wage growth. Based on this evidence, we conclude that the 2.9% increase in consumer prices caused by the fall in sterling led to a decline in real wage growth of a similar magnitude. Thus, by June 2018 the average U.K. household had to spend around 1.4 additional weeks' wages to afford the same consumption basket. Through this channel, the Brexit vote delivered a swift negative shock to U.K. living standards.

[17] Average annual U.K. household expenditure in 2018 was £29,900 and there were 27.2 million households.



NOTES: This histogram plots the distribution of inflation effects due to the Brexit depreciation across 4,912 households in Great Britain. The households are weighted such that the distribution is representative across all British households. The effects are computed using household-level expenditure weights across COICOP classes assuming complete import cost pass-through and a 10% depreciation due to the Brexit vote. See text for further details.

FIGURE 6

DISTRIBUTION OF INFLATION EFFECTS DUE TO THE BREXIT DEPRECIATION ACROSS BRITISH HOUSEHOLDS
[COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

7.2. *Distributional Consequences.* We have shown that the referendum led to larger price increases for COICOP classes with higher import shares. Consequently, households that spend relatively more on classes with greater import shares faced larger cost of living increases. To shed light on the magnitude of this distributional effect of the Brexit depreciation, we use data on the composition of household expenditure from the ONS Living Costs and Food Survey for the financial year ending March 2016.

We start by computing the expenditure share of each COICOP class by household for 4,912 households in Great Britain (i.e., the United Kingdom excluding Northern Ireland).[18] Let η_g^h denote the expenditure share of household h on class g. We then calculate the effect of a 10% depreciation on the price of each household's consumption basket by using the household-specific expenditure weights to aggregate class-level price changes.[19] That is, we calculate

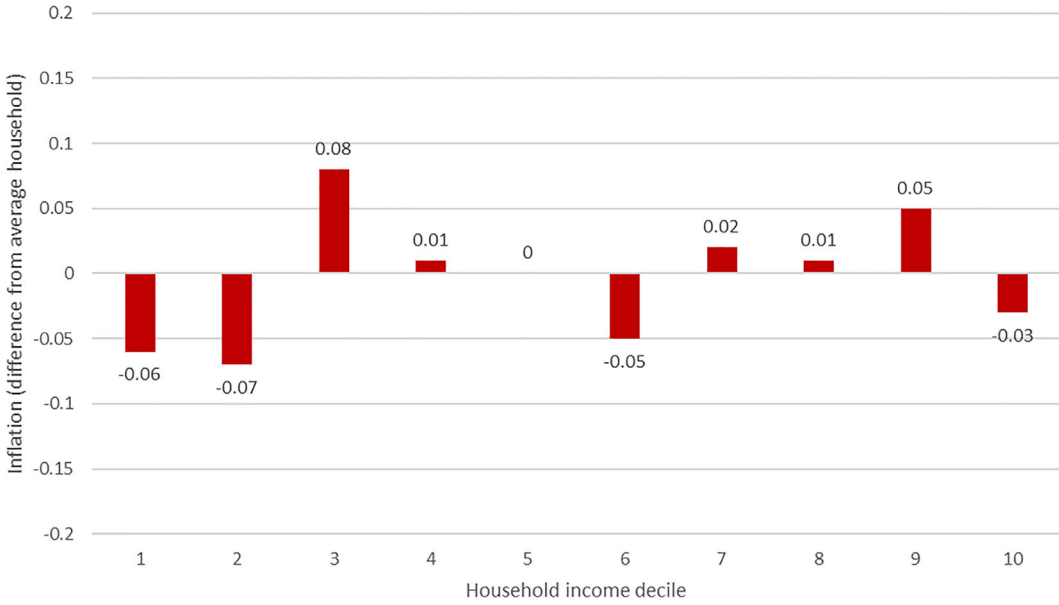
$$\hat{p}^{C,h} = \sum_{g=1}^{G} \eta_g^h \times ImportShare_g \times 0.1,$$

where $\hat{p}^{C,h}$ is the inflation effect on household h due to the Brexit depreciation.

Figure 6 plots the histogram of inflation effects across households, where the households are weighted such that the distribution is representative across all households in Great Britain. The bulk of the distribution is concentrated in the range from 2% to 4%, and the median is close to our aggregate inflation impact. A household at the 75th percentile of the

[18] The data are reported at the level of COICOP items. We map items to classes using a concordance provided by the ONS.

[19] In these calculations, the assumption that the price index of a class with a zero import share is unaffected by the Brexit depreciation affects the level of inflation for each household but not differences in inflation between households.



Notes: For each decile of the disposable household income distribution, we show the estimated inflation increase due to the Brexit depreciation minus the increase for the average U.K. household (in percentage points). Decile 1 captures the poorest households, decile 10 the richest. The increase for the average U.K. household is 2.9 percentage points. The effects are computed using household expenditure weights across COICOP classes by income decile assuming complete import cost pass-through and a 10% depreciation due to the Brexit vote. See text for further details.

Figure 7

INFLATION EFFECTS BY INCOME DECILE DUE TO THE BREXIT DEPRECIATION
[COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

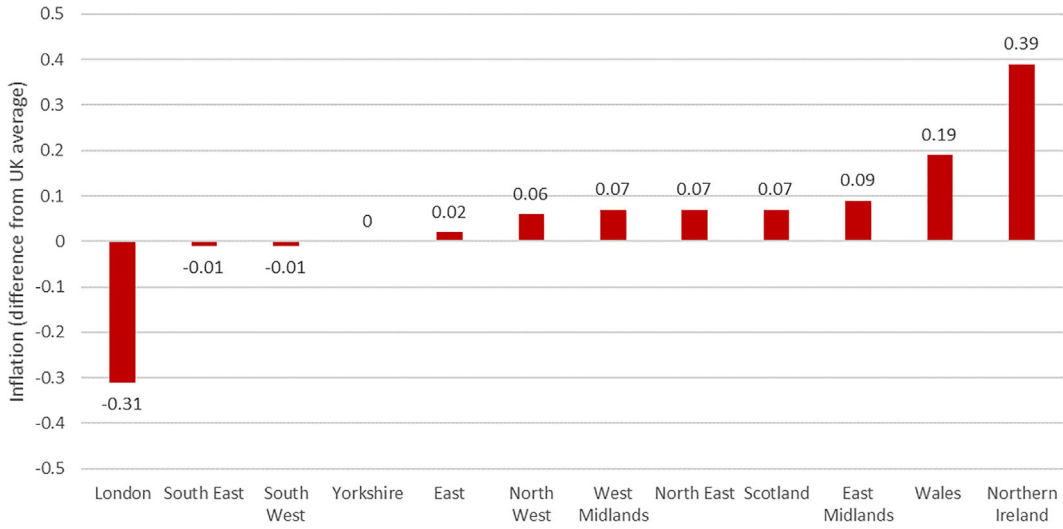
distribution experienced a 1 percentage point higher price increase than a household at the 25th percentile. This shows that there was considerable heterogeneity across households in how the depreciation affected the cost of living.

How did the distributional consequences of the referendum vary across different types of household? To address this question, we repeat the exercise above using the expenditure weights for household aggregates by income decile and by region. Figure 7 presents inflation effects by decile of the household income distribution. For each decile, we show the estimated inflation increase due to the Brexit depreciation relative to the 2.9 percentage point effect for the average U.K. household. Decile 1 is the poorest households, decile 10 the richest. Overall, inflation varies little across income deciles, implying that the cost of living rises due to the referendum shock are evenly shared throughout the income distribution.

This result differs from Cravino and Levchenko (2017) who study the effects of the 1994 Mexican peso devaluation on the cost of living. They find that as a consequence of different expenditure weights on tradable versus nontradable categories, the cost of living increased by about 25% more for the bottom income decile of Mexican households compared to the top decile. By contrast, in our data there is no systematic correlation between household income and the expenditure share of imports. This comparison illustrates how the distributional effects of an exchange rate shock may differ between an emerging economy and a high-income economy because of differences in household expenditure patterns. However, like Cravino and Levchenko (2017), our results show the importance of local distribution costs in mediating the pass-through of exchange rate movements into consumer prices.[20]

Cravino and Levchenko (2017) also find that, within product categories, poorer Mexican households consume lower-priced varieties and that such varieties faced steeper price in-

[20] See Subsection 5.3 on the importance of distribution costs.



NOTES: For each region, we show the estimated inflation increase due to the Brexit depreciation minus the increase for the average U.K. household (in percentage points). The increase for the average U.K. household is 2.9 percentage points. The effects are computed using household expenditure weights across COICOP classes by region assuming complete import cost pass-through and a 10% depreciation due to the Brexit vote. See text for further details.

FIGURE 8

INFLATION EFFECTS BY REGION DUE TO THE BREXIT DEPRECIATION
[COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

creases following the peso devaluation. This within-category effect amplifies the anti-poor impact of the peso devaluation. Unfortunately, we do not have corresponding U.K. data on cross-household variation in exposure to import costs within COICOP classes.

Figure 8 shows the estimated inflation effects by region, again relative to the average U.K. household. Exposure to higher import costs varies considerably across regions. The effect is smallest for London (0.31 percentage points below average) because households in London tend to spend relatively more on classes with low import shares such as rent. Households in Northern Ireland, however, face a considerably larger rise in inflation (0.39 percentage points above average) because they spend a relatively greater fraction of their income on higher import share classes such as food and drink, clothing, and fuel. Welsh households also face a notable above-average inflation increase, while differences across the remaining regions are more muted.

Similarly, Cravino and Levchenko (2018) document sizeable inflation differences across six Mexican regions in the wake of the 1994 peso devaluation. They find that this variation is partly related to differences in consumption baskets across regions, with the smallest price increases occurring in Mexico City. This is consistent with our finding that expenditure in the most urban U.K. region, London, is least exposed to the Brexit depreciation.

8. CONCLUSINS

The United Kingdom's surprise vote in favor of Brexit in June 2016 led to a sharp and unanticipated depreciation in the value of sterling. We exploit this depreciation to study the effect of the leave vote on U.K. living standards through changes in consumer prices. Our identification strategy is based on the fact that exposure to exchange rate movements varies across products depending on both the share of household expenditure directly allocated to imported goods and the extent to which imported intermediates are used in domestic production. We implement this strategy using a simple model of price determination that shows how to measure the import share of consumer expenditure from data in input–output tables.

Consistent with the model we find that in the two years following the referendum, consumer price inflation rose more for products with higher import shares and that producer price inflation rose more for products where imported inputs account for a larger share of production costs. We also show how our approach can be used to estimate exchange rate pass-through while accounting for differences in import shares across products and controlling for time fixed effects. We cannot reject the hypothesis that there is complete pass-through of import costs into consumer prices which, for the United Kingdom, implies an aggregate exchange rate pass-through of 0.29. This is roughly double the estimate obtained using the same data from a pass-through specification that does not account for import share heterogeneity.

We use our estimates to quantify how the roughly 10% depreciation of sterling in the immediate aftermath of the Brexit referendum affected living costs in the United Kingdom. Our preferred estimate is that the depreciation increased consumer prices by 2.9% and that this led to a comparable decline in real wage growth. Increases in the cost of living were similar across households in different deciles of the income distribution but not across regions. London suffered least, while Northern Ireland and Wales were hit worst.

The decision to leave the EU is the most important change in U.K. economic policy for a generation. There is a broad consensus among economists that the long-run welfare effects of Brexit will be negative but it will be years, if not decades, before these predictions can be tested. However, as with other financial assets, exchange rate movements are forward looking, and our results document that voters are already paying a price for Brexit as a consequence of the cost of living increase caused by the post-referendum depreciation.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table A1: Import shares by COICOP class
Table A2: Import cost pass-through showing full set of coefficient estimates
Table A3: Exchange rate pass-through without import share interactions showing full set of coefficient estimates

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