The Consequences of the Brexit Vote for UK Inflation and Living Standards: First Evidence

Holger Breinlich Elsa Leromain Dennis Novy Thomas Sampson*

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Abstract

We analyze the impact of the Brexit referendum in June 2016 on UK inflation and living standards. We propose a theoretical framework in which households are exposed to imported goods directly through the consumption of foreign final goods and indirectly through the use of foreign intermediates in domestic production. We generate empirical measures of the direct and indirect exposure to imported goods based on UK input-output tables. The pound depreciated by around 10% immediately following the referendum and we show that product groups with larger direct and indirect import shares experienced higher inflation after the vote. Our results suggest that the referendum increased aggregate UK inflation by 1.7 percentage points within one year. Exploiting differences in expenditure patterns across household types we find that the increase in inflation is evenly shared across the income distribution, but not across regions. London is the least affected region, while Scotland, Wales and Northern Ireland are hardest hit. We conclude that voting to leave the EU has already raised the cost of living for UK households.

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1 Introduction

The result of the Brexit referendum held on 23 June 2016 took many observers by surprise. The British electorate voted to leave the European Union with a majority of 51.9%. As soon as the eventual vote outcome became clear during the referendum night, the pound depreciated sharply against the US dollar and the euro. This decline in the exchange rate persisted in the subsequent months, with sterling still around 10% below its pre-referendum value by November 2017. The decline in the value of the pound is consistent with the referendum outcome causing market participants to downgrade their expectations about the future performance of the UK economy. Both increased uncertainty and the likelihood that the UK would in future become less open to trade, investment and immigration with the EU probably contributed to this downgrade in expectations.

Standard economic theory predicts that a strong and sustained depreciation of a country's exchange rate should lead to an increase inflation by raising the cost of imports. In fact, CPI inflation in the United Kingdom rose from 0.5% in June 2016 to to 2.6% in June 2017 and 3.0% in September 2017. To what extent can we attribute this rise in inflation to the Brexit vote and subsequent exchange rate depreciation, compared to other factors such as changes in oil prices and inflationary pressures resulting from faster growth in the Euro area and the US?

In this technical report we estimate the impact of the Brexit vote on CPI inflation in the UK, focusing primarily on how the exchange rate shock following the referendum affected inflation. We treat the referendum outcome, and the resulting exchange rate depreciation, as an unanticipated shock to the UK economy and study their consequences. After accounting for other determinants of inflation, we find that products with a larger import share in consumer expenditure experienced higher inflation following the referendum. This shows that the exchange rate depreciation caused by the Brexit vote has put upwards pressure on inflation. We find evidence that higher import prices for both final goods and intermediate inputs used by UK producers have contributed to the rise in inflation.

Section 2 of the report lays out a theoretical framework to motivate our estimation approach. Section 3 describes the data we use and how we construct our main variables. Section 4 introduces our estimation specification and Section 5 presents the results. Finally, Section 6 discusses the implications of our findings for aggregate inflation and for differences in inflation rates across household types, before Section 7 concludes.

2 Theoretical framework

We are interested in how UK consumer prices changed after the referendum shock led to the depreciation of sterling. Building on Berlingieri, Breinlich and Dhingra (2017), we sketch a framework that will provide the basis of our empirical strategy.

The representative household in the domestic economy derives utility from the consumption of a basket of G goods.[1] The consumption of good g, C_g, is a composite of an imported good M_g and a domestic good D_g such that

$$C_g = M_g^{\gamma_g} D_g^{1-\gamma_g},$$

with γ_g being the share in the total consumption of g that the household spends on the imported good. We can express the logarithmic change in the consumer price index for good g as

$$\ln\left(\frac{P_{g,t}}{P_{g,t-1}}\right) = \gamma_g \ln\left(\frac{P_{gM,t}}{P_{gM,t-1}}\right) + (1-\gamma_g)\ln\left(\frac{P_{gD,t}}{P_{gD,t-1}}\right), \tag{1}$$

where $P_{g,t}$ is the price index for the composite good g in period t, and $P_{gM,t}$ and $P_{gD,t}$ are the prices of the imported and domestic goods. The first term on the right-hand side of equation (1) indicates that a change in the price $P_{gM,t}$ of the imported good feeds into the price index $P_{g,t}$ *directly* through household expenditure. In addition, a change in the price of the imported good also feeds into the price index *indirectly* to the extent that the imported good is used as an input in the production of the domestic good and thus affects $P_{gD,t}$. The magnitude of the direct effect crucially depends on the value of γ_g. The magnitude of the indirect effect depends on how much the price of the domestic good is affected by changes in intermediate input prices.

We assume that the production of the domestic good g requires a primary factor (e.g., labour), and a bundle of domestic and imported intermediate inputs. More specifically, the production function of the representative domestic firm in sector g is

$$y_g = \phi_g l^{1-\alpha_g} \left({i_{Dg}}^{1-\varepsilon_g} {i_{Mg}}^{\varepsilon_g}\right)^{\alpha_g},$$

where ϕ_g is total factor productivity (TFP), l is the primary factor, i_{Dg} is the domestic intermediate input and i_{Mg} is the imported intermediate input, α_g denotes the share of total intermediate consumption in gross output of sector g, and ε_g is the share of imported intermediates in total intermediate consumption. With a perfect pass-through

[1] We use "goods" to refer to any product consumers purchase. In the empirical implementation this will cover both goods and services.

from production costs to prices, this technology implies a price ratio for domestic good g of

$$\frac{P_{gD,t}}{P_{gD,t-1}} = \left(\frac{\phi_{g,t}}{\phi_{g,t-1}}\right)^{-1} \left(\frac{w_t}{w_{t-1}}\right)^{1-\alpha_g} \left(\left(\frac{P_{gID,t}}{P_{gID,t-1}}\right)^{1-\varepsilon_g} \left(\frac{P_{gIM,t}}{P_{gIM,t-1}}\right)^{\varepsilon_g}\right)^{\alpha_g}, \quad (2)$$

where w_t is the factor price for the primary factor, $P_{gID,t}$ is the price index of the domestic intermediate input and $P_{gIM,t}$ is the price index of the imported intermediate input. The exchange rate shock can affect prices through changes in TFP, factor prices and the cost of intermediate inputs (domestic or imported). Given the difficulty of convincingly identifying productivity and factor prices effect (to the extent they exist), we focus on intermediate inputs for now. However, we will allow for general equilibrium effects more broadly in our empirical results. Without changes in TFP or factor prices, the price ratio for the domestic good can then be expressed as

$$\frac{P_{gD,t}}{P_{gD,t-1}} = \left(\left(\frac{P_{gID,t}}{P_{gID,t-1}}\right)^{1-\varepsilon_g} \left(\frac{P_{gIM,t}}{P_{gIM,t-1}}\right)^{\varepsilon_g}\right)^{\alpha_g}. \quad (3)$$

We assume that the domestic input bundle for sector g is produced using the output of all other sectors in the economy. Hence, its price ratio is given by

$$\frac{P_{gID,t}}{P_{gID,t-1}} = \prod_{j=1}^{G} \left(\frac{P_{jD,t}}{P_{jD,t-1}}\right)^{\psi_{jg}}, \quad (4)$$

where ψ_{jg} is the share of intermediate expenditure on group j by group g in total domestic intermediate expenditure. Note that the prices on the right-hand side of equation (4) correspond to the last term of equation (1). Similarly, we assume that the imported intermediate bundle consists of imported inputs from all other sectors. The ratio of the imported input price can hence be written as

$$\frac{P_{gIM,t}}{P_{gIM,t-1}} = \prod_{j=1}^{G} \left(\frac{P_{jM,t}}{P_{jM,t-1}}\right)^{\mu_{jg}}, \quad (5)$$

where μ_{jg} is the share of intermediate expenditure on group j by group g in total imported intermediates. The prices on the right-hand side of equation (5) correspond to the first term on the right-hand side of equation (1).

Combining equations (3) and (4), we can express the ratio of the domestic good price as

$$\frac{P_{gD,t}}{P_{gD,t-1}} = \left(\prod_{j=1}^{G} \left(\frac{P_{jD,t}}{P_{jD,t-1}}\right)^{\psi_{jg}}\right)^{\alpha_g(1-\varepsilon_g)} \left(\frac{P_{gIM,t}}{P_{gIM,t-1}}\right)^{\alpha_g\varepsilon_g}. \quad (6)$$

Taking the logarithm of equation (6) we obtain

$$\ln\left(\frac{P_{gD,t}}{P_{gD,t-1}}\right) = \sum_{j=1}^{G} \alpha_g(1-\varepsilon_g)\psi_{jg} \ln\left(\frac{P_{jD,t}}{P_{jD,t-1}}\right) + \alpha_g \varepsilon_g \ln\left(\frac{P_{gIM,t}}{P_{gIM,t-1}}\right). \tag{7}$$

Note that we have G such equations for the entire economy (one per good). We can rewrite this system in matrix notation as

$$\overrightarrow{\Delta P_D} = \Omega_D \overrightarrow{\Delta P_D} + \Omega_M \overrightarrow{\Delta P_{IM}}, \tag{8}$$

where $\overrightarrow{\Delta P}$ are $G \times 1$ column vectors of logarithmic price changes. Ω_D is a $G \times G$ matrix with the element of row g and column i, ω_{gi}^D, equal to $\alpha_g(1-\varepsilon_g)\psi_{ig}$. Ω_M is a $G \times G$ diagonal matrix with the ith element on the diagonal, ω_{ii}^M, equal to $\alpha_i \varepsilon_i$. Solving for the vector of domestic good price changes, $\overrightarrow{\Delta P_D}$, we arrive at

$$\overrightarrow{\Delta P_D} = (I - \Omega_D)^{-1} \Omega_M \overrightarrow{\Delta P_{IM}}. \tag{9}$$

where I is the $G \times G$ identity matrix. Given the change in imported good prices, we can infer the change in the price of the imported input goods from equation (5) and subsequently the change in the price of domestic goods from equation (9).

To study the effect of the exchange rate shock, we assume that the change in imported goods prices is identical across sectors. We will be more specific about how we measure the size of the shock below, but for now we simply denote it as β, i.e.,

$$\ln\left(\frac{P_{gM,t}}{P_{gM,t-1}}\right) = \beta \; \forall g = 1, \ldots, G.$$

Hence, the direct effect is $\beta\gamma_g$ in equation (1), while the indirect effect is the product of $1-\gamma_g$ and the change in domestic good prices. From equation (5), it follows that $\overrightarrow{\Delta P_{IM}}$ is a $G \times 1$ column vector with all elements equal to β. Hence, we have $\overrightarrow{\Delta P_D} = (I - \Omega_D)^{-1}\Omega_M \beta$. From equation (1), the vector of overall price changes is then

$$\overrightarrow{\Delta P} = \Omega_\gamma \beta + \Omega_{1-\gamma}(I - \Omega_D)^{-1}\Omega_M \beta, \tag{10}$$

where Ω_γ and $\Omega_{1-\gamma}$ are $G \times G$ diagonal matrices with the ith elements on the diagonals equal to γ_i and $1-\gamma_i$, respectively.

This system of equations will form the basis of our estimation. For what follows, it is instructive to look at the price change in one particular sector g (corresponding to equation g in the system)

$$\ln\left(\frac{P_{g,t}}{P_{g,t-1}}\right) = \gamma_g\beta + (1-\gamma_g)\sum_{i=1}^{G}\omega_{gi}\beta = \left(\gamma_g + (1-\gamma_g)\sum_{i=1}^{G}\omega_{gi}\right)\beta, \tag{11}$$

where ω_{gi} is the element of row g and column i of the $G \times G$ matrix $(I - \Omega_D)^{-1}\Omega_M$. Equation (11) tells us that the referendum shock β has a direct effect on prices of good g that depends on the import share (through γ_g), and an indirect effect that depends on the input-output linkages of intermediates used in the production of g (through the remaining terms). As indicated by the parentheses on the right-hand side of equation(11), we can also compute a summary measure of these two effects by simply adding up the direct and indirect effects and multiplying them by the size of the shock, β. Correspondingly, in our empirical analysis we will present results for the summary measure as well as separately for the direct and indirect effects.

3 Data

3.1 Inflation

To measure UK inflation in a way consistent with equation (1), we use the logarithmic price ratio (i.e., the growth rate in prices) for a given product g. We use price indices provided by the Office for National Statistics (ONS) for 84 products collected at monthly frequency. A product is defined as one COICOP (Classification of Individual Consumption according to Purpose) class.[2] The price index for each class is defined the average price of goods and services within that class bought for the purpose of consumption by households in the UK and foreign visitors to the UK.[3]

Our estimates use both annual and quarterly measures of inflation. Since the referendum occurred in late June we define annual inflation for year t as the logarithmic ratio of the class price index in June of year t over the price index in June of year $t-1$. Our annual estimates use inflation data for June 2015, June 2016 and June 2017. Quarterly inflation is computed as the ratio of the class price index in the last month of the quarter over the class price index in the last month of the previous quarter. Our quarterly estimates use data from the first quarter of 2015 to the third quarter of 2017.

3.2 Measuring import exposure

To test to what extent inflation following the referendum is due to the exchange rate depreciation, we need to build a product-specific measure of import exposure, denoted $ImportShare$. Based on equation (11), we compute this measure as the sum of two

[2]We choose to use price data at the COICOP class level because it approximately matches the level of aggregation used in the UK input-output tables.

[3]See the Consumer Price Indices Technical Manual published by the ONS for more details.

terms: a direct import exposure measure, $DirectImportShare$, and an indirect exposure measure, $IndirectImportShare$. From equation (11) the direct exposure is simply given by consumer expenditure on imported goods, γ_g. In the UK input-output tables we observe for each sector the value of household expenditure on both domestic and imported goods, and we calculate γ_g as the expenditure on imported goods g over total household expenditure (domestic and imported) on g. We base our calculations on the UK input-output analytical tables for the year 2013, which is the most recent version available from the ONS.

Indirect import exposure is the product of $(1-\gamma_g)$ and the change in the price of domestic good g. From equations (10) and (11), the latter is determined by the elements of the Ω_D and Ω_M matrices which can be calculated using UK input-output tables. We compute α_g as total intermediate consumption (domestic and imported) over total output of sector g. Similarly, we compute ε_g as total imported intermediate expenditure over total intermediate consumption in sector g. Finally, ψ_{jg} is the intermediate expenditure on domestic good j for the production of good g over total intermediate expenditure for the production of good g.

The sectors in the UK input-output tables are defined according to the Statistical Classification of Products by Activity (CPA). To map our import share measure to the classification used for inflation, we need to convert from CPA sectors to COICOP classes. We use a CPA-COICOP concordance table provided by the ONS that maps to 115 COICOP classes. We then aggregate across some classes to obtain import share measures for the COICOP classes used in the Harmonised Index of Consumer Prices (HICP).[4] The ONS publishes price data for 85 COICOP classes, but we drop Second-hand cars because we are unable to calculate the indirect import share for Second-hand cars.

3.3 Measuring the exchange rate depreciation

We now return to the measurement of the change in import prices, $\ln\left(P_{gM,t}/P_{gM,t-1}\right)$. In our baseline estimation, we will simply regress changes in annual or quarterly inflation on our $ImportShare$ measure, or separately on its two components, $DirectImportShare$ and $IndirectImportShare$. The change in import prices is then implicitly given by the regression coefficient on these measures (i.e., β in equation (11)).

As an alternative, we use actual changes in the exchange rate faced by UK importers, ΔXR_t, to proxy for changes in price indices of imported goods. In particular, we assume

$$\ln\left(\frac{P_{gM,t}}{P_{gM,t-1}}\right) = \beta_e \Delta XR_t \; \forall g = 1, \ldots, G.$$

[4] We compute arithmetic means of our measures whenever aggregating across classes.

where β_e measures the pass-through from exchange rate changes to import prices, and the computation of ΔXR_t is described below. Given this assumption we compute an exchange rate measure for each good g in each period t that is the sum of two components: a direct exchange rate measure and an indirect exchange rate measure. Note that these are simply $DirectImportShare$ and $IndirectImportShare$ multiplied by ΔXR_t. Analogous to our import share measure, an increase in the exchange rate measure captures an increase in the relative price of imported goods.

The exchange rate change faced by UK importers, ΔXR_t, is a trade-weighted mean of exchange rate changes given by

$$\Delta XR_t = \sum_c w_c \times \ln\left(\frac{XR_{c,t}}{XR_{c,t-1}}\right),$$

where the import weight w_c is the share of partner c in total UK imports, and $XR_{c,t}$ is denominated as sterling per unit of foreign currency of country c at time t such that an increase represents a depreciation of sterling. The import weights are calculated from UN Comtrade using UK imports across all goods from 176 partner countries for the year 2013.[5] The exchange rate data are taken from the International Financial Statistics database provided by the International Monetary Fund (IMF), and the missing data points are filled in using the online currency converter service Oanda. Analogous to the definition of annual inflation, the annual exchange rate change is taken as the logarithmic ratio of the exchange rate in June of year t over the exchange rate in June of year $t-1$. The quarterly change is the logarithmic ratio of the average exchange rate during the quarter over the average during the previous quarter.

3.4 Other variables

To disentangle the effect of the referendum from other factors that may influence inflationary trends in the UK, we employ two additional variables. The first is a measure of inflation in the Euro area. We use the price index for each COICOP class from the Harmonized Index of Consumer Prices (HCIP) provided by Eurostat. This aggregate is computed from the HICP of the nineteen Euro area countries. For the UK, the HICP is the same as the CPI produced by the ONS.

The second measure aims at capturing the effect of oil price changes on input prices through direct or indirect imported oil use in the UK. To capture the impact of changes in imported crude oil on UK consumer price indices, we follow a similar methodology as for the import share measure. However, it turns out the oil measure only has an indirect component because households do not directly consume or import crude oil (i.e., $\gamma_{oil} = 0$).

[5] The year was chosen to be consistent with the year of the UK Input-Output tables.

The indirect component is fully determined by changes in domestic prices due to changes in the imported crude oil price. We assume

$$\ln\left(\frac{P_{gM,t}}{P_{gM,t-1}}\right) = \begin{cases} \ln\left(\frac{P_{oil,t}}{P_{oil,t-1}}\right) & \text{if } g \in \{Oil\}, \\ 0 & \text{otherwise.} \end{cases}$$

To determine $\overrightarrow{\Delta P_{IM}}$ we need $\mu_{oil,g}$, which is the intermediate expenditure on imported crude oil over total expenditure on imported intermediates for good g. This can be retrieved from the imported use table provided in the UK input-output tables. Once we determine $\overrightarrow{\Delta P_{IM}}$, we compute the changes in domestic prices due to changes in imported crude oil, $\overrightarrow{\Delta P_D}$, using equation (9). To proxy changes in crude oil prices we use the APSP (Average Petroleum Spot Price) crude oil index provided by the IMF Commodity Price database. It is an average index of prices of Brent crude, Dubai and West Texas Intermediate crude. Descriptive statistics for all our variables are shown in Table 1.

4 Empirical specification

We implement a difference-in-differences approach to quantify to what extent the rise of inflation following the referendum is due to an increasing cost of imports. For that purpose we analyze the UK inflation trend before and after the referendum and distinguish products by degree of import exposure.

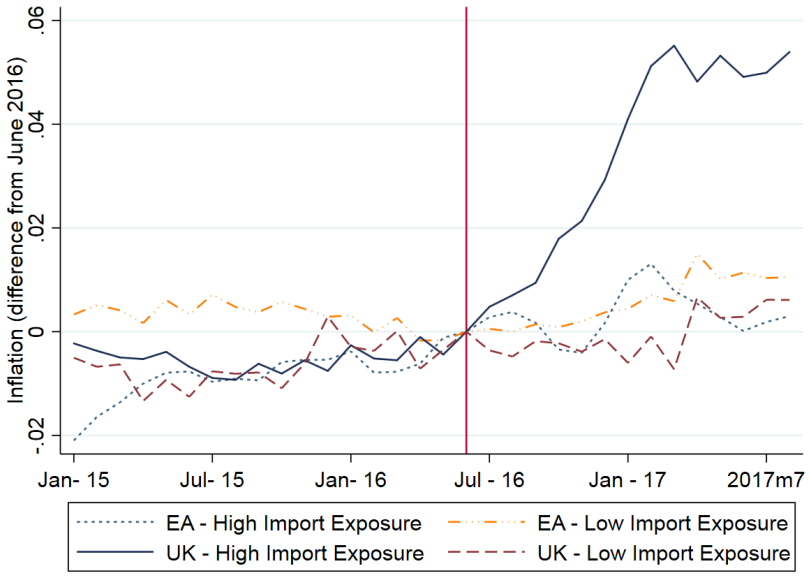

Figure 1: Inflation rates by import exposure measure

As motivation, Figure 1 displays both UK and Euro area (EA) inflation rates with respect to

the same month in the previous year. The solid line is the UK average inflation rate for products with high import exposure, while the dark dashed line is the average inflation rate for products with low import exposure. The dotted line is the Euro area average inflation rate for products with high import exposure, while the grey dashed-dotted line is the Euro area average inflation rate for products with low import exposure. For each of the four groups, the inflation rate is expressed as the difference from the average group inflation rate in June 2016. High import exposure products are those with an import exposure measure above the median; other products are counted as low import exposure. The trend in inflation for these groups of products is similar before the referendum but clearly different afterwards. Inflation increases drastically after the referendum for products with high import exposure in the UK, consistent with the notion that this diverging trend may be due to increasing import costs.

More formally, we estimate the following equation for 84 COICOP classes g:

$$Inflation_{gt} = \beta(Post \times ImportShare)_{gt} + X_{gt} + \delta_t + \delta_g + \varepsilon_{gt}. \tag{12}$$

The dependent variable $Inflation$ is the inflation rate for a given COICOP class in period t. $Post$ is a dummy variable that takes the value 1 for all periods after the referendum. $ImportShare$ is the import exposure measure that captures both the direct and indirect increases in import costs. X_{gt} are additional factors that are likely to influence inflationary trends in the UK, namely the measure of the impact of oil price changes on domestic good price g in period t, Oil, and the measure of euro area inflation for a given product g in period t, $EuroAreaInflation$. Period fixed effects and product fixed effects are denoted by δ_t and δ_g. The coefficient of interest is β. It captures the effect of the referendum that is channelled through rising import costs. We expect β to be positive. Alternatively, we estimate equation (12) interacting $Post$ with the $ExchangeRate$ measure.

5 Estimation results

Tables 2 and 3 report the results of estimating equation (12) at annual frequency. Table 2 displays the total effect of the referendum as captured by the interaction between the $Post$ dummy and the overall $ImportShare$ measure. Table 3 distinguishes between the direct effect (captured by the interaction of the $Post$ dummy and the $DirectImportShare$ measure) and the indirect effect (captured by the interaction of the $Post$ dummy and the $IndirectImportShare$ measure). In both tables, columns (2) to (3) introduce controls one at a time. Product fixed effects as well as annual dummies for 2015 and 2017 are included in all regressions.[6]

[6]To avoid possible confusion, recall that the annual data for year t covers the period between June in year $t-1$ and June in year t. Thus, the 2017 fixed effect covers the post-referendum period after June 2016.

Our preferred specification is presented in column (3) where we control for both changes in oil prices and the inflationary trend in the euro area. In column (4) we use the alternative dependent variable $Inflation\_Difference$, which is the difference between UK and Euro area inflation for a given product in a specific year. In column (5) we decompose the timing in the referendum effect by interacting the import share measure with individual year dummies rather than the $Post$ dummy (the omitted reference period is 2015). Overall, the estimated β coefficients are positive, statistically significant and rather stable across the various specifications. Products with higher import exposure experienced a greater increase in inflation following the referendum.

Recall that interpreted through the lens of our model, the coefficient on the import share regressor captures the change in import prices. According to our preferred coefficient estimate of 0.0709 (Table 2, column 3) this means that import prices increased by around 7% post-referendum. Given that the trade-weighted exchange rate depreciated by around 10%, the implied-pass through rate seems plausible and consistent with the wider literature on exchange rate pass-through. Moreover, for our preferred specification we cannot reject the hypothesis that the coefficients on our direct and indirect import share measures are the same (Table 3, column 3), as consistent with our theoretical framework.

Tables 4 and 5 report the results of estimating equation (12) at quarterly frequency. Columns (1) to (4) of Table 4 are similar to columns (1) to (4) of Table 2. In column (5) we introduce $Period \times division$ fixed effects. A division refers to a 2-digit COICOP code, and there are 12 COICOP divisions in total. In column (6) we estimate the direct and indirect effects separately. The quarterly results are broadly consistent with annual estimates: the β coefficients are positive, statistically significant and rather stable across the various specifications. In particular, products with higher import exposure experienced a greater increase in inflation following the referendum.

Table 5 decomposes the effect by quarter for the overall measure in column (1), and for the direct and indirect measures in column (2). The interaction of the quarter dummies and the import share measures is always insignificant prior to the referendum and then is positive and significant in all quarters after the referendum except for the second quarter of 2017, at least for the total and direct import share measures.

Table 6 reports the results of estimating the baseline specification at the quarterly frequency using exchange rate changes to capture import price changes. We add lags to allow for delayed pass-through from the exchange rate to domestic prices. In column (1) we use our composite exchange rate regressor whereas in column (2), we decompose the total

effect into direct and indirect effects as before. Column (1) indicates that exchange rate depreciations increase domestic inflation with a lag of one to two quarters, with the strongest effects visible after two quarters and the three-quarter lag not being statistically different from zero. This timing is broadly consistent with column (1) of Table 5 where we found significantly positive effects from the third quarter of 2016 through to the first quarter of 2017. When we split up the total exchange rate effect into its direct and indirect components (column 2), we find that the direct effect is similar to the aggregate effect from column (1). The indirect effects are very imprecisely measured, however, with all lags being statistically insignificant.

6 Aggregate inflation

Using our annual estimates along with prices and CPI weights for COICOP classes, we can compute an aggregate counterfactual rate of inflation and compare it with the actual rate of inflation to capture the overall referendum effect. We define the counterfactual rate of inflation as

$$InflationRate^{C}_{2017} = \left(\frac{\sum_{g=1}^{84} w_{2016,g} P^{C}_{2017,g}}{\sum_{g=1}^{84} w_{2017,g} P_{2016,g}} - 1 \right) * 100,$$

where $w_{2017,g}$ is the weight of product g in the aggregate index in 2017, $w_{2016,g}$ is the weight of product g in the aggregate index in 2016, $P_{2016,g}$ is the price for product g in 2016 and $P^{C}_{2017,g}$ is the counterfactual price for product g in 2017. Under the assumption that the referendum affects prices only through increasing import costs, we compute the counterfactual price for product g in 2017 as $P^{C}_{2017,g} = P_{2017,g}/e^{B_g}$ with $B_g = \hat{\beta} * ImportShare_g$. However, the referendum might have affected inflation through other channels. For example, if the vote led to an increase in wages or other domestic production costs, then we would expect prices to rise in all sectors of the economy. Alternatively, if producers expect Brexit to lead to slower future growth they may choose smaller price increases leading to lower inflation. To account for such potential general equilibrium effects, we compute the counterfactual price as $P^{C}_{2017,g} = P_{2017,g}/e^{B^{GE}_g}$ with $B^{GE}_g = \hat{\beta} * ImportShare_g + \hat{\delta}_{2017}$, where we interpret the 2017 period dummy as absorbing these other effects.[7]

The referendum effects are expressed as percentage point increases in inflation over the period from June 2016 to June 2017. In all specifications in Table 2 the general equilibrium adjustment as captured by the 2017 dummy is negative. Our estimate (excluding the general equilibrium adjustment) would then be an upper bound of the referendum effect. More specifically, based on our estimate for β in column (3) of Table 2, we find that the referendum increased inflation by 3.17 percentage points in the year after the referendum (excluding the general equilibrium adjustment). Accounting for general equilibrium effects,

[7]When computing the aggregate inflation effect we assign Second-hand cars an import share of zero.

we find that the referendum increased inflation by 1.71 percentage points. We regard this overall referendum shock effect as a conservative estimate of the impact on aggregate inflation since we choose to attribute the *entire* negative general equilibrium effect to the Brexit vote.

It is useful to compare this baseline estimate of the referendum effect with the effect implied by the estimates in column (1) of Table 6, which uses quarterly data and includes exchange rate movements both before and after the referendum to capture import price changes. We apply the approach described above to calculate counterfactual inflation rates for each quarter from the third quarter of 2016 to the second quarter of 2017. We then combine these quarterly impacts to obtain an estimate of the overall referendum effect between June 2016 and June 2017. When calculating the counterfactual inflation rates we use the estimated effect of the first and second exchange rate lags only, as the other exchange rate variables are all insignificant. We also do not include any general equilibrium adjustment. Our estimates suggest there may have been a positive general equilibrium effect in the second quarter of 2017, but to obtain a conservative estimate of the impact on aggregate inflation we do not account for this effect.

The import weighted quarterly average exchange rate depreciated by 2.0% in the second quarter of 2016 and 7.9% in the third quarter of 2016. Attributing both these changes to the referendum implies the referendum increased inflation by 2.28 percentage points in the year after the vote. Alternatively, if we take a more conservative approach and only attribute the change in the third quarter to the impact of the referendum, we obtain an increase in inflation of 1.57 percentage points. Both these estimates are similar in magnitude to our baseline result.

6.1 Distributional consequences

In addition, to explore the distributional consequences of the referendum shock due to variation in expenditure patterns across households, we compute aggregate indices specific to certain types of households. The ONS provides expenditure for each of our 84 products by disposable income decile, age and region. Using ONS expenditures from the Family Spending tables for the financial year ending 2016 we compute household-specific weights and use the corresponding weights to calculate group-specific aggregate effects.

The results are displayed in Table 7. The increases in inflation rates by household type are computed using the estimates from our preferred specification (Table 2, column 3) including general equilibrium effects. Inflation varies little across income deciles, implying that the costs from the referendum shock are evenly shared throughout the income distribution. We conclude that the referendum increased inflation by approximately the same amount

for poor, middle income and rich households.

By contrast, there are significant differences across age groups and regions. Increases in inflation rates are substantially lower for households under 30 and households living in London because these groups spend relatively more on rent than the average household and rent has a very low import share. In general the north of England is harder hit than the south. Scotland, Wales, and Northern Ireland are the worst affected areas. Our estimates imply inflation in Northern Ireland increased by 0.47 percentage points more than the UK average because of the Brexit vote. This is because households in Northern Ireland spend relatively more on food and drink, clothing and fuel which are high import share product groups and relatively less on rent and sewerage which have low import shares.

7 Conclusion

We present a theoretical model in which households consume both domestic and imported foreign goods. This directly exposes households to inflation stemming from price rises in imported goods. In addition, households are indirectly exposed to price rises in imported intermediate goods since those are used as inputs in the production of domestic consumption goods. The model thus delivers a relationship between inflation and the exposure to imported goods.

On the empirical side, we employ UK input-output tables to construct measures of import exposure at the product level. We then relate those measures to the UK inflation experience before and after the June 2016 Brexit referendum, also controlling for the effect of oil price changes and inflation in the Euro area. We observe a positive relationship across products between import exposure and price increases following the referendum. Our preferred point estimate is that the referendum shock led to an increase in aggregate UK inflation by 1.7 percentage points in the year following the referendum.

We also consider how household expenditure shares differ by income, age and regions, and we then calculate how the referendum shock affects these groups differentially. We find that the inflation increase is shared evenly throughout the income distribution but not across regions. London is the least affected while Scotland, Wales and Northern Ireland experience the strongest increases in inflation. Young people are less affected because they spend a larger share of their income on items that are hardly affected by foreign imports, in particular rents.

References

Berlingieri, G., H. Breinlich and S. Dhingra (2017), "The Impact of Trade Agreements on Consumer Welfare - Evidence from the EU Common External Trade Policy," forthcoming, *Journal of the European Economic Association*.

Table 1: Descriptive statistics

VARIABLES	Mean	Median	Standard deviation	Min	Max
Inflation	0.006	0.012	0.044	-0.296	0.134
Import share	0.507	0.564	0.318	0.010	0.999
Direct import share	0.386	0.400	0.352	0	0.999
Indirect import share	0.121	0.108	0.089	0.001	0.444
Exchange rate measure	0.017	0.015	0.043	-0.064	0.095
Direct exchange rate	0.013	0.001	0.038	-0.064	0.095
Indirect exchange rate	0.004	0.005	0.0108	-0.028	0.042
Oil	-0.006	-0.010	0.023	-0.181	0
Euro area inflation	0.007	0.009	0.032	-0.219	0.256

Notes: The variables *Import share*, *Direct Import share*, and *Indirect Import share* are time-invariant. The descriptive statistics for these variables are computed on 84 observations. All other statistics are computed using annual observations (252 observations).

Table 2: Annual specification: Import share

VARIABLES	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation Difference	(5) Inflation
Post × Import share	0.0760***	0.0709***	0.0709***	0.0706***	
	(0.0185)	(0.0148)	(0.0140)	(0.0141)	
2016 × Import share					-0.00295
					(0.0106)
2017 × Import share					0.0694***
					(0.0155)
Oil		0.846**	0.672**	0.232	0.673**
		(0.393)	(0.296)	(0.164)	(0.297)
Euro area inflation			0.282		0.283
			(0.201)		(0.200)
2015 dummy	-0.00996**	-0.00449	-0.00510	-0.00666	-0.00659
	(0.00394)	(0.00410)	(0.00399)	(0.00499)	(0.00637)
2017 dummy	-0.0123*	-0.0136**	-0.0146**	-0.0170*	-0.0153**
	(0.00735)	(0.00662)	(0.00693)	(0.00861)	(0.00720)
Observations	252	252	252	252	252
R-squared	0.337	0.459	0.491	0.256	0.491
Number of products	84	84	84	84	84
Product fixed effects	YES	YES	YES	YES	YES

Notes: The dependent variable in columns (1)-(3) and (5) is the annual UK inflation rate. In column (4) it is the difference between the UK and Euro area annual inflation rates. Post is a dummy variable for the post-referendum period. Sample covers 2015-17. We define year t as the period from June of year $t-1$ to June of year t. See the main text for additional details. Constant not reported. OLS estimation. Standard errors in parentheses clustered by product. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Annual specification: Direct and indirect import shares

VARIABLES	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation Difference	(5) Inflation
Post × Direct import share	0.0916***	0.0760***	0.0719***	0.0612***	
	(0.0209)	(0.0147)	(0.0126)	(0.0126)	
Post × Indirect import share	0.310**	0.138**	0.0850*	-0.0520	
	(0.125)	(0.0597)	(0.0499)	(0.0669)	
2016 × Direct import share					-0.00606
					(0.0122)
2017 × Direct import share					0.0673***
					(0.0154)
2016 × Indirect import share					-0.0479
					(0.0572)
2017 × Indirect import share					0.0432
					(0.0778)
Oil		0.729*	0.651*	0.447*	0.741*
		(0.391)	(0.328)	(0.227)	(0.393)
Euro area inflation			0.277		0.264
			(0.206)		(0.207)
2015 dummy	-0.00996**	-0.00524	-0.00525	-0.00527	-0.0128
	(0.00395)	(0.00399)	(0.00396)	(0.00498)	(0.0100)
2017 dummy	-0.0466**	-0.0231**	-0.0166**	0.000453	-0.0182**
	(0.0204)	(0.00989)	(0.00736)	(0.00978)	(0.00717)
Observations	252	252	252	252	252
R-squared	0.409	0.462	0.491	0.268	0.492
Number of products	84	84	84	84	84
Product fixed effects	YES	YES	YES	YES	YES

Notes: The dependent variable in columns (1)-(3) and (5) is the annual UK inflation rate. In column (4) it is the difference between the UK and Euro area annual inflation rates. Post is a dummy variable for the post-referendum period. Sample covers 2015-17. We define year t as the period from June of year $t-1$ to June of year t. See the main text for additional details. Constant not reported. OLS estimation. Standard errors in parentheses clustered by product. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Quarterly specification

VARIABLES	(1) Inflation	(2) Inflation	(3) Inflation	(4) Inflation Difference	(5) Inflation	(6) Inflation
Post × Import share	0.0199***	0.0189***	0.0195***	0.0205***	0.0176***	
	(0.00442)	(0.00377)	(0.00378)	(0.00409)	(0.00419)	
Post × Direct import share						0.0172***
						(0.00407)
Post × Indirect import share						0.0110
						(0.0135)
Oil		0.597**	0.438**	0.196*	0.483**	0.487**
		(0.274)	(0.214)	(0.114)	(0.219)	(0.218)
Euro area inflation			0.395		0.374	0.374
			(0.238)		(0.242)	(0.242)
Observations	840	840	840	840	840	840
R-squared	0.036	0.090	0.178	0.033	0.281	0.281
Number of products	84	84	84	84	84	84
Product fixed effects	YES	YES	YES	YES	YES	YES
Period fixed effects	YES	YES	YES	YES	NO	NO
Period × division fixed effect	NO	NO	NO	NO	YES	YES

Notes: The dependent variable in columns (1)-(3) and (5)-(6) is the quarterly UK inflation rate. In column (4) it is the difference between the UK and Euro area quarterly inflation rates. Post is a dummy variable for the post-referendum period. Sample covers Q1 2015-Q2 2017. See the main text for additional details. Constant not reported. OLS estimation. Standard errors in parentheses clustered by product. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Quarterly specification: Decomposition

VARIABLES	(1) Inflation	(2) Inflation
2015Q2 × Import share	-0.00688	
	(0.00765)	
2015Q3 × Import share	0.00345	
	(0.00934)	
2015Q4 × Import share	-0.00425	
	(0.00880)	
2016Q1 × Import share	0.00840	
	(0.00835)	
2016Q2 × Import share	-0.00318	
	(0.00931)	
2016Q3 × Import share	0.0188**	
	(0.00860)	
2016Q4 × Import share	0.0236*	
	(0.0122)	
2017Q1 × Import share	0.0454***	
	(0.0127)	
2017Q2 × Import share	-0.0114	
	(0.00903)	
2017Q3 × Import share	0.0267***	
	(0.00824)	
2015Q2 × Direct import share		-0.00783
		(0.00809)
2015Q3 × Direct import share		0.00402
		(0.00936)
2015Q4 × Direct import share		-0.00164
		(0.00904)
2016Q1 × Direct import share		0.00834
		(0.00871)
2016Q2 × Direct import share		-0.00374
		(0.0101)
2016Q3 × Direct import share		0.0204**
		(0.00849)
2016Q4 × Direct import share		0.0293**
		(0.0121)
2017Q1 × Direct import share		0.0348***
		(0.0101)
2017Q2 × Direct import share		-0.00815
		(0.00921)
2017Q3 × Direct import share		0.0283***
		(0.00841)
2015Q2 × Indirect import share		-0.0168
		(0.0762)
2015Q3 × Indirect import share		0.0130
		(0.0679)
2015Q4 × Indirect import share		0.0364
		(0.0686)
2016Q1 × Indirect import share		0.00822
		(0.0375)
2016Q2 × Indirect import share		-0.00568
		(0.0598)
2016Q3 × Indirect import share		0.0447
		(0.0471)
2016Q4 × Indirect import share		0.113
		(0.0723)
2017Q1 × Indirect import share		-0.109
		(0.0863)
2017Q2 × Indirect import share		0.0388
		(0.0843)
2017Q3 × Indirect import share		0.0538
		(0.0400)
Oil	0.443**	0.480**
	(0.214)	(0.233)
Euro area Inflation	0.398*	0.401*
	(0.231)	(0.239)
2015Q1 dummy	-0.00467	-0.00466
	(0.00529)	(0.00855)
2015Q2 dummy	0.00101	0.00218
	(0.00477)	(0.00846)
2015Q3 dummy	-0.000819	-0.00228
	(0.00666)	(0.0111)
2015Q4 dummy	0.000874	-0.00521
	(0.00648)	(0.0114)
2016Q1 dummy	-0.00910	-0.00912
	(0.00746)	(0.0102)
2016Q3 dummy	-0.00716	-0.0111
	(0.00552)	(0.00729)
2016Q4 dummy	-0.00631	-0.0196**
	(0.00751)	(0.00902)
2017Q1 dummy	-0.0234*	-0.000882
	(0.0120)	(0.0107)
2017Q2 dummy	0.0113*	0.00372
	(0.00617)	(0.0116)
2017Q3 dummy	-0.00756*	-0.0117**
	(0.00416)	(0.00534)
Observations	924	924
R-squared	0.203	0.226
Number of products	84	84
Product fixed effects	YES	YES
Period × division fixed effects	NO	NO

Notes: The dependent variable in columns (1)-(2) is the quarterly UK inflation rate. Sample covers Q1 2015-Q3 2017. See the main text for additional details. Constant not reported. *OLS* estimation. Standard errors in parentheses clustered by product. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Quarterly specification: Exchange rate

VARIABLES	(1) Inflation	(2) Inflation
Exchange rate	-0.00215	
	(0.0715)	
Exchange rate lag 1	0.159*	
	(0.0954)	
Exchange rate lag 2	0.351**	
	(0.136)	
Exchange rate lag 3	-0.146	
	(0.107)	
Direct exchange rate		0.0556
		(0.0824)
Direct exchange rate lag 1		0.163
		(0.128)
Direct exchange rate lag 2		0.218**
		(0.101)
Direct exchange rate lag 3		-0.0491
		(0.0889)
Indirect exchange rate		0.836
		(0.558)
Indirect exchange rate lag 1		0.286
		(0.840)
Indirect exchange rate lag 2		-1.593
		(1.196)
Indirect exchange rate lag 3		1.274
		(1.047)
Oil	0.431**	0.513***
	(0.208)	(0.181)
Euro area inflation	0.388	0.393
	(0.236)	(0.245)
2015Q1 dummy	0.00531	0.00569
	(0.00454)	(0.00998)
2015Q2 dummy	0.00870*	0.00811
	(0.00465)	(0.0114)
2015Q3 dummy	0.0153**	0.00931
	(0.00629)	(0.0117)
2015Q4 dummy	0.0113**	0.00653
	(0.00562)	(0.0108)
2016Q1 dummy	0.00631	-0.00650
	(0.00482)	(0.0117)
2016Q3 dummy	0.00153	-5.02e-05
	(0.00436)	(0.00614)
2016Q4 dummy	0.00834	-0.00524
	(0.00702)	(0.00625)
2017Q1 dummy	-0.00626	0.00802
	(0.00790)	(0.00900)
2017Q2 dummy	0.0154**	0.00507
	(0.00700)	(0.0148)
Observations	840	840
R-squared	0.185	0.202
Number of products	84	84
Product fixed effects	YES	YES
Period × division fixed effects	NO	NO

Notes: The dependent variable in columns (1)-(2) is the quarterly UK inflation rate. Sample covers Q1 2015-Q2 2017. See the main text for additional details. Constant not reported. OLS estimation. Standard errors in parentheses clustered by product. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Aggregate inflation effect by household type

By income decile	
1st decile	1.58
2nd decile	1.51
3rd decile	1.57
4th decile	1.54
5th decile	1.64
6th decile	1.59
7th decile	1.51
8th decile	1.70
9th decile	1.69
10th decile	1.50
All	1.59

By age group	
Under 30	1.03
Between 30 and 49	1.56
Between 50 and 64	1.70
Between 65 and 74	1.78
Between 75 and over	1.64
All	1.59

By region	
North East	1.76
North West	1.69
Yorkshire and the Humber	1.64
East Midlands	1.66
West Midlands	1.73
East	1.63
London	1.26
South East	1.58
South West	1.54
England	1.57
Wales	1.82
Scotland	1.79
Northern Ireland	2.08
United Kingdom	1.61

Notes: The weights used to compute the effects by household type come from the ONS Family Spending tables for the financial year ending 2016. These weights differ slightly from the official CPI weights used for to compute our aggregate inflation effect. Income deciles are based on disposable household income. Age groups are based on the household reference person.