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New dawn fades: Trade, labour and the Brexit exchange rate depreciation

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ABSTRACT

This paper studies consequences of the large exchange rate depreciation occurring when the UK electorate unexpectedly voted to leave the European Union. Sterling plummeted, recording the biggest one-day depreciation of any of the world's four major currencies since Bretton Woods. The prospect of Brexit happening generated sizable differences in how much sterling depreciated against different currencies. Coupled with pre-referendum cross-country trade patterns, this generated variations in exchange rates facing businesses in different industries. The paper offers evidence of a cost shock from the prices of intermediate imports rising by more in higher depreciation industries, but with no revenue offset from exports. Workers were impacted by these increased cost pressures, not in terms of job loss but through relative real wage declines in higher depreciation, larger cost shock industries. This resulted in an aggregate fall in real wage growth of 3 to 3.6% cumulatively over the three years after the referendum.

1. Introduction

When the UK electorate unexpectedly voted to leave the European Union in June 2016, the British pound experienced its biggest one day loss since the introduction of free-floating exchange rates in the early 1970s. In less than twenty four hours, overnight on June 23/24 2016, the pound-dollar exchange rate fell by a massive 8%, and the pound-euro rate by a big, but smaller, 6%. These exchange rate movements were much larger than on Black Wednesday in 1992 when the UK withdrew from the Exchange Rate Mechanism, bigger than its drop during the height of the financial crisis in 2008 and after the recent mini-budget of the Truss-Kwarteng government in 2022. In fact, the Brexit vote-induced sterling drop is the biggest one-day fall that has ever occurred in any of the world's four major currencies that make up the bulk of global hard cash reserves since the 1971 collapse of Bretton Woods.

Importantly, and as already noted for the examples of the dollar and the euro, the pound depreciated to varying degrees against different world currencies. Trading in world markets was characterised by variations in the size of the sterling depreciation, and therefore in the magnitude of any cost and revenue shocks they experienced as a consequence of the exchange rate shift. This paper

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leverages this cross-currency variation in the fall in the value of the pound to study the trade and labour market consequences of the Brexit exchange rate depreciation. The cross-currency variation in sterling depreciation is big, and the overnight fall on referendum day ranges from 4.3% (Polish Zloty) to 11.1% (Japanese Yen). This is much larger than even the level drops observed on Black Wednesday when, for example, the pound fell 4.3% against the dollar.

In conventional international trade theory, an exchange rate depreciation can benefit workers through a positive revenue shock from increased export volumes or a reduction in import competition. An exchange rate appreciation would have the opposite effect. Some early empirical studies did provide evidence of workers being hurt from an exchange rate appreciation, with the US manufacturing industry studies of Grossman (1987) and Revenga (1992) leveraging a dollar appreciation from the 1980s to uncover a negative impact on workers' wages and/or employment.

Since that research, one key development in trade patterns that makes these conventional trade predictions less clearcut and more ambiguous in their predictions about the impact of exchange rate movements on contemporary labour markets has been the huge rise of trade in intermediate goods and services (Yi, 2003). This opens up the scope for cost shocks to operate, over and above the revenue shocks from the two channels studied in the earlier work, and to impact workers (Feenstra and Hanson, 1997; Grossman and Rossi-Hansberg, 2008, 2012). More recent empirical research, pioneered by Feenstra and Hanson (1999), confirms the importance of this cost channel, with results emerging that show the impact of imports on worker outcomes may prove positive in some settings and negative in others (see also Campa and Goldberg, 2001; Hummels et al., 2018; Egger et al., 2018).

This paper sets up an empirical framework to first consider the nature of differential cost and revenue shocks in the case of the unexpected Brexit exchange rate depreciation. To do so, it considers how the sterling depreciation generated revenue and/or cost shocks through trade prices, by studying the empirical relevance of the revenue channel from exports and the cost channel from intermediate imports. The latter is shown to dominate as the price of intermediate imports rose by more in higher depreciation industries, but with no offsetting revenue gain from exports.

Then the analysis moves on to evaluate the labour market impact. There is strong evidence that the depreciation hurt workers, by reducing wages. The depreciation acted to impose extra costs on businesses, thereby making intermediate imports more expensive and as a consequence reducing real wage growth. Employment and hours remained stable, but real wage growth declined in relative terms and stagnated in higher depreciation industries. In the aggregate, the Brexit vote resulted in real wages falling permanently by about 3 to 3.6% over the three year period after the referendum, compared to a counterfactual of sterling depreciation across currencies following a gravity pattern.

Whilst there is a specificity to the Brexit referendum setting that needs to be acknowledged, these findings add to and advance what we know from several literatures. First of all, recent surges in nationalist politics, embodied in the Brexit vote and the Trump tariff war, have led to a growing body of research on the potential and actual impacts of populism on economic welfare. These include the price, trade and welfare impacts summarised in Dhingra and Sampson (2022) for Brexit and Fajgelbaum and Khandelwal (2022) for the Trump tariffs. Some findings reported in this paper relate to these debates, in particular the new evidence of adverse effects on real wages arising from the vote for economic nationalism that led to the decision to leave the EU.[1] The new dawn referred to in the title of this paper did in fact fade for workers, despite the protestations that wages and incomes would improve under Brexit from those who advocated Leave.

The findings reported in the paper highlight that offshoring has important consequences for labour market impacts in a globalised economy. This connects to the sizable literature on trade and labour markets, albeit in a different way to other work which directly relates labour outcomes to trade.[2] Here, there are four key sets of relevant findings. First, we provide evidence that the Brexit exchange rate depreciation reduced real wages by more in industries that faced a bigger depreciation cost shock. Second, in the most affected industries real wage growth stagnated. Third, when considered relative to a coherently defined counterfactual, these cost shocks led to an aggregate fall in real wages. And, fourth, there is evidence of a complementarity between domestic workers and offshoring.

While variations in tariffs and exchange rates have often been too small to credibly study labour market impacts (see Liu and Trefler, 2019; Ebenstein et al., 2014; and Hummels et al., 2018 for discussion), the exchange rate change we study is of unprecedented magnitude in research studying the four major world currencies.[3] It offers a quite unique opportunity to explore economic consequences of a big change, of a scale which has rarely arisen elsewhere because, in the recent past, exchange rates and trade policies in most developed countries have remained relatively stable.

Moreover, above the sheer scale of the depreciation, the unexpected nature of the vote – discussed in more detail later – makes for a

[1] Many studies of Brexit examine post-referendum data on various outcomes including stock market valuations of firms, prices, entry and exit of exporters of merchandise goods, economic uncertainty, trade policy uncertainty, productivity and employment growth (Davies and Studnicka, 2018, Fisman and Zitzewitz, 2019, Greenland et al., 2022; Breinlich et al., 2022; Crowley et al., 2018; Bloom et al., 2019, Hassan et al., 2023; Graziano et al., 2021; Faccini and Palombo, 2021; Javorcik et al., 2020 respectively). For a comprehensive survey of the research, see Dhingra and Sampson (2022).

[2] Key papers include: Feenstra and Hanson (2008); Trefler (2004); Helpman et al. (2010); Autor et al. (2013); Pierce and Schott (2016); Hakobyan and McLaren (2016); Dix-Carneiro and Kovak (2017); and also see surveys by Feenstra (1998); Goldberg and Pavcnik (2016); Helpman (2017); and Muendler (2017).

[3] In their handbook chapter, Burstein and Gopinath (2014) consider the price passthrough of exchange rate movements including large depreciations, among major industrialised countries. The advanced economies experiencing large depreciations include Finland, Italy, Sweden and UK in 1992 and Iceland during the financial crisis. Other papers in international finance study the passthrough of exchange rate shifts ranging from general exchange rate movements such as Berman et al. (2012) for France to large depreciations such as in Mexico, Switzerland and various emerging markets (Cravino and Levchenko, 2017; Auer et al., 2021; Burstein et al., 2005).

more credible exogenous research design to be exploited than has tended to be looked at in other exchange rate research (see Lorenzoni, 2014, for a survey of the literature on exchange rate movements in financial crises). The referendum induced exchange rate depreciation provides variation that is credibly exogenous to labour market outcomes, certainly compared to general exchange rate movements or other large shocks to exchange rates. Consider the example of exchange rate devaluations or of depreciations driven by monetary policy actions. These are often adopted during times of economic crises or slowdown to bolster employment. Another example would be exchange rate depreciations from oil price shocks because they incorporate the direct substitution effects between energy and labour, along with the indirect impacts from a secular economic slowdown.

A final substantive research advance arises because the large, credibly exogenous exchange rate depreciation provides variation in trade, particularly services trade, for which the usual trade policy instruments (tariffs) are lacking. This advances research by expanding the coverage of border price passthrough and labour market impacts beyond trade in goods and the manufacturing sector. Services trade and price data in the UK are unique in being rich in detail and providing comprehensive coverage to enable measurement of trade and labour market impacts that have been elusive in the services sector. Importantly, this enables a study of aggregate labour market impacts which are otherwise difficult to ascertain in economies where services form the bulk of employment and output (e.g. United Kingdom, United States, India).

The remainder of the paper is structured as follows. Section 2 details the context of the sterling depreciation that occurred as the unexpected Leave vote came about, first showing the scale and variation of the exchange rate movements in the period surrounding the referendum. It goes on to define the exchange rate movements and the difference-in-differences (DiD) research design that is used in the empirical work. Section 3 shows the impact of the sterling depreciation on trade prices, with a particular focus on whether revenue and cost channels are at work, and section 4 the impact on an array of labour market outcomes. The final part of section 4 quantifies the aggregate wage impact across counterfactuals including a gravity pattern of sterling depreciation across currencies, showing a permanent and sizable aggregate real wage loss. The implications of the core results are further discussed broadly in section 5, through a range of extensions and refinements. These both assess the robustness of the core findings, but also place them into the wider context of the literatures discussed above. Section 6 concludes.

2. The EU referendum vote and the sterling depreciation

2.1. The events of June 23/24 2016

On 22 February 2016, the then Prime Minister David Cameron announced to the UK House of Commons that, following an agreement in a meeting in Brussels the previous week, the country would hold an In-Out referendum on Thursday 23 June 2016. This was the culmination of earlier discussions, including the EU Referendum Bill in the Queen's speech of 27 May 2015 and the calls for national sovereignty that had been heavily stepped up, most notably by Nigel Farage, leader of the UK Independence Party (UKIP).[4]

The referendum took place on that day, with the electorate being given two possible answers to the question "Should the United Kingdom remain a member of the European Union or leave the European Union?". The answers were: "Remain a member of the European Union" or "Leave the European Union". When the referendum took place, 72% of eligible voters cast a ballot, with 52% voting "Leave" and 48% voting "Remain".

As has been widely documented, this result was not expected (e.g. O'Rourke, 2019). In the run-up to the referendum, most polls and bookmakers had predicted a win for the Remain campaign, albeit with a modest margin. Even up to polling day, arch Brexit supporters conceded that Remain was likely to win. This indeed seemed the case when the polling stations across the country closed at 10 pm on June 23. A YouGov opinion poll released then suggested Remain were on course for victory with 52% and Leave on 48%. By 10.15 pm, Farage conceded the Brexit campaign may be beaten and said Remain "will edge it."[5]

The exchange rate movements then confirmed this expectation. Fig. 1a shows the pound dollar and pound euro minute by minute exchange rates indexed to 1 at 10 pm when the polls closed, so as to clearly show the before/after shifts, between 6 pm and 11-25 pm on June 23 (11–25 being the time the first result was reported). Sterling jumped at 10 pm, after rising modestly the hour before, and surged against the US dollar, rising to very nearly 1.5 dollars by 11–25, its strongest performance in 2016. It also rose against the Euro, though not by as much, but reached a value of 1.314 Euro by 11–25.

In comparison with exchange rate movements studied in the literature, these movements up to 11-25 pm were large. But they are just dwarfed by what followed. At 11-25 pm, the first result came in, a big Remain vote from Gibraltar of 96%. Then things started to change. As with other UK elections, various constituencies in the North East of England engaged in a race to report first and the first big result came from there. Minutes after midnight, Newcastle reported, as expected, a win for Remain. But it was very marginal - 50.7% against 49.3% – which was nowhere near the margin many thought would occur.

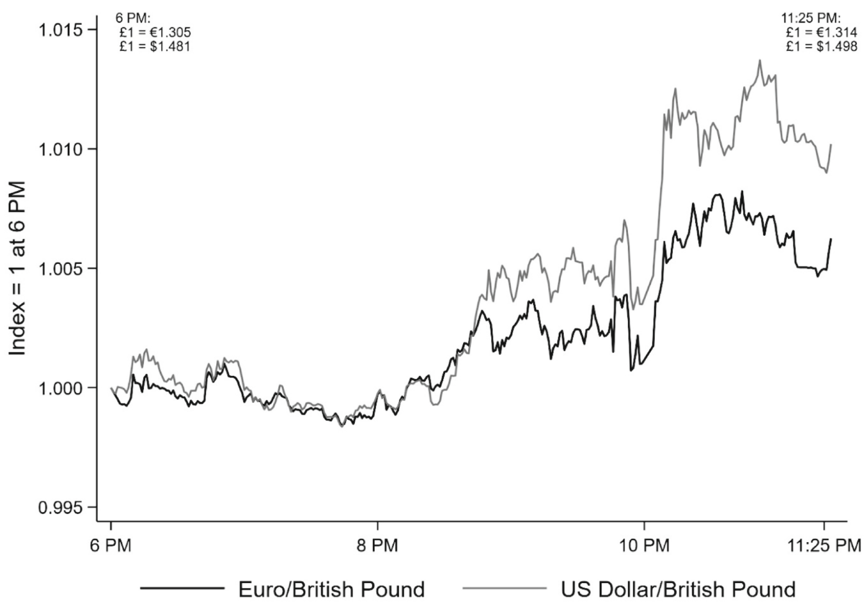
Then twenty minutes later at 12-20 am, all hell broke loose. Again in the North East, and very interestingly in the home of the big Nissan car factory, Sunderland voted to Leave by a significant margin, by 61 compared to 39%. Sterling plummeted, and went from being up, to within seconds an instantaneous near 4.7% drop. This alone, in seconds, was a bigger fall than the Black Wednesday crash in 1992.

Fig. 1b shows the minute by minute exchange rate movements of the night, now in the time window from 6 pm on June 23 and 8 am

[4] UKIP was then a single issue party campaigning for Britain's exit from the EU.

[5] Appendix A has a timeline of the events occurring from polling station close at 10 PM on Thursday June 23, through to 8–50 AM on Friday June 24.

a: Exchange Rate Movements 6 PM To 11-25 PM June 23 2016



b: Exchange Rate Movements 6 PM June 23 2016 To 8 AM June 24 2016

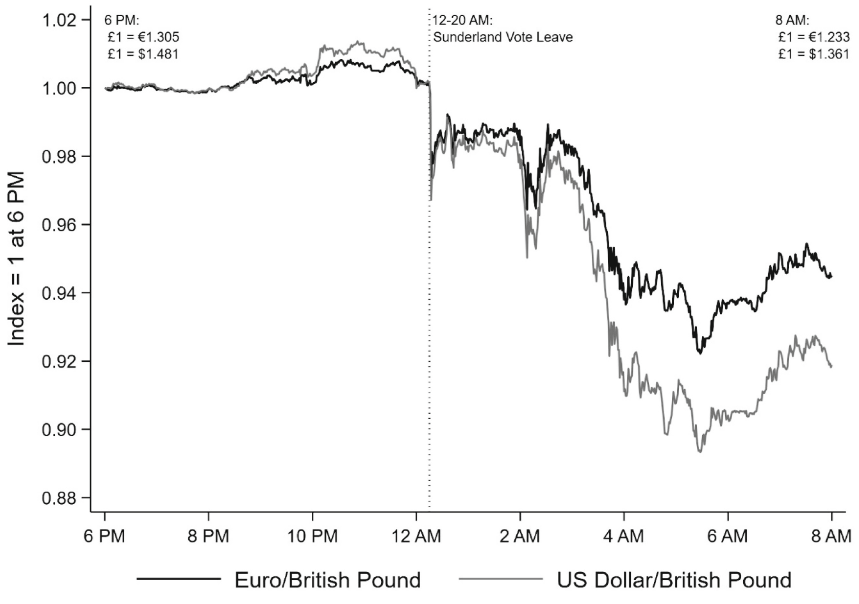


Fig. 1. a: Exchange Rate Movements 6 PM To 11–25 PM June 23, 2016.
Notes: Minute by minute Euro/British Pound and US Dollar/British Pound exchange rates from HistData (FOREX) from 6 PM to 11:25 PM on June 23, 2016. The exchange rates are indexed to 1 at 6 PM on June 23, 2016.
b. Exchange Rate Movements 6 PM June 23, 2016 To 8 AM June 24, 2016.
Notes: Minute by minute Euro/British Pound and US Dollar/British Pound exchange rates from HistData (FOREX) from 6 PM on June 23, 2016 to 8 AM on June 24, 2016. The exchange rates are indexed to 1 at 6 PM on June 23, 2016.

on June 24. It makes very clear how the big gains up to 11-25 pm look tiny compared to what subsequently happened. The precipitous drop triggered by the Sunderland vote is shown by the vertical line at 12-20 am.

Sentiment changed immediately. Bookmakers' odds flipped and sharply reversed. People began to feel that Leave could be winning, and it showed in Google searches in the next hour. Other Brexit wins followed and by 2-17 am, Nigel Farage tweeted he is "so happy with the results in North East England".[6] A few big wins went to Remain subsequently, but from then on the Leave campaign enjoyed more and more gains across Wales, Northern Ireland, Yorkshire and the Midlands to outweigh the majority of Remain's support in Scotland and London. By 7 am on June 24, the Leave campaign had officially won.

Fig. 1b shows that, throughout the night, sterling's slide against the dollar and euro continued. By 8 am on June 24, a pound fetched 1.36 dollars, hugely down from its high of the previous night of nearly 1.50 dollars. The pound was then worth 1.23 Euros, also a huge fall, but notably not as big as against the dollar. In fact the 24 h fall was a huge 8% against the dollar and 6% against the Euro.

The unexpected aspect of this very big exchange rate depreciation, and that exchange rate movements were of significantly different magnitude for different currencies is the variation we study in this paper. That there is considerable variation is shown in Table 1 for 26 exchange rates - the Bank of England's major currencies used to define the sterling effective exchange rate index - in the 24 h period surrounding the referendum. Sterling depreciated most against the Japanese Yen (11%) and the US dollar (8%). In the context of what the referendum was about, Brexit, this is entirely intuitive as they would be seen as relatively safe haven assets by forex traders and analysts.[7] By contrast, sterling depreciated relatively less against EU currencies like the Euro and the Polish Zloty, whose fortunes were perceived to be more tied to sterling's in this event window. In fact, the depreciation of sterling across currencies to some degree reflects a gravity trade pattern, with larger drops against more distant and larger countries like the United States and China. This is leveraged later to construct a counterfactual to examine the average impacts of the sterling depreciation. Being one of the major currencies of the world, the flight from sterling also differentially changed the value of a whole host of other more minor currencies as forex traders looked for new avenues and trades.[8] This provides rich variation in the depreciation of sterling across world currencies.

The construction of depreciation measures uses data on all world currencies. It also leverages the credibly exogenous variation of the referendum night, after which other events unrelated to the Brexit vote move exchange rates, as seen in the one week and two week windows after the vote (see Fig. A1a and A1b of Appendix C). That said, it is noteworthy that sterling stayed persistently lower for the next three years.[9]

2.2. Measuring industry by currency sterling depreciations

As in many studies, the exchange rate at a point in time can be thought of in terms of the real and financial "fundamentals", say $\mathscr{S}$ which is a vector of all relevant variables in the economy that can be viewed as fixed, and the public's best estimate of $\mathscr{S}$, denoted by $\widetilde{\mathscr{S}}$ which changes with news that occurs in an event study window (see Andersen et al., 2003; Engel, 2014). As an example, market access policies between the UK and the EU can be considered an economic fundamental which does not change with the news of the referendum, but the public's perception of it changes with the news of the unexpected Brexit vote.

Then the equilibrium exchange rate of the pound with respect to country c's currency is $E_c = \phi_c\left(\mathscr{S}, \widetilde{\mathscr{S}}\right)$. For a given time window, linearising and time differencing gives $\Delta E_c = \widehat{\phi}_{1c}\Delta\mathscr{S} + \widehat{\phi}_{2c}\Delta\widetilde{\mathscr{S}}$ where Δ is a log-difference operator, $\widehat{\phi}_{1c} = \phi_{1c}\mathscr{S}/\phi_c$, $\widehat{\phi}_{2c} = \phi_{2c}\widetilde{\mathscr{S}}/\phi_c$ and ϕ_{1c}, ϕ_{2c} are the partial derivatives. The fundamentals do not change in this narrow window (when most markets except the forex market in London were closed). Conditional on information at the beginning of the window $\widetilde{\mathscr{S}}$ and the surprise of the Brexit referendum news, B, the state variable changes by $\Delta\widetilde{\mathscr{S}} = B$ and the exchange rate consequently changes by $\Delta E_c = \widehat{\phi}_{2c}B$. Without loss of generality, let $\Delta E_c > 0$ denote an increase in the value of currency c in terms of sterling, so that larger values correspond to a bigger sterling depreciation.

Because sterling depreciated differently across currencies due to the Brexit vote, this generated differences across industries in the cost and revenue shocks they subsequently faced because industries buy and sell across different source and destination countries. For example, financial services purchases inputs primarily from the United States and would have experienced a larger cost shock than, for example, insurance services which buys inputs primarily from Germany. Industries cannot immediately switch their supply chains and customer base, so the Brexit depreciation exposed them to different cost and revenue shocks.

Constructing an industry-level depreciation measure requires two components, the exchange rate shifts by currency and the country shares applied to them to determine economic linkages with the UK. The depreciation measure is then a shift-share measure of

[6] https://www.bbc.co.uk/news/uk-politics-eu-referendum-36598599

[7] That the relative depreciation was driven by a flight into safe haven assets is also reflected in the subsequent rise in the price of gold and the stock market valuations of commodity firms. For example, the day after the Brexit vote saw a gold price rise of over 5% - the highest surge since the depth of the 2008 financial crisis (https://www.coinworld.com/news/precious-metals/2016/06/brexit-vote-european-union-gold-price-surge-kitco.all.html). The Royal Mint reported a 550% increase in traffic on its online purchase site compared to the same time the previous day.

[8] https://www.euromoney.com/article/b12kpbtwmrnrp7/fx-traders-pick-through-brexit-wreckage

[9] Also reassuring for the approach we take is what happened to forward exchange rate at the times. The ranking of the exchange rate depreciation across currencies in the spot market is highly similar to their movement in the forward exchange rate market over the same 24 h window. Column 2 of Table A1 in Appendix C reports the one year forward exchange rate depreciations across major currencies. Depreciations across currencies for other forward durations, 2 years and 5 years, are also highly similar, though there are fewer currencies that are traded over longer forward durations (available upon request).

Table 1
EU Referendum Depreciation Of Sterling For Major Currencies.

Country	Currency	Depreciation (Percent)
Japan	Japanese Yen	11.1
United States	US Dollar	8.0
Saudi Arabia	Saudi Riyal	8.0
Hong Kong	Hong Kong Dollar	7.9
Thailand	Thai Baht	7.6
China	Chinese Yuan	7.5
Singapore	Singapore Dollar	7.4
Taiwan	Taiwan Dollar	7.2
Russia	Russian Ruble	7.2
India	Indian Rupee	7.1
New Zealand	New Zealand Dollar	7.1
Australia	Australian Dollar	6.9
Canada	Canadian Dollar	6.9
Israel	Israeli Shekel	6.8
Switzerland	Swiss Franc	6.6
Turkey	Turkish Lira	6.5
Malaysia	Malaysian Ringgit	6.3
Denmark	Danish Krone	6.1
Euro Zone	Euro	6.0
Czech Republic	Czech Koruna	5.9
South Korea	Korean Won	5.7
South Africa	South African Rand	5.3
Hungary	Hungarian Forint	5.2
Norway	Norwegian Krone	5.2
Sweden	Swedish Krona	5.1
Poland	Polish Zloty	4.3

Notes: Sterling depreciations for the 24 h window from 4 PM June 23, 2016 to 4 PM June 24, 2016, daily spot exchange rates from Reuters Datastream for the Bank of England's 26 major currencies.

generic form $\sum_c S_{co} f(\Delta E_c)$, where S_{co} is the economic linkage share of country c and ΔE_c is the sterling depreciation against country c's currency defined for functional form $f(.)$. Below in the descriptive analysis we look at the level of the depreciation, defined in general notation for now, before the shares are more precisely defined, as $D_o = \sum_c S_{co} \Delta E_c$ and in empirical difference-in-differences models as the log of the depreciation, defined as $lnD_o = \sum_c S_{co} ln\Delta E_c$.[10]

Shift-share measures like these, with different shifts and shares definitions for the research question of interest, have been widely used in empirical work in a variety of research areas and settings over the years, dating back to the original Bartik (1991) measures. Recently, shift-share variables have featured prominently in the burgeoning literature on difference-in-differences methodology, including to do with their measurement, use and interpretation and on drawing appropriate statistical inference when using them in empirical work (see, especially, Borusyak et al., 2022).

On a practical level, there are various ways the share term S_{co} can be measured. There are a range of possible economic linkages that industries have with different countries, but for the focus and interest of this paper, the most natural one to consider is trade linkages. Thus, for most of the analysis in this paper, two trade shares (one for exports, one for intermediate imports) are used to construct industry-specific depreciation measures that respectively pick up the revenue and cost channels through which an exchange rate depreciation can work. Later in the paper, we do however consider a number of economic linkage shares to construct alternative measures of the sterling depreciation.

To be more concrete, we use data on all 2-digit industries in the UK put together with 148 world currencies across 229 countries/territories to measure industry depreciation across the whole economy. 85 industries (33 manufacturing, 52 services) are aggregated up to 83 following ONS practice due to two low employment industries (see Data Appendix B for more detail). The industry trade structure refers to exports and intermediate imports of the industries across countries measured before the referendum.[11]

For each of these, and defining an output industry o, combining exchange rate variations measured in levels and trade shares produces two trade weighted depreciation measures (now with superscripts $j = [x, i]$ delineating trade shares for exports x and intermediate imports i attached):

i) Exports (x): $D^x_o = \sum_c S^x_{co} \Delta E_c$ where S^x_{co} is the share of foreign destination country c in export sales of output industry o,

[10] $\sum_c S_{co}$ sums to one across all foreign countries c. Note that, in the log functional form, the weights that sum the industry log depreciations are in levels.

[11] Later, import competition is also examined by expanding imports to include final consumption imports of households, though it should be noted that this does come with the usual difficulty of distinguishing between further sales of intermediate imports to final consumers.

ii) Intermediate imports (i): $D_o^i = \sum_c S_{co}^i \Delta E_c$ where $S_{co}^i = \sum_i S_{ico}$ and S_{ico} is the share of imports of intermediate i purchased from foreign source country c by output industry o.

The industry-country trade shares are based on pre-referendum data combining goods trade from UN COMTRADE, services trade from the International Trade in Services (ITIS) microdata and the detailed Import Supply-Use Tables of the Office of National Statistics (ONS) for 2015. Industry-currency shares for services trade are taken from the industry-country values of exports and imports reported in the ITIS by firms and from bespoke freedom of information requests to the ONS for certain industries and services that are not covered by ITIS.

The ITIS survey has been collecting very rich services information from over 16,000 UK businesses each year since the early 2000s to provide statistics on both the UK's services imports and exports. The survey collects firm-country level information covering exports and imports of 52 different services with over 200 countries worldwide. Results from the annual ITIS survey are used to compile both the balance of payments account and estimates of gross domestic product. It therefore provides rare firm-service-country detail on trade patterns and high quality information on services for most industries in the UK. Trade patterns for a few industries and services that are not covered by ITIS are obtained from the ONS which collects this information through alternative sources (e.g. the International Passenger Survey of the UK for travel services).

For goods, the UK does not conduct a corresponding export sales and import purchases survey across firms. As is standard, under a proportionality assumption across manufacturing industries, import supply-use tables of the UK are combined with import values from the UN COMTRADE data to construct the industry-currency shares as a product of the import shares across source country currencies for an input S_{ic} and the share of that input in the intermediate imports of the industry S_{io}.

After trimming currency shares of below 1% in an industry, 98 countries and 81 currencies are used to construct the exports weighted depreciation measure and 71 countries and 52 currencies are used to construct the intermediate imports weighted measure.[12]

2.3. Descriptives

Fig. 2 shows the broad currency composition of the two depreciation measures, D_o^x and D_o^i. For each measure, it plots the broad currency structure of trade (dollar, euro and the rest) in above median and below median depreciation industries. It is very clear that the dollar share is higher in the above median depreciation industries, and that the euro share is lower, validating how the industry depreciation measures pick up the cross-currency variations.

Table 2 gives more detail by listing the top and bottom four depreciation industries, together with their depreciations and their trade shares (in percent) of the top three currencies of the countries with which they trade. There are some very clear patterns. Service industries tend to rank at the top of both of the measures. Manufacturing industries feature in the bottom four. The top four for both depreciation measures is characterised by more dollar trades, and the bottom four by euro trades. And the depreciations of the top four and bottom four are sizable, but with ranges of around 1.2 to over 1.8 percentage points between them (from 5.8 to 7.7 from bottom to top for exports, and from 6.2 to 7.4% from bottom to top for intermediate imports).

Honing in on particular industries, Cultural activities, Repairs and installation of machinery and Education and Membership organisations export largely to the United States and China and are the top four affected industries in terms of the exports-weighted depreciation. At the bottom end, Wholesale and retail trade, Programming and broadcasting, Water collection and treatment and Electricity, gas and other energy supply export mostly to European countries and are the least affected in terms of the magnitude of the exports weighted depreciation.

The top and bottom four industries in terms of exports are different from the industries that were affected through intermediate imports. Activities auxiliary to financial and insurance services (like fund management), Programming and broadcasting and Scientific research and development import intermediates mostly from the United States and are the top three intermediate import-affected industries. Architectural and engineering services is in fourth place, despite more than a third of its intermediates coming from the Eurozone because it buys an equivalent share from the United States and China. In contrast, the higher share of European countries in intermediate imports of Accommodation, Manufacture of paper and paper products, Manufacture of coke and petroleum products and Electricity, gas and other energy supply puts them in the bottom four for the intermediate imports-weighted depreciation.

The identifying variation in the shift-share can be inspected by plotting country-level depreciation shifts against the trade share with that country (averaged across industries). This is a useful exercise to consider what empirical variation the shift-share is picking up. Fig. A2 in Appendix C plots the country exchange rate shifts against the country's average industry-weighted trade shares for D_o^x and D_o^i. Neither is at all highly correlated, in fact the fitted line through the data points is almost flat, so the shift-share design very clearly benefits from variation in depreciation shocks that are not driven by the trade shares (a feature also confirmed by more robustness checks presented later in the paper where trade shares are added as additional controls).

[12] Small shares are trimmed to reduce measurement error as in Revenga (1992), but results are qualitatively similar for no trimming and alternative trimming thresholds as discussed later.

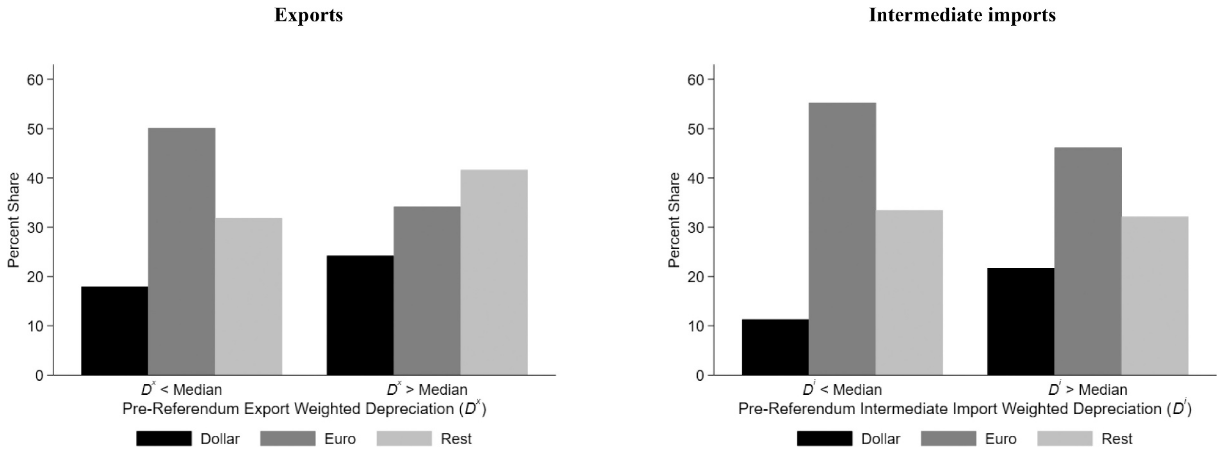


Fig. 2. Currency Structures, Exports and Intermediate Imports Depreciation.
Notes: Currency shares of the Dollar, Euro and the Rest broken down into above and below median sterling depreciations for the 24 h window from 4 PM June 232,016 to 4 PM June 242,016. Left chart for export share weighted depreciations (78 exporting industries), right chart for intermediate imports weighted depreciations (83 intermediate importing industries).

Table 2
Top Four and Bottom Four Depreciation Industries.

Exports, D_o^x		
Depreciation	Top Four Industries (SIC)	Top Three Currencies (%)
7.65	Cultural activities (91)	USD (65), Euro (16), Yen (8)
7.55	Repair and installation of machinery (33)	USD (61), Saudi Riyal (11), Euro (10)
7.36	Education (85)	USD (29), Euro (16), Yuan (11)
7.35	Membership organisations (94)	Yuan (17), Malaysia Ringgit (12), Pakistan Rupee (11)
Depreciation	Bottom Four Industries (SIC)	Bottom Three Currencies (%)
6.05	Electricity, gas and other energy supply (35)	Euro (99), USD (1)
6.03	Water collection and treatment (36)	Euro (100)
5.90	Programming and broadcasting (60)	Euro (51), Zloty (10), Sweden Krona (6)
5.82	Wholesale and retail trade (45)	Euro (54), Sweden Krona (36), USD (9)

Intermediate Imports, D_o^i		
Depreciation	Top Four Industries (SIC)	Top Three Currencies (%)
7.39	Activities aux. to financial and insurance services (66)	USD (46), Euro (26), Yen (6)
7.03	Programming and broadcasting (60)	USD (54), Euro (41), Yuan (4)
6.96	Scientific research and development (72)	USD (40), Euro (33), Sweden Krona (11)
6.90	Architectural and engineering services (71)	Euro (36), USD (30), Yuan (7)
Depreciation	Bottom Four Industries (SIC)	Bottom Three Currencies (%)
6.25	Electricity, gas and other energy supply (35)	Norway Krone (43), Euro (12), Qatar Rial (8)
6.24	Manufacturing coke and petroleum products (19)	Norway Krone (45), Qatar Rial (10), Algeria Dinar (9)
6.23	Manufacture of paper and paper products (17)	Euro (61), Yuan (11), USD (9)
6.22	Accommodation (55)	Euro (71), USD (7), Yuan (5)

Notes: Four highest and lowest industry exports and intermediate imports weighted depreciations and their top and bottom three currency shares. D_o^x and D_o^i are defined in the text, and the data sources used in Appendix B.

2.4. Research design

The main empirical analysis is based upon a difference-in-differences research design that studies what happened before and after the referendum to the economic outcome of interest - defined generally for now as Y, but which will be industry trade prices and individual worker outcomes with precise details on measurement specified later.

The empirical analysis is undertaken using quarterly data for the four years prior to and the three years after the referendum. Thus, it runs for 28 quarters from 2012Q3 to 2019Q2. The starting point is reduced forms for different pre-referendum trade measures *j* of the before/after referendum evolution of a given outcome Y related to the industry depreciation measures for output industry o in time period qt, where q is quarter and t is year. The baseline difference-in-differences estimating equation is:

$$lnY_{oqt} = \alpha_o + \alpha_{qt} + \beta_Y \times lnD_o^j \times \mathbb{1}\left(qt \geq Referendum_{qt}\right) + \varepsilon_{oqt} \tag{1}$$

where α_o is a full set of industry fixed effects (these absorb the time-invariant level of lnD_o^j and so this is controlled for throughout in the empirical work), α_{qt} are quarter-year fixed effects and $\mathbb{1}\left(qt \geq Referendum_{qt}\right)$ switches on to one from 2016Q3 onwards and is zero before that, and ε_{oqt} is an error term.

The log-log functional form in (1) enables β_Y to be interpreted as an elasticity for outcome Y. For example, when Y is a trade price, the estimated coefficient from the log-log form can be interpreted as a passthrough parameter, like those used in the international prices and exchange rate literatures mentioned earlier.[13] In the labour outcome equations, it can conveniently be interpreted as a percentage effect on the labour market outcome in question associated with a given percent higher depreciation.[14]

To be congruent with trade theory that considers both foreign and domestic trade shares, and to further explore empirically whether estimated effects also differ systematically with these trade shares, a generalised version of (1) additionally includes interactions of lnD_o^j with the relevant trade shares λ_o^j, defined respectively for exports as the share of exports in total home and foreign demand and for intermediate imports as the share of imported intermediates in total intermediate purchases. These interactions and additional relevant levels of interactions are included in the estimating equation which becomes:

$$lnY_{oqt} = \alpha_o + \alpha_{qt} + \beta_{Y1} \times lnD_o^j \times \mathbb{1}\left(qt \geq Referendum_{qt}\right) + \beta_{Y2} \times lnD_o^j \times \mathbb{1}\left(qt \geq Referendum_{qt}\right) \times \lambda_o^j + \beta_{Y3} \times \mathbb{1}\left(qt \geq Referendum_{qt}\right) \times \lambda_o^j + \varepsilon_{oqt} \tag{2}$$

In (2), the relevant elasticity becomes $dlnY_{oqt}/d\left(lnD_o^j \times \mathbb{1}\left(qt \geq Referendum_{qt}\right)\right) = \beta_{Y1} + \beta_{Y2} \times \lambda_o^j$, which is evaluated at the median value of λ_o^j. Throughout the paper, for ease of notation, shares S_{co} have foreign trade in the denominator while λ_o has total domestic and foreign trade in the denominator.

To provide more detail on the actual magnitudes of changes arising after the referendum, a more restrictive model using a discrete functional form for the depreciation shock and restricting time effects to compare changes in outcomes before and after the referendum for industries with above or below median depreciation, can be specified as follows:

$$lnY_{oqt} = \alpha_o + \beta_{Ya} \times \left(D_o^j > Median\right) \times \mathbb{1}\left(qt \geq Referendum_{qt}\right) + \beta_{Yb} \times \left(D_o^j < Median\right) \times \mathbb{1}\left(qt \geq Referendum_{qt}\right) + \varepsilon_{oqt} \tag{3}$$

In (3), time effects are not included and β_{Ya} is therefore the estimated before/after change in the outcome for industries that face above median depreciation, and β_{Yb} the analogous measure for the below median depreciation industries. Therefore, $\beta_{Ya} - \beta_{Yb}$ is the difference-in-differences estimate of interest that shows the relative change in Y in the upper and lower halves of the depreciation distribution before and after the referendum.

Finally, the specification in (3) can be further generalised to estimate the before/after change in the outcomes for industries in the top four, bottom four and middle 75 exposure groups as follows:

$$lnY_{oqt} = \alpha_o + \alpha_{qt} + \sum_g \left(\beta_{Yg} \times \left(D_o^j \in g\right) \times \mathbb{1}\left(qt \geq Referendum_{qt}\right)\right) + \varepsilon_{oqt} \tag{4}$$

where g denotes broader groups of industries than the above/below median specification. Estimates are reported below for industries in the top four, bottom four and middle 75 of the D_o^j distributions.

3. Trade prices and the Brexit exchange rate depreciation

In this section, Y is measured by trade prices, specifically in terms of export prices (hereafter P^x) and intermediate import prices (P^i), which are related to the trade weighted exchange rate depreciations with an aim of empirically evaluating whether revenue or cost channel responses (or both) occurred as a consequence of the Brexit exchange rate depreciation.

3.1. Trade prices

Quarterly data on export and import price indices at the industry level come from price observations reported by firms to the ONS.

[13] All regressions are weighted by employment weights of industries to keep them consistent across trade price and labour market outcome specifications.

[14] Adopting a log-log functional form offers a clear means of evaluating magnitudes of the β estimate, as compared to a semi-log function that relates lnY_{oqt} to $\mathbb{1}\left(qt \geq Referendum_{qt}\right) \times D_o^j$. But calculating elasticities from the semi-log function evaluated at the mean or median depreciation level produced more or less identical results throughout the empirical analysis.

Publicly available price indices are collated with those for uncovered service industries (like travel and tourism) obtained from the ONS through bespoke freedom of information requests. Export and import price indices cover the entire UK economy, with five industries being non-traded. Intermediate import price indices are computed for all 83 industries, including the five non-traded ones as each of them uses intermediate imports, based on supply-use tables that are constructed from the ITIS microdata and from the ONS Import Supply-Use Tables for goods and uncovered services. The sample period ends in 2018Q4 because the price series change afterwards which could result in comparability issues.

The focus on prices as a trade outcome is motivated by the vast literature in international economics which studies passthrough of exchange rate depreciations to prices (survey in Burstein and Gopinath, 2014). Prices are considered a key outcome for exchange rate movements, and they are also a preferred measure when studying the entire economy because quantities and trade flows are difficult to define in services industries (see Feenstra et al., 2010 for discussion). Most statistical agencies (example, in the US and the UK) report "quantities" as deflated trade values, often for fairly aggregated categories. The UK price data, in contrast, is collected from specialised firm-level surveys where a number of quality checks are undertaken by the Office of National Statistics to ensure that similar units and quality are being reflected over time for the same firm.

3.2. Descriptive analysis

Starting with descriptive analysis, Fig. 3 plots trade price changes before and after the referendum against the relevant depreciation. The Exports panel shows a flat line when the log change in export price before and after the referendum is plotted against the export destination weighted depreciation from the referendum window. Export prices (in sterling) rose but display almost zero correlation with the export destination share-weighted depreciation.

By contrast, the Intermediate imports panel shows a steep positive slope in the relation between the change in intermediate import prices and the intermediate import weighted depreciation before and after the referendum. Industries that experienced a higher intermediate-import weighted depreciation had bigger price increases for their imported inputs. Industries therefore differed systematically in the cost shocks they experienced from the Brexit sterling depreciation, but without such a pattern emerging on the revenue side.

3.3. Regression estimates

Table 3 systematises these findings in the DiD estimating eqs. (1)–(4), respectively presented in the four Panels of the Table. In column (1) export price equations are reported, and the estimates show no evidence of a before/after differential change in export prices (in sterling) in industries with a higher depreciation. This is true for the results contained in all four Panels. The price elasticity estimates in Panels A and B are small and statistically insignificant. And there are no differences across the high to low groups of Panels C and D.

It is the case that export prices did rise in the aggregate following the referendum, but by a highly similar 10% or so in both the above/below median and in the top four/middle 75/bottom four export depreciation industries, with there being no systematic differences across the depreciation distribution. Maybe surprisingly at first thought, one cannot reject the null hypothesis that the Brexit vote induced exchange rate depreciation had no differential effect on industry export prices. Below we will consider this further when we examine cross-effects in fuller passthrough models.

Moving to intermediate imports, in column (2), the story is different. In line with the descriptive scatterplots, there is strong evidence across all of the column (2) estimates of Table 3 that the sterling depreciation had a significant price-increasing impact on intermediate imports. In Panel A, the estimated elasticity is 0.498 and in Panel B in the interacted model is 0.487 evaluated at the median share. Panels C and D provide further evidence on the magnitude of these changes. In Panel C, intermediate import prices rose by 8.4% among industries with above median depreciation compared to 5.4% for below median industries. This gives a DiD estimate of a 3% higher intermediate import price passthrough across the two sets of industries. The gap is even bigger between the top and bottom of the distribution, with the top four/bottom four difference-in-differences in Panel D being a very sizable 6.1% higher growth in intermediate import prices.

In column (3), the focus remains on intermediate import prices, but for a restricted sample where the five non-traded export industries are excluded.[15] A similar, slightly reduced in magnitude, but still a large passthrough effect is seen for the continuous depreciation measures in Panels A and B. And the discretised relative comparisons are essentially the same.

Overall, the passthroughs seen for intermediate import prices in Table 3 are sizable and in line with magnitudes seen in other work (e.g. Chen et al., 2022 with disaggregated goods customs data).

3.4. Pre-trends

The estimates reported so far rely on there being no pre-referendum trend differences in the outcome of interest. To examine this in more detail, Fig. 4 shows event study estimates of eq. (3) for intermediate import prices where separate year specific estimates of β_{Pa} and β_{Pb} are shown (with associated confidence intervals) for the three post-referendum periods (2016/17, 2017/18 and 2018H2) and

[15] Results are unchanged when the export specifications are estimated on the full sample of industries and an indicator for non-traded industries is entered to account for missing prices in these industries.

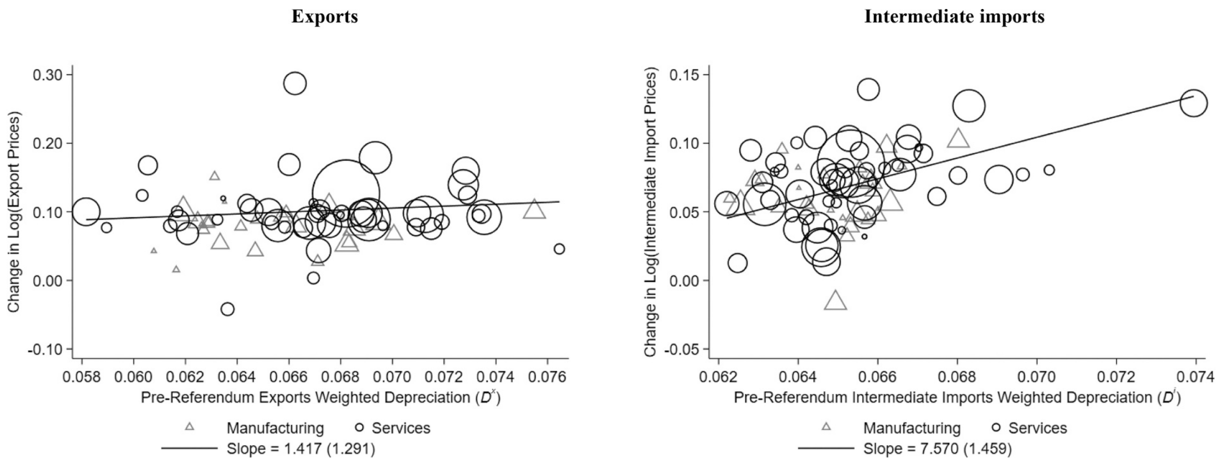


Fig. 3. Scatters – Trade Prices And Depreciation.
Notes: Scatterplots of the post-pre referendum change in trade prices (measured between the post quarters 2016Q3-2018Q4 and pre quarters 2012Q3-2016Q2) and the pre-referendum weighted depreciation. Left chart for exports (78 exporting industries), right chart for intermediate imports (83 intermediate importing industries).

Table 3
Trade Prices and Depreciation.

	(1)	(2)	(3)
	lnP^x	lnP^i	lnP^i
A. Continuous			
lnD^x x Post-Referendum	0.094 (0.076)		
lnD^i x Post-Referendum		0.498 (0.132)	0.459 (0.116)
B. Share Interactions			
lnD^x x Post-Referendum at Median Share of x	0.072 (0.065)		
lnD^i x Post-Referendum at Median Share of i		0.487 (0.090)	0.450 (0.085)
C. Above/Below Median			
(D^x > Median) x Post-Referendum	0.109 (0.007)		
(D^x < Median) x Post-Referendum	0.094 (0.008)		
(D^i > Median) x Post-Referendum		0.084 (0.004)	0.084 (0.004)
(D^i < Median) x Post-Referendum		0.054 (0.005)	0.058 (0.005)
Difference-in-Differences	0.015 (0.011)	0.030 (0.007)	0.026 (0.006)
D. Top Four/Middle75/Bottom Four			
(D^x Top Four) x Post-Referendum	0.093 (0.003)		
(D^x Middle 75) x Post-Referendum	0.103 (0.007)		
(D^x Bottom Four) x Post-Referendum	0.116 (0.015)		
(D^i Top Four) x Post-Referendum		0.097 (0.017)	0.097 (0.017)
(D^i Middle 75) x Post-Referendum		0.069 (0.005)	0.073 (0.004)
(D^i Bottom Four) x Post-Referendum		0.036 (0.014)	0.036 (0.014)
Difference-in-Differences	−0.024 (0.015)	0.061 (0.022)	0.061 (0.022)
Industry and Time Dummies	Yes	Yes	Yes
Sample Size	2028	2158	2028

Notes: Panels A through D respectively report estimates of eqs. (1)–(4) defined in the main text of the paper for trade prices, for quarters 2012Q3 to 2018Q4 for 78 exporting industries in columns (1) and (3) and for 83 intermediate importing industries in column (2). Standard errors (BHJ adjusted in panel A) in parentheses.

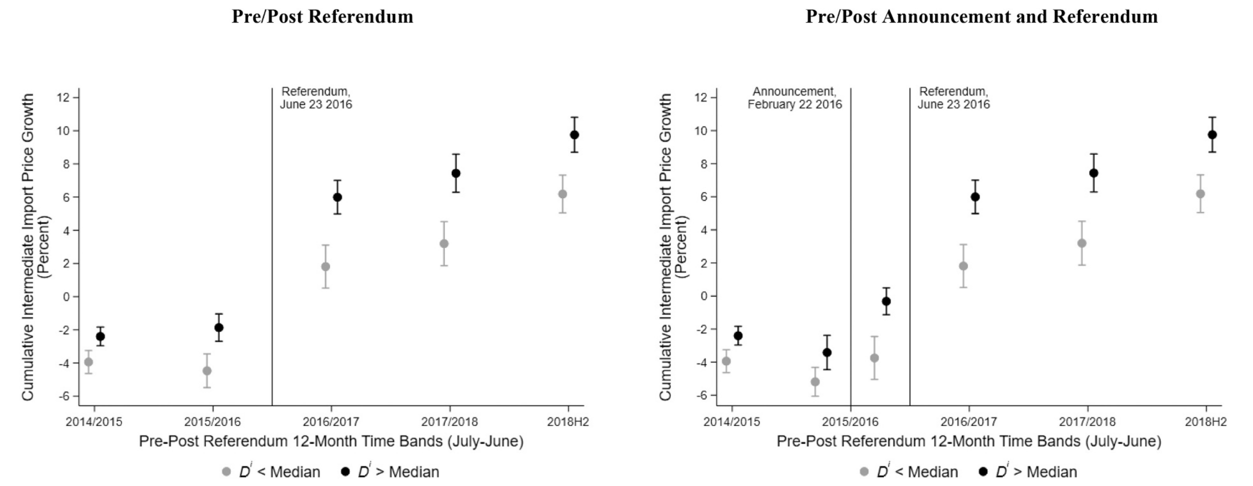


Fig. 4. Event Study – Intermediate Import Prices And Intermediate Imports Weighted Depreciation.
Notes: Event study estimates of eq. (3) in the main text of the paper for intermediate import prices, where the DiD estimates vary in the left chart with pre and post referendum 12 month time bands (defined from July to June for Q3 in a year to Q2 in the following year) and in the right chart where they vary in the same way, but with an additional variation within the year before the referendum (July to December for 2015 Q3 and Q4, and January to June for 2016 Q1 and Q2).

two pre-referendum years (2014/15 and 2015/16).[16]

The event study chart on the left of Fig. 4 very clearly shows the strong price passthrough that occurred as there is significantly higher price growth in each of the three post-referendum periods. Looking at the pre-periods shows similar trends in intermediate import prices for the above and below median industries over the first two years, but also some divergence in the year just before the referendum.[17] In the 2015/16 year, there is some indication of a pre-referendum increase in intermediate prices in the above median depreciation group of industries relative to the below median group. The announcement that the referendum would take place was made on 22 February 2016. Splitting the 2015/16 year into two six month periods reveals more as is shown in the right hand event study, as all the differential price growth before the referendum is in the 2016H1 time periods.

We therefore also re-estimated all of the specifications of Table 3, allowing for possible anticipation of the referendum after it had been announced. This is done by shifting back the post-date by two quarters as 2016Q1 and Q2 are included in the post period and the specifications are re-estimated. The results are shown in Table 4. In practical terms, it does not make much difference, and if anything, the passthrough rises a little to 0.532 (from 0.498) for the intermediate imports elasticity in Panel A, and from 0.487 to 0.520 in the shares specification in Panel B. It makes very little difference to the export prices, which show a slight pickup after the announcement from the exports weighted depreciation. Thus, the overall effects are robust to pre-trends and to possible announcement effects being at play. And binning into finer sectoral categories of above/below median and top four, middle 75 and bottom four depreciations shows the same very clear monotonic pattern in the passthrough of the depreciation to intermediate import prices in Panels C and D of Table 4.

3.5. *Cross effects*

Can the presence of a cost shock via more expensive intermediate imports in higher depreciation industries and no revenue shock from exports varying with depreciation be reconciled with one another? Previous work finds the lack of an export effect because exporting industries also increasingly rely on imported inputs (Amiti et al., 2014; De Soyres et al., 2021). Table 5 looks at cross effects by including both export and import weighted depreciation variables in the continuous depreciation DiD models. There is significant evidence, in column (1) of Panel A that, export prices do indeed rise with the intermediate imports weighted depreciation for the industry. The cross effect passthrough is estimated at 0.314, much larger in magnitude than the passthrough of the exports weighted depreciation.

These findings rationalise and reinforce the notion that the cost shock dominated the revenue shock in this depreciation. Whilst export prices did rise, they rose by more where the cost shock of more expensive intermediates took place. Hence there was no

[16] Note 'years' here refers to year time periods from July to June, thus covering the two last quarters of the calendar year and the two first from the next one. This, of course, is because of the dating of the referendum in June 2016. Also, in these trade price specifications the final estimate, for 2018H2, covers only the last two quarters of 2018. The trade price series were collected differently from 2019Q1 onwards, forcing us to stop the analysis then.

[17] For completeness, the equivalent event study charts are shown for export prices and the above/below median export weighted depreciation in Figure A3 of Appendix C. They show no evidence of a differential pre-trend.

Table 4
Trade Prices and Depreciation, Announcement Effects.

	(1)	(2)	(3)
	lnP^x	lnP^i	lnP^i
A. Continuous			
lnD^x x Post-Announcement	0.106 (0.073)		
lnD^i x Post-Announcement		0.532 (0.168)	0.493 (0.162)
B. Share Interactions			
lnD^x x Post-Announcement at Median Share of x	0.080 (0.063)		
lnD^i x Post-Announcement at Median Share of i		0.520 (0.094)	0.485 (0.088)
C. Above/Below Median			
(D^x > Median) x Post-Announcement	0.099 (0.007)		
(D^x < Median) x Post-Announcement	0.084 (0.008)		
(D^i > Median) x Post-Announcement		0.072 (0.004)	0.073 (0.004)
(D^i < Median) x Post-Announcement		0.039 (0.005)	0.044 (0.005)
Difference-in-Differences	0.015 (0.011)	0.033 (0.007)	0.029 (0.007)
D. Top Four/Middle75/Bottom Four			
(D^x Top Four) x Post-Announcement	0.085 (0.002)		
(D^x Middle 75) x Post-Announcement	0.092 (0.007)		
(D^x Bottom Four) x Post-Announcement	0.106 (0.015)		
(D^i Top Four) x Post-Announcement		0.086 (0.016)	0.086 (0.016)
(D^i Middle 75) x Post-Announcement		0.056 (0.005)	0.060 (0.004)
(D^i Bottom Four) x Post-Announcement		0.012 (0.024)	0.012 (0.024)
Difference-in-Differences	−0.021 (0.015)	0.074 (0.029)	0.074 (0.029)
Industry and Time Dummies	Yes	Yes	Yes
Sample Size	2028	2158	2028

Notes: As for Table 3.

Table 5
Trade Prices, Cost and Revenue Channels.

	(1)	(2)
	lnP^x	lnP^i
lnD^x x Post-Referendum	0.035 (0.065)	0.057 (0.046)
lnD^i x Post-Referendum	0.314 (0.096)	0.425 (0.126)
Industry and Time Dummies	Yes	Yes
Sample Size	2028	2028

Notes: As for Table 3. Standard errors (BHJ adjusted) in parentheses.

differential revenue gains which made exports in higher depreciation industries cheaper. It was offset by the cost shock being bigger there also.

Thus, the sizable depreciation of sterling following the EU referendum vote made intermediate imports more expensive for UK producers. Input prices for imports rose more in industries that suffered a larger *cost shock* due to their pre-referendum import structure and the differential depreciation of sterling against various source currencies. Export prices showed little systematic variation with respect to the revenue shocks from the destination-weighted depreciation, but they rose on account of the reliance of exporting industries on intermediates from foreign sources. The question we next pose, in the following section, is to ask whether this differential cost shock induced by the Brexit exchange rate depreciation affected workers' wages and/or employment.

4. Worker outcomes and the Brexit exchange rate depreciation

This section studies an array of labour market outcomes - changes in wages, hours, employment inflows and outflows - before and after the referendum. Individual level data on private sector workers from the Quarterly Labour Force Survey (QLFS) of the UK are considered from 2012Q3 through 2019Q2 (sixteen quarters pre-referendum and twelve quarter post). The four following composition-adjusted outcomes are studied, where the composition adjustment standardises for age, gender and education using QLFS microdata on individuals throughout the analysis (more detail on data construction, specific definitions and sources is given in Data Appendix B):

i) Real wages, W_{koqt} – full-time weekly wages (deflated by the consumer price index CPIH) for worker k employed in output industry o during quarter-year qt.

ii) Hours, H_{koqt} - hours worked in a week by worker k.
iii) Inflows of workers into the industry I_{oqt}.
iv) Outflows of workers from the industry O_{oqt}.

4.1. Descriptive analysis

Figs. 5a and 5b plot pre-post referendum (composition-adjusted) changes in wages and hours worked, and employment inflows and outflows against the depreciation measures for all industries. Fig. 5a shows the labour market outcomes against the exports weighted depreciation for each industry and Fig. 5b against the intermediate imports weighted depreciations.

For all outcomes considered, the pattern in Fig. 5a is stark, as the slope of the line fitted through the scatter plot for each labour market outcome is almost flat in each case. In line with the previous section's finding of no revenue channel at work, there is no descriptive evidence of adjustment of labour market outcomes to the export weighted depreciation. Much the same is true for the intermediate imports weighted depreciation scatters in Fig. 5b, with one striking exception. Whilst the fitted line for hours and for the two employment flows are flat, the line on the real wage chart – in the north west quadrant of the Figure – slopes strongly down. It appears that real wages declined in relative terms in industries facing a larger cost shock. The descriptive findings suggest that the cost channel reduced wages. But with no job loss, which is consistent with the low aggregate rate of unemployment during the period after the referendum (Dhingra and Sampson, 2022).

4.2. Regression estimates

The descriptive analysis is confirmed by regression estimates of eq. (1) for wages, hours, inflows and outflows shown in Table 6. The Table shows six specifications of the baseline estimation eq. (1) for each, in columns (1) to (3) for the pre-post referendum comparison

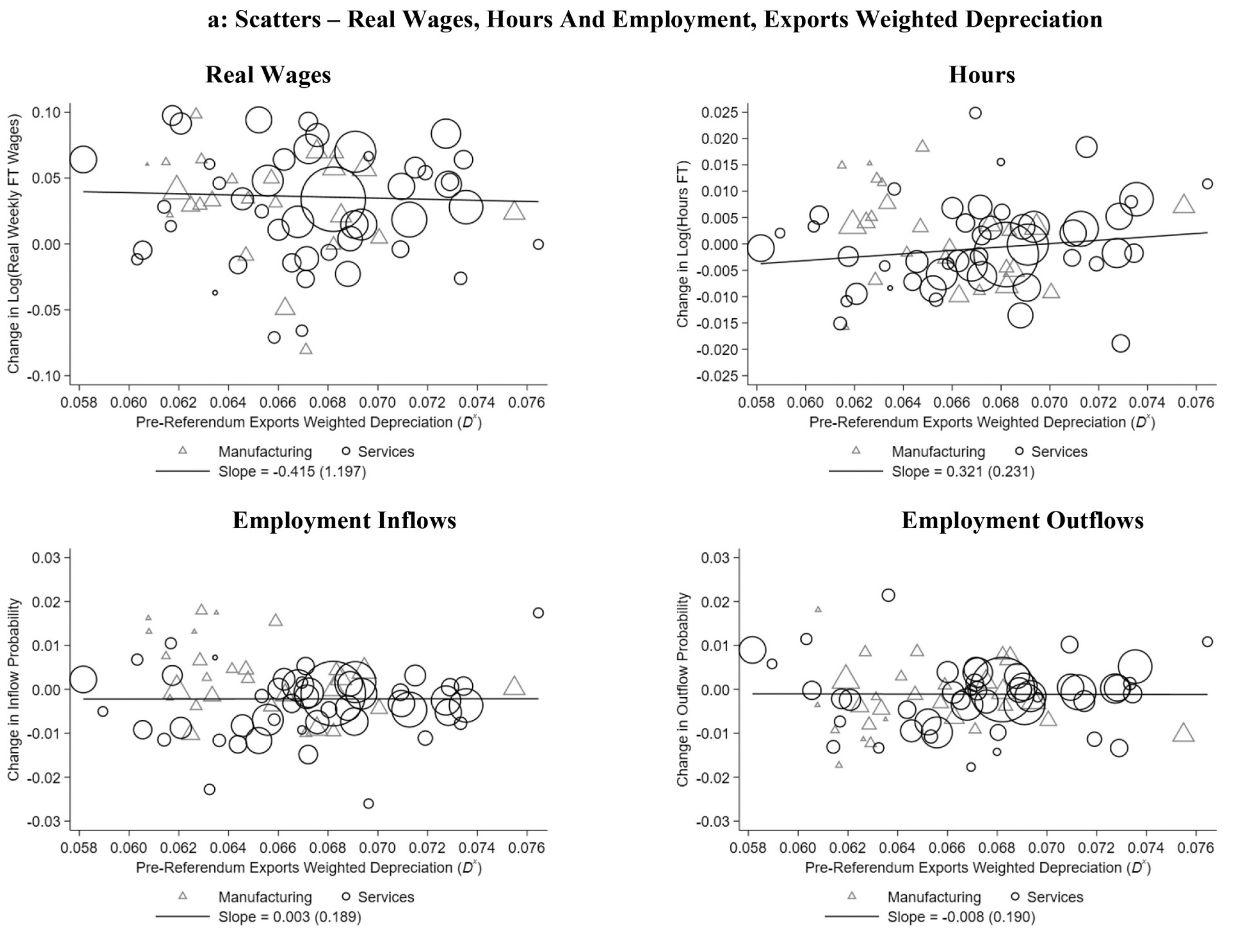


Fig. 5a. Scatters – Real Wages, Hours And Employment, Exports Weighted Depreciation.
Notes: Scatterplots of the post-pre referendum change in labour outcomes (measured between the post quarters 2016Q3-2019Q2 and pre quarters 2012Q3-2016Q2) and the pre-referendum weighted depreciation (78 exporting industries).

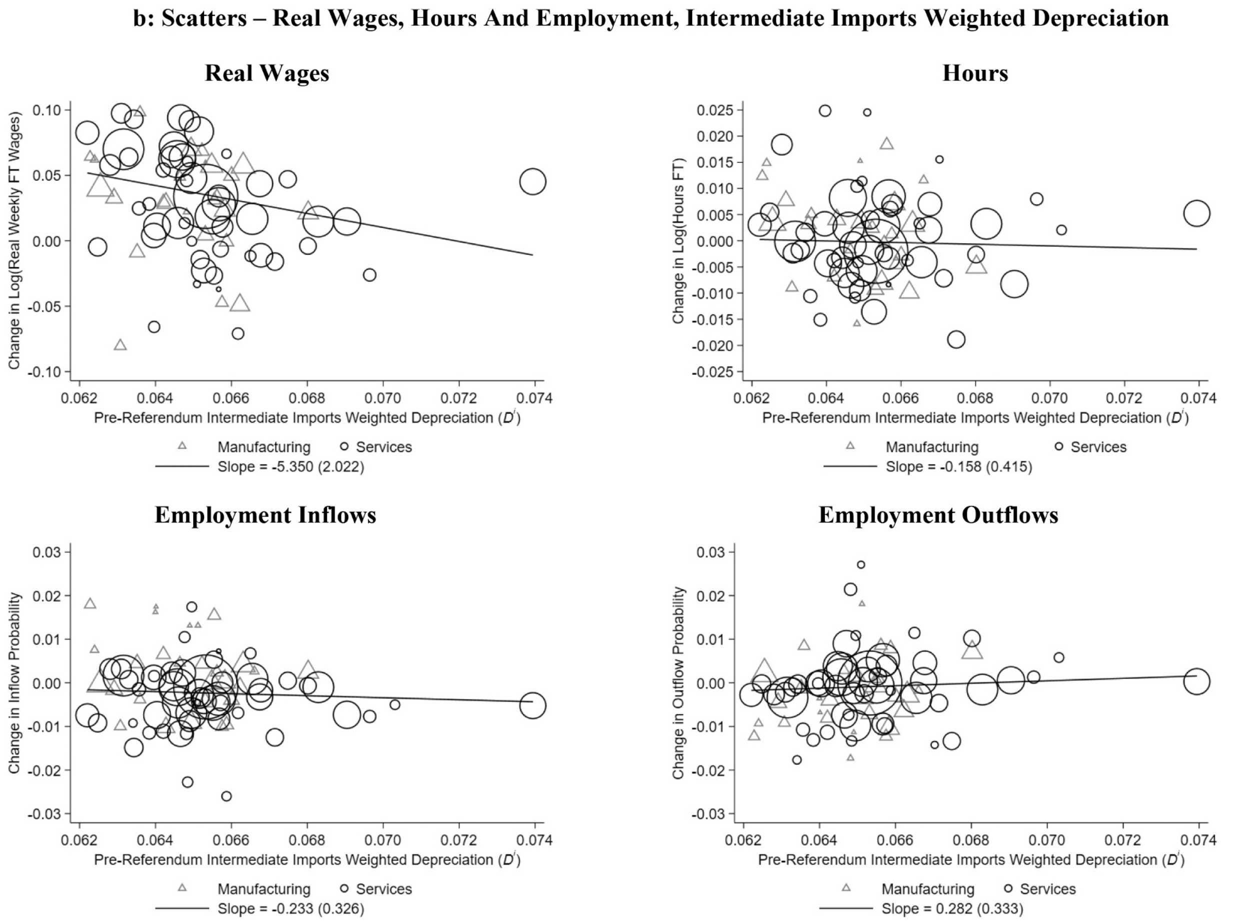


Fig. 5b. Scatters – Real Wages, Hours And Employment, Intermediate Imports Weighted Depreciation.
Notes: Scatterplots of the post-pre referendum change in labour outcomes (measured between the post quarters 2016Q3-2019Q2 and pre quarters 2012Q3-2016Q2) and the pre-referendum weighted depreciation (83 intermediate importing industries).

and in columns (4) to (6) for the pre-post announcement comparison (where *Post-T* in the Table refers to $T = Referendum$ in (1) to (3) and $T = Announcement$ in (4) to (6)). In (1), (2), (4) and (5) the lnD_0^j depreciations are entered singly and in (3) and (6) simultaneously.

Panel A of the Table makes it clear that real wage growth was slowed down and systematically lower in industries with a larger intermediate imports weighted depreciation. This is not the case on the exports side, where the coefficient on exports weighted depreciation is small and statistically insignificant (−0.036 with an associated standard error of 0.079). There is a sizable wage-reducing effect of the intermediate imports weighted depreciation, with an estimated elasticity of −0.459.

Panels B through D show that hours and employment flow responses are however small and mostly statistically insignificant. Hours worked respond to some degree to the intermediate imports weighted depreciation but the magnitude is very small, so that any earnings reduction is primarily from reduced wage growth. Inflows and outflows show very little response to any measure of depreciation in the industry and are statistically indistinguishable from zero.

The main finding therefore is of a strongly negative wage response to the intermediate import weighted depreciation. To focus more on the magnitudes and variation in the wage impact, Table 7 shows wage equation estimates from eqs. (1) to (4) for both full-time weekly wages (column 1) and for hourly wages (column 2). Throughout the Table, the full-time weekly and hourly wages results are highly congruent, and consistently they both show strong evidence that wages fell in relative terms by more in the higher cost shock, higher intermediate import weighted depreciation industries.

Panel A shows that the fulltime weekly wage and hourly wage elasticities are very similar, respectively being −0.459 and −0.444. The magnitudes of these relative wage falls are considered in terms of real wage growth across the depreciation distribution in Panels C and D of Table 4, which respectively present the discretised difference-in-differences estimates comparing above to below median or the top four/middle75/bottom four cuts of the distribution. Panel 3 shows that real wages in industries with above median intermediate imports weighted depreciation grew only by 1.4% over the three years after the referendum. In the below-median industries, real wages grew by 4.8%, which results in a DiD coefficient between the above/below median industries of −3.4%.

Panel D explores the distributional divergence further by splitting industries into the top four, middle 75 and bottom four of intermediate imports weighted depreciations. The top four industries experienced real wage stagnation, growing by just 0.7% over the

Table 6
Real Wages, Hours And Employment.

	(1)	(2)	(3)	(4)	(5)	(6)
	T = Post-Referendum			T = Post-Announcement		
A. ln(FT real weekly wage)						
lnD^x x Post-T	−0.036 (0.079)		0.062 (0.063)	−0.047 (0.069)		0.043 (0.053)
lnD^i x Post-T		−0.459 (0.088)	−0.500 (0.098)		−0.435 (0.060)	−0.465 (0.068)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	86,108	86,108	86,108	86,108	86,108	86,108
B. ln(Hours)						
lnD^x x Post-T	0.021 (0.012)		0.026 (0.012)	0.014 (0.014)		0.020 (0.015)
lnD^i x Post-T		−0.017 (0.025)	−0.026 (0.022)		−0.026 (0.014)	−0.032 (0.015)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	86,108	86,108	86,108	86,108	86,108	86,108
C. Employment Inflows						
lnD^x x Post-T	0.004 (0.011)		0.008 (0.012)	0.003 (0.007)		0.006 (0.008)
lnD^i x Post-T		−0.014 (0.013)	−0.020 (0.015)		−0.008 (0.009)	−0.015 (0.011)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	355,510	355,510	355,510	355,510	355,510	355,510
D. Employment Outflows						
lnD^x x Post-T	0.001 (0.011)		−0.003 (0.012)	−0.002 (0.007)		−0.003 (0.009)
lnD^i x Post-T		0.010 (0.013)	0.015 (0.013)		−0.001 (0.016)	0.005 (0.015)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	356,244	356,244	356,244	356,244	356,244	356,244

Notes: Panels A through D respectively report estimates of eqs. (1) defined in the main text of the paper for the four labour market outcomes, with individual level LFS data for quarters 2012Q3 to 2019Q2 for 83 industries (including a dummy interacted with Post-T for the five non-exporter industries). Standard errors (BHJ adjusted) in parentheses.

Table 7
Real Wages Across The Depreciation Distribution.

	(1)	(2)
	ln (FT real weekly wage)	ln (Hourly real wage)
A. Continuous		
lnD^i x Post-Referendum	−0.459 (0.088)	−0.444 (0.074)
B. Share Interactions		
lnD^i x Post-Announcement at Median Share of i	−0.483 (0.146)	−0.464 (0.164)
C. Above/Below Median		
(D^i > Median) x Post-Referendum	0.014 (0.006)	0.022 (0.008)
(D^i < Median) x Post-Referendum	0.048 (0.006)	0.048 (0.007)
Difference-in-Differences	−0.034 (0.008)	−0.026 (0.010)
D. Top Four/Middle 75/Bottom Four		
(D^i Top Four) x Post-Referendum	0.007 (0.011)	0.010 (0.009)
(D^i Middle 75) x Post-Referendum	0.031 (0.005)	0.035 (0.005)
(D^i Bottom Four) x Post-Referendum	0.056 (0.021)	0.060 (0.022)
Difference-in-Differences	−0.049 (0.024)	−0.050 (0.024)
Industry and Time Dummies	Yes	Yes
Sample Size	86,108	111,600

Notes: Panels A through D respectively report estimates of eqs. (1)–(4) defined in the main text of the paper for real wages, with individual level LFS data for quarters 2012Q3 to 2019Q2 for 83 industries. Standard errors (BHJ adjusted in panel A) in parentheses.

three years after the referendum. In contrast, the bottom four industries grew by 5.6%, resulting in a DiD coefficient of −4.9% between the top and bottom four industries. The middle 75 had more muted wage growth, in between the top and bottom four industries, of 3.1% over the post-referendum period. These imply a wide dispersion of real wage growth reductions across the industries more and less affected by the Brexit exchange rate depreciation.

To sum up, the main labour market adjustment from the Brexit depreciation took place through lower real wage growth in industries suffering larger cost shocks.[18] In the next subsection, we therefore focus on pre-trends in wages to ensure that the intermediate imports weighted depreciations are driving this slowdown.

4.3. Pre-trends

Fig. 6a and b plot event study coefficients showing real wage growth for workers in the above/below median intermediate imports weighted depreciation industries. There is no suggestion of any pre-trends in real wage growth as the pre-referendum estimates are highly similar. Post-referendum the two lines diverge significantly, with real wage growth being significantly lower for workers employed in the above median depreciation industries. Much of the relative wage decline occurs in the two years following the referendum (2016/17 and 2017/18). In the third year, real wage growth differences are less stark across the two sets of industries and show slight signs of recovery in the above median industries.

Looking closely at the above/below median difference-in-differences charts in Fig. 4 for intermediate import prices and Fig. 6 for wages reveals that the jump up in intermediate import prices took place almost straight away in the quarters following the announcement and the referendum. Wage adjustment, however, was not so instantaneous and actually the more sizable wage disparities begin to emerge at the start of 2017 (when new pay settlements take place among firms who are on a calendar or financial year cycle).

4.4. Real wage stagnation

The descriptive and statistical analysis shows similar real wage growth across above/below median industries before the referendum. After the vote, real wage growth slowed significantly in the industries with above median depreciation and it fully stagnated in the top four industries. Thus, some workers suffered real wage declines in relative terms due to the Brexit depreciation. The relative gap was driven by a slowdown in nominal wage growth in the above median industries because the price deflator is the same in the above and below median cases.

But what about overall in the aggregate? This requires specification of a counterfactual to the actual Brexit depreciation to enable a quantification of aggregate effects, rather than the relative effects across differently exposed industries seen in the analysis so far. One straightforward counterfactual in international trade models would be that exchange rates would not have shifted and so there would be no depreciation shock (for example, in analogous fashion to the Fajgelbaum et al., 2020 Trump tariff shock). In this case, the DiD provides the relevant elasticities, $dlnP^i = \beta_P \, dlnD^i$ and $dlnW = \beta_W \, dlnD^i$, which predict price and wage changes at the average of 3.3% and −3.0%. This would be the short-run outcome when factor quantities cannot adjust.

In this empirical exercise, however, these average changes do not reflect common economy wide impacts. The relevant question to draw aggregate implications is by how much? An estimate of the common economy-wide impact can be directly obtained from consumption expenditures (or, equivalently, domestic consumption shares). However, there may also be other aggregate shocks that make it difficult to ascribe the directly observed shifts in aggregate demand outcomes to the exchange rate depreciation alone. To address this, in the quantitative trade literature (as in the comprehensive survey of Costinot and Rodríguez-Clare, 2014) the common impact works through balanced trade. Solving for balanced trade between the UK and foreign sources (with foreign prices of goods and services produced in the foreign country normalised to be the numeraire),[19] the aggregate import price rises by 3.9% which is higher than the direct estimate of 3.3%. The corresponding wage fall is consequently also larger in magnitude at $dlnW = (\beta_W/\beta_P) \times dlnP^i =$ -3.6%. The direct wage elasticity therefore underestimates the magnitude of the fall in real wages, which is about 0.6 pp. higher when the general equilibrium trade balance is incorporated.

The trade literature typically focuses on the status quo counterfactual, such as no tariff changes to quantify the impact of the Trump tariff war (Fajgelbaum et al., 2020) and no sterling depreciation shocks in the current setting to arrive at the aggregate impacts. Standard models of international finance, such as Obstfeld and Rogoff (2005) and Engel (2014), instead consider how exchange rates would have evolved in the absence of the event under study. This is a difficult question to answer in any setting and even more so in this literature because modelling exchange rate movements is empirically challenging.

Recent advances in shift-share research designs do, however, enable specification and direct estimation of counterfactual impacts. Borusyak and Hull (2023) (BH hereafter) propose inclusion of an additional variable reflecting the counterfactual – an "expected shift-share instrument" - in the estimating equations. Inclusion of an expected shift-share instrument has the advantage of overcoming omitted variable bias that can arise in shift-share estimators when the assignment of shocks is not random across different observations. Removing the non-random component of variation in the actual instrument can correct for the bias and provide a counterfactual

[18] Results are highly similar when observations of the QLFS for individuals who were interviewed within a four week window of the referendum date are excluded from the analysis.

[19] Balanced trade gives $\widehat{Z}_j Z_j = \sum_i (X_{ji}/Z_i)\left(\widehat{Z}_j \widehat{E}_{ji}^{\beta_P}\right)^{-\theta} \widehat{Z}_i Z_i / \sum_l (X_{li}/Z_i)\left(\widehat{Z}_l \widehat{E}_{li}^{\beta_P}\right)^{-\theta}$ where X_{ij} are exports from i to j and expenditure in j is $\sum_i X_{ij} = Z_j$. It is evaluated at the mean depreciation of 6.5%, DiD elasticity $\beta_P =$ -0.498 for intermediate imports and negligible for sterling-denominated exports, export share $X_{uk,f}/Z_{uk} = 0.16$ from the UK to foreign countries f, foreign import consumption share $X_{uk,f}/Z_f = 0.03$ and own domestic consumption share $X_{uk,uk}/Z_{uk} = 0.71$. Having solved for the balanced trade conditions, $\widehat{Z}_j$ gives the change in the domestic price index in j. The aggregate price effect in j is an average of the domestic and import price changes, weighted by their expenditure shares.

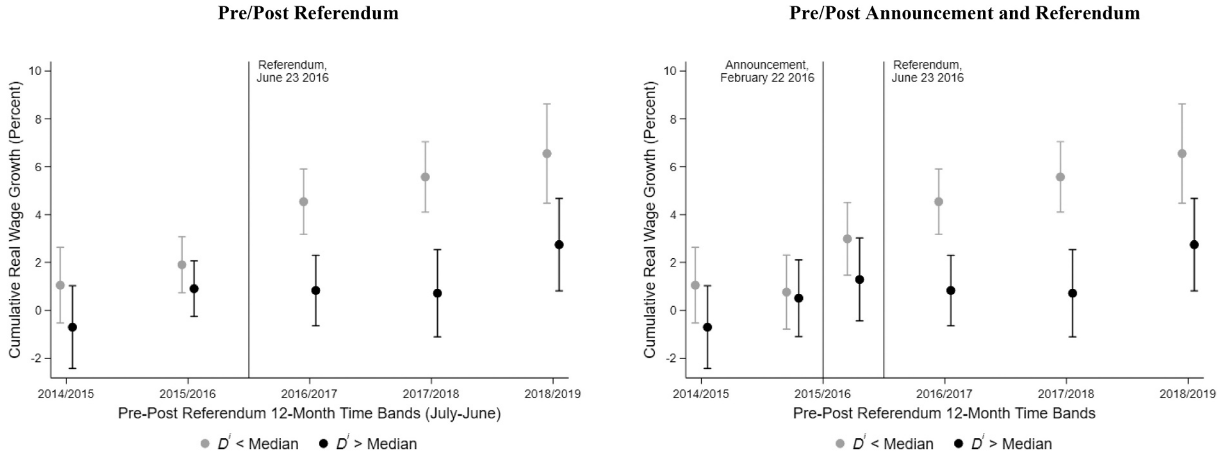


Fig. 6. Event Study – Real Wages and Intermediate Imports Weighted Depreciation.
Notes: Event study estimates of eq. (3) in the main text of the paper for real wages, where the DiD estimates vary in the left chart with pre and post referendum 12 month time bands (defined from July to June for Q3 in a year to Q2 in the following year) and in the right chart where they vary in the same way, but with an additional variation within the year before the referendum (July to December for 2015 Q3 and Q4, and January to June for 2016 Q1 and Q2).

to compare the actual outcomes with. BH suggest leveraging institutional knowledge of the shocks to set up and measure such a counterfactual, but this is often a challenging task. In our setting, a long tradition of work in trade theory and empirics provides a natural candidate for the expected systematic component of the shift-share measure. This is gravity-based economic linkages of countries with the UK.

The baseline difference-in-differences estimating equation is augmented with the inclusion of a gravity-expected counterfactual depreciation interacted with the post-referendum indicator $ln\widetilde{D}^j_o \times \mathbb{1}\left(qt \geq Referendum_{qt}\right)$. The coefficient on the expected depreciation measures the counterfactual growth in the outcome that would be expected from a gravity pattern of depreciation shocks and the coefficient on the original depreciation is re-interpreted as the growth associated with deviations of the actual depreciation from gravity-expected depreciation after the Leave vote. Because the actual and counterfactual depreciations are weighted averages across many currencies within each industry, standardised coefficients enable a direct interpretation and comparison of the implied magnitudes.[20] Then the means of the actual and counterfactual depreciations are zero and their coefficients reflect changes in outcomes for a one standard deviation shift in the depreciations, that are being entered on the RHS of the estimating equations for each industry.

A gravity-based counterfactual depreciation can be set up following the literature in international economics (Head and Mayer, 2014; Donaldson and Hornbeck, 2016), where c's exports to the UK are $X_{c,uk} = \delta^{\theta}_{c,uk} G_c G_{uk}$ for trade costs $\delta_{c,uk}$, $\delta_{uk,uk}$ (normalised to one), country-specific shifters G_c and G_{uk} and trade elasticity θ. The gravity measure is normalised with respect to domestic trade to arrive at $X_{c,uk}/X_{uk,uk} = \delta^{\theta}_{c,uk} G_c/G_{uk}$. While the focus of the gravity trade literature is on bilateral exports, the gravity measure is common to studies of various economic linkages across countries, such as foreign investment and migration. As in Head and Mayer (2014), the country-specific shifters in the gravity measure are proxied with real GDP and trade costs with distance (taken from the CEPII Gravity Database for distance to London from the most populated city of the trade partner). The baseline results consider a distance elasticity of -1 because the median elasticity is between -0.89 and -1.14 in Head and Mayer and in the original market potential formulation of Harris (1954).

Countries are ranked according to the gravity measure and sterling shocks are considered to be systematically related to it. The main counterfactual is an assignment of lower gravity measures to higher depreciation shocks, starting with the highest to the lowest actual depreciation shocks and assigning depreciation shocks proportional to the gravity measure in between these end points. The low gravity to high depreciation assignment follows from the observation that low gravity countries are less exposed to the unexpected Brexit vote and sterling therefore depreciates more against their currencies.

A counterfactual depreciation is also implemented following random assignment of shocks based on exposure through the gravity measure. BH create clusters of units with similar exposure within which the shocks can be considered to have been randomly assigned. The shocks within each exposure cluster are permuted across units to recompute a shift-share instrument, and the procedure is repeated multiple times. The expected instrument for each unit is constructed as an average across the multiple draws, and its inclusion implies that the coefficient on the actual instrument is the impact of random deviations of realised shocks from the expected counterfactual shocks. The BH procedure is adapted by clustering countries by the gravity measure into bins of about five countries each. The depreciation shocks are permuted within each cluster and the procedure is repeated 1000 times to obtain the expected depreciation.

[20] We are grateful to an anonymous referee for suggesting the use of standardised coefficients in these quantification exercises.

Robustness is examined with −5 for the trade elasticity in the gravity measure, and by considering only distance because size and distance could potentially have different implications for the depreciation shocks. More distant countries are expected to have the highest depreciation shock because they are least directly exposed to Brexit and the ranking is assigned accordingly.

Table 8 provides results for the actual and counterfactual depreciations. Panel A re-estimates the baseline specification where the original depreciation is standardised. A one standard deviation increase in the industry depreciation increases import prices by 1.5 pp. and lowers real wages by 1.4 pp. This follows directly from scaling down the non-standardised baseline estimates in Tables 3 and 6 by about a third - the population covered by a one standard deviation shift in the RHS variable.

With the inclusion of the expected depreciation in Panel B of Table 8, the estimated elasticities of the original depreciation stay the same. The expected depreciation has coefficients of similar signs to the actual depreciation, although they are small and statistically insignificant at conventional levels. For import prices, the counterfactual coefficient is 0.1 pp. and the direct average price growth is therefore 1.4 pp. higher than under the counterfactual of gravity-expected depreciation for a standard deviation rise in the depreciation. The counterfactual wage elasticity is −0.3 pp., and the direct average wage growth after the Leave vote is 1.1 pp. lower than the counterfactual wage growth for a standard deviation rise in the depreciation, or 2.2 pp. for a 95% confidence level. The assignment procedure of BH in Panel C shows almost identical results for import prices and real wages with the original standardised depreciation and a negligible relationship with the counterfactual depreciation. Table A9 in the Appendix also considers a gravity measure with a trade elasticity of −5 and a ranking based just on log of distance. It shows that the (absolute) magnitudes of the inferred price growth and loss in real wage growth are very similar under these gravity counterfactuals.

Moving beyond the direct depreciation elasticities, economy-wide impacts that are common to industries can also be compared across the actual and counterfactual depreciations to quantify the aggregate import price and wage effects, as in the quantitative trade literature discussed before. To account for means, the quantification now has the actual depreciation and sets the counterfactual depreciation to be the gravity-expected depreciation (instead of zero). The import price elasticities for the actual depreciation is almost the same as before 0.499 (with an associated standard error of 0.137) and the elasticity for the gravity-expected counterfactual depreciation is 0.042 (0.195).[21] The aggregate import price rises by 3.6 pp. or over 0.6 pp. more than the direct effect under the actual depreciation relative to the counterfactual of gravity-expected depreciation after the Leave vote. The corresponding wage elasticities are −0.462 (0.076) and −0.089 (0.145). The direct wage fall is −2.4 pp. and another −0.6 pp. is the indirect effect, relative to the gravity-expected counterfactual.[22,23] These aggregate impacts are somewhat smaller in absolute magnitudes than the zero depreciation counterfactual.

The calculations produce a bottom line of a one-off permanent loss in aggregate real wages. Cumulative real wage growth was 2.1% over the three years after the referendum (between July 2016 to June 2019). Had the depreciation followed a gravity-predicted pattern, cumulative real wage growth would have been 3.0 to 3.3 pp. higher over these three years. This three-year loss amounts to about £770 to £850 per year (in June 2016 values).

5. Extensions and refinements

The main finding is of real wage reductions for workers employed in industries that experienced a larger cost shock from the Brexit exchange rate depreciation, with aggregate growth of real wages falling as a consequence of the big depreciation cost shocks that occurred due to the Leave vote. In this section, we discuss extensions and refinements in the context of several quite wide-ranging literatures that the analysis undertaken so far can speak to.

The are five broad sets of extensions on: import competition; alternative depreciation measures; additional controls; trade policy and uncertainty; and vehicle currency adjustments; Table 9 summarises results from an array of specification adaptations to show how considering them affects the baseline wage-intermediate import depreciation elasticity of −0.459. In extended models, full results are given in additional Tables presented in Appendix C, as detailed in the final column of the Table. This section then concludes with discussion of the implications of the main findings in light of the trade and labour literatures that present estimates of labour-offshoring elasticities.

The extensions are:

1) *Import competition channel*: UK producers may have also experienced an indirect revenue shock from easing of foreign competition due to competing imports becoming more expensive from the sterling depreciation. Analogously to the earlier definitions of depreciation, a total imports weighted depreciation is defined as Imports (m): $D_o^m = \sum_c S_{co}^m \Delta E_c$ where S_{co}^m is the share of source

[21] Results are obtained as before except balanced trade is evaluated with β_P = (0.499–0.042) for intermediate imports.

[22] From –(0.462–0.089) × 6.5 +(β_W/β_P)× 0.6 for the direct wage effect (evaluated at the mean depreciation) and the indirect price effect obtained from the balanced trade conditions multiplied by the coefficients on the actual depreciations in the gravity-augmented specification.

[23] Alternatively, balanced trade can be solved for with elasticities from the standardised coefficients by setting β_P = (0.015–0.001) for intermediate imports and $\widehat{E} = \sqrt{\pi}$ for the average sterling depreciation where the value is the integral of Gaussian depreciation shocks. The corresponding import price effect is 3.2 pp. = 2.5 (direct) + 0.7 (indirect) and the wage effect is −3.0 pp. = −2.4 (direct) - 0.6 (indirect).

Table 8
Actual and Counterfactual Standardised Difference-in-Differences Estimates.

	(1)	(2)
	lnP^i	ln (FT real weekly wage)
A. Baseline		
lnD^i x Post-Referendum	0.015 (0.004)	−0.014 (0.003)
B. Counterfactual Depreciation by Gravity Rank		
lnD^i x Post-Referendum	0.015 (0.004)	−0.014 (0.002)
$ln\widetilde{D}^i$ x Post-Referendum	0.001 (0.005)	−0.003 (0.004)
C. BH Counterfactual by Gravity Percentiles		
lnD^i x Post-Referendum	0.015 (0.004)	−0.013 (0.003)
$ln\widetilde{D}^i$ x Post-Referendum	−0.003 (0.003)	−0.002 (0.004)
Industry and Time Dummies	Yes	Yes
Sample Size	2158	86,108

Notes: As for Table 3 for column (1) and as for Table 7 in column (2). Standard errors (BHJ adjusted) in parentheses.

Table 9
Elasticity of Real Wage to Intermediate Imports Weighted Depreciation in Extended Specifications.

Specification Extensions, All x Post-Referendum	Variables Included, All x Post-Referendum	Real Wage Elasticity, $dlnW/dlnD^i$	Full Results Appendix C Table
A. Import Competition Channel			
Exports, Intermediate Imports and Imports Weighted Depreciations	lnD^x, lnD^i, lnD^m	−0.510 (0.120)	A2
B. Alternative Depreciation Measures and Currency Trims			
Migration Weighted Depreciation	lnD^i, lnD^{mig}	−0.409 (0.089)	A3, Panel A
Inward FDI and Outward FDI Weighted Depreciation	lnD^i, $lnD^{fdi,in}$, $lnD^{fdi,out}$	−0.421 (0.083)	A3, Panel B
Upstream and Downstream Depreciation	lnD^i,lnD^{up}, lnD^{down}	−0.421 (0.094)	A3, Panel C
No trimming of low trade shares	lnD^i	−0.561 (0.104)	A4, Panel A
Trimming of trade shares <2%	lnD^i	−0.387 (0.069)	A4, Panel B
C. Additional Controls			
EU Share of Intermediate Imports and EU Share of Exports	lnD^i, S^i_{EU}, S^x_{EU}	−0.474 (0.169)	A5, Panel A
Share of EU Migrants in Workforce and Share of Non-EU Migrants in Workforce	lnD^i, $\lambda^{mig}S^{mig}_{EU}$, $\lambda^{mig}S^{mig}_{Non-EU}$	−0.451 (0.103)	A5, Panel B
Share of EU in Inward FDI and Share of EU in Outward FDI	lnD^i, $S^{fdi,in}_{EU}$, $S^{fdi,out}_{EU}$	−0.408 (0.084)	A5, Panel C
D. Trade Policy			
Hard Brexit Trade Barriers (Tariffs τ and Services NTBs η)	lnD^i, τ^j_h, η^j_h	−0.376 (0.086)	A6, Panel A
Soft Brexit Trade Barriers (Tariffs τ and Services NTBs η)	lnD^i, τ^j_s, η^j_s	−0.366 (0.045)	A6, Panel B
Hard-Soft Brexit Trade Barriers	lnD^i, $\tau^j_h - \tau^j_s$, $\eta^j_h - \eta^j_s$	−0.371 (0.115)	A6, Panel C
E. Vehicle Currency			
Vehicle Currency Adjustment	$lnD^{i,veh}$	−0.311 (0.117)	A7, Panel A
Vehicle Currency Adjustment, Exports, Intermediate Imports and Imports Weighted Depreciations	$lnD^{x,veh}$, $lnD^{i,veh}$, $lnD^{m,veh}$	−0.311 (0.157)	A7, Panel B

Notes: As for Table 7 for estimates of the real wage elasticity. More details on the definitions of the additional variables included in the extensions are given in the full results Tables in Appendix C which are listed in the final column. Standard errors (BHJ adjusted in Panels A to D) in parantheses.

country c in imports of goods and services that belong to output industry o and that are imported as final consumption or as intermediates into the economy.[24]

Inclusion of this third depreciation measure, along with the exports and intermediate imports weighted depreciations considered

[24] It is worth noting that the import competition channel still captures intermediate consumption from businesses reselling the imported goods and services to other industries. This is because trade data do not distinguish between imports for final use and imports for intermediate use or reselling. For this import competition based depreciation measure, the currency structure and scatterplots against the import price and labour market outcomes are shown in Appendix C Figures A4a andA4b.

earlier, does not turn out to make much difference. In Panel A of Table 9 (with Table A2 in Appendix C showing the full model including all three measures), the baseline elasticity gets a little larger (in absolute terms) at −0.510, and the imports weighted depreciation contributes no additional explanatory power and has a very small, estimated coefficient.[25]

2) *Alternative Depreciation Measures*: Quite naturally, the analysis so far used trade shares as the measure of economic linkage to construct shift-share depreciation measures. Other economic linkages may have mattered and can be used in computing the shift-share. Two possibilities are the country structure of migrants and FDI (inwards and outwards) in the UK. Adding shift-share industry depreciation shocks based on migration and FDI shares is considered in Panel B of Table 9. Inclusion of these depreciations does not alter the main finding for intermediate imports and they are economically and statistically insignificant on their own.

Another extension in terms of alternative depreciation measures permits an examination of indirect impacts from sectoral spillovers through upstream and downstream linkages across industries (as in Acemoglu et al., 2016). Upstream and downstream shift-share measures can be constructed from the Leontief inverse of the input-output matrix and included in the baseline specifications. These have negligible impacts, suggesting that the general equilibrium counterfactuals appropriately focus on economy-wide demand effects, rather than cross-sectoral spillovers.

Finally, alternative trimming of low trade shares is examined, with no trimming at all and a 2% threshold for smaller trade partners. The wage-depreciation elasticity is between −0.387 and −0.561 across these reformulations.

3) Additional *Controls*: Panel C considers what happens to the baseline elasticity when interactions between the post-referendum dummy and EU shares in initial trade, migration and FDI across industries are included. The results are again highly clustered around the baseline estimate for the wage-depreciation elasticity.

In additional checks, industry-quarter fixed effects are included to control for seasonality and region-time fixed effects to account for differences in real wages arising from different consumer price evolution across regions. The baseline wage elasticity barely changes (−0.457 and −0.425). The analysis can also be conducted at the regional level, but the key variation remains at the currency level (see Dhingra and Sampson, 2022 for discussion).

4) *Trade Policy and Uncertainty*: Because of the exchange rate movements resulting from the news of the unravelling of the UK's membership in the world's deepest trade agreement, the findings relate to de-globalisation. The role of expected changes in trade barriers after Brexit is examined by including interactions of the post-referendum dummy with measures of tariffs and services trade restrictiveness indices that would apply under hard and soft Brexit scenarios in Panel D of Table 9. To capture trade policy uncertainty arising from the lack of political commitment on the form of Brexit, the difference between hard and soft trade barriers is entered with guidance from the trade policy uncertainty literature (e.g., Limao and Maggi, 2015; Pierce and Schott, 2016).

Following Dhingra et al. (2017), a soft Brexit scenario is benchmarked by low trade barriers with the EU, while a hard Brexit scenario is modelled as moving from EU membership to the level of integration between the United States and the EU. In Panel D of Table 9, these two are considered, along with the gap between the two. Across each specification, there is some correlation between the main measure of intermediate imports weighted depreciation and the trade barriers, but they do not affect the baseline estimate substantively. While entering individual trade barriers separately enables flexible modelling of trade policy uncertainty, their coefficients need to be interpreted with caution because they have different units and apply to different products – tariffs on goods and trade restrictiveness indices for services. Further, they cannot be directly differenced across hard and soft Brexit specifications because they have been trade-weighted across products and countries to arrive at industry-level measures (see Graziano et al., 2023 for more on Brexit tariff uncertainty).[26]

Although intertwined, uncertainty after the Brexit vote was not confined to trade policy. Another channel through which the unexpected rise in economic nationalism embodied in the Brexit vote may have affected labour markets is through economic uncertainty for businesses. Bloom et al. (2019) study this by examining survey responses from the Decision Makers' Panel of the Bank of England and find that changes in business expectations from the Brexit vote were not as pronounced in most of the time period that we examine. Uncertainty from the Brexit vote hits a peak after the Salzburg summit in September 2018 when the EU did not accept the UK's Brexit proposal, leading to a rise in the likelihood of a no-deal Brexit.[27]

One concern with this reasoning is that the Decision Makers' Panel cannot be used to compare the pre and post referendum trends in uncertainty across industries because the survey started after the Brexit referendum. The UK however has a long-standing survey of

[25] Expected depreciations for exports and total imports can also be included in their specifications, but this does not alter the main result of negligible wage impacts through the revenue channel (available upon request).

[26] A soft Brexit scenario refers to zero tariffs and intra-European Economic Area services trade restrictiveness indices (STRIs) with the EU and status quo with the rest of the world. Hard Brexit refers to EU MFN tariffs and EU-US STRIs. The product-specific trade barriers are weighted by 2015 trade shares to construct a measure of each trade barrier for each industry.

[27] Bloom et al. (2019) examine the Decision Makers' Panel from the Bank of England and find that survey questions on business uncertainty seem to capture the change in business expectations better than standard measures of uncertainty like stock market volatility and the policy uncertainty index (of Baker et al., 2016).

firms which includes similar questions on business expectations. Although smaller in size, the survey is conducted by the UK's premier business organisation, the Confederation of British Industry (CBI) and has a strong track record as a reliable source of qualitative and real-time firm-level information.

The CBI quarterly survey asks each firm: "Are you more, or less, optimistic than you were three months ago about the general business situation of your sector?". Fig. A5 shows no gap in the evolution of business expectations across industries with above median and below median intermediate imports weighted depreciation, and there only being a spike up in the quarter directly following the referendum. Thus, whilst a more uncertain business environment clearly seems to be a feature of what happened in the UK economy following the Brexit vote, this seems to apply in a highly similar manner in industries that faced bigger and smaller depreciation induced cost shocks.[28]

5). *Currencies*: A growing literature in international finance has documented the prevalence of invoicing in currencies other than those of the source and destination countries (example, Gopinath et al., 2010). When prices are sticky or invoiced in local currency, the estimated import price passthrough could be low in a given time period if few suppliers are able to reset their prices in that window to reflect changes in source costs relative to destination prices. Then the passthrough rate for prices would differ from that based on source country shares. However, this does not seem to apply in the current setting because the estimated passthrough rates are high, in line with standard estimates for a two-year horizon during which vehicle currency divergences are small. Customs transactions data for non-EU goods trade shows moreover that passthrough is highly similar when source country currency is replaced with the reported vehicle currency during this episode (Chen et al., 2022).[29]

Despite the reassurance for our analysis from this work, as a robustness check it is possible to recompute the depreciation shocks adjusting for the shares of different types of invoicing across various source countries. As in most countries, the currency of invoicing is not recorded in the UK for services trade (and for goods trade with the EU). The exchange rate measure is therefore re-defined by using the aggregate goods-trade shares of currency invoicing prevalent in UK-US trade. Specifically, the re-defined exchange rate measure changes from the source country depreciation ΔE_c to a weighted average of the source currency and a vehicle currency: $\Delta \check{E}_c \equiv S_{USA}^{PCP}\Delta E_c + \left(1 - S_{USA}^{PCP}\right)\Delta E_v$ where the weight S_{USA}^{PCP} is the share of producer currency pricing in UK imports from the United States that are priced in producer or vehicle currencies (denoted by v). We then can define a vehicle currency adjusted depreciation $D^{i,veh}$ in analogous fashion to the D^i measures we have used.

Following the dominant currency literature (Gopinath et al., 2020), the vehicle currency is defined as the US Dollar for all countries except European countries for which it is the Euro. The adjustment, shown in Panel E of Table 9, produces the same qualitative finding of relative wage reductions. Not surprisingly, there is some loss of precision because there is less variation when the currency shock variation is restricted to the dollar and the euro, but the main results remain robust.

5.1. Comparison of offshoring elasticity with trade and labour literatures

The main estimates also relate to the trade and labour literatures that have a long tradition of empirical work examining the offshoring elasticity between labour and intermediate imports (for example, Revenga, 1992; Autor et al., 2013; Hummels et al., 2014). Under the assumption that the depreciation was a cost shock that impacted trade prices and at the same time did not have other direct effects on labour markets, the estimates presented earlier provide two reduced form relations between trade prices and depreciation (the first stage) and between wages and depreciation (the reduced form), which underpin the standard Wald estimator for the offshoring elasticity. A just identified instrumental variable specification (with wages as the dependent variable and import prices as the endogenous variable that is instrumented with the depreciation), the offshoring elasticity is $dlnW_o/dlnP_o^i = \beta_W/\beta_P =$ -0.922. A 1% higher price for imported inputs reduces wages by a little <1%. Increases in import prices are detrimental to wage growth, showing that offshoring is complementary to workers.[30]

The finding of complementarity accords well with the nature of inputs that are imported into industries. Table A8 in Appendix C shows the top four intermediate imports of high and low depreciation industries. Examples include activities that are auxiliary to financial and insurance services which mainly import financial services, business services and telecommunication services from abroad. Other examples include programming and broadcasting that pay for intellectual property services, scientific research and development that buy computer and electronic items from abroad and architectural and engineering services that purchases business and construction services. These examples embody intermediates that are more likely to be used by workers to supply services from their own industry, rather than inputs that would be displacing domestic workers through outsourcing of their tasks to foreign workers.

Over and above the intuition offered by these trade patterns, the offshoring elasticity from this paper can be appraised in the light of theories of production (for example, Allen, 1934; Hicks, 1970; Blackorby and Russell, 1989). Elasticities of substitution in production

[28] Similar patterns arise across above and below median industries when examining questions regarding expectations over the change in sales volume or export volumes over the next three months (available upon request).

[29] Highly disaggregate goods trade results of Chen et al. (2022) show that the import price passthrough barely changes (from 0.41 to 0.43) when the actual currency of invoicing is used instead of the source country's currency over this two-year window. Corsetti et al. (2022) also find that import prices adjusted fully to the weak pound within 36 weeks irrespective of the currency of invoicing. Further, Chen et al. show that export responses are mostly erratic and insignificant, even when the currency of invoicing is used.

[30] When the same samples are used to estimate wages and import prices, the offshoring elasticity changes slightly to -0.938 (detailed results in Costa et al., 2022).

can be measured in different ways, such as the Hicks/Allen-Uzawa elasticity, the Hotelling elasticity and the Morishima elasticity. The theoretical counterpart to the baseline empirical specification is the Hotelling elasticity, which is the dual to the commonly used Allen-Uzawa elasticity (that holds output scale constant). The Hotelling elasticity is derived from the profit function (and not the cost function) and holds the price of output constant (Stern, 2011). Assuming profit maximisation by firms, labour market clearing results in an offshoring elasticity of $d\ln W_o = \left(\sigma_{WP^i}/\left(\sigma^S_{WW} - \sigma_{WW}\right)\right)\left(S_{P^i\Pi}/S_{W\Pi}\right)d\ln P^i_o$ where $S_{P^i\Pi} \equiv P^i_o Q^i_o/\Pi$ is the share of intermediate import costs in profits and $S_{W\Pi} \equiv WL/\Pi$ is the share of labour costs in profits. The underlying Hotelling elasticity between intermediate imports and labour is $\sigma_{WP^i} \equiv -\left(\Pi_{WP^i}P^i_o/\Pi_W\right)\left(\Pi/\Pi_{P^i}\right) = \varepsilon_{WP^i}/S_{P^i\Pi}$, which normalises the cross-price elasticity between the two factors (ε_{WP^i}) with factor shares, and similarly for the Hotelling labour demand and supply elasticities, σ_{WW} and σ^S_{WW} (see Appendix D for a fuller outlined model).[31]

Under a zero profit condition, increases in intermediate import prices reduce wages by the ratio of the intermediate import costs to labour costs to maintain zero profits and the offshoring elasticity is $d\ln W_o = -\left(S_{P^i\Pi}/S_{W\Pi}\right)d\ln P^i_o$. The aggregate share of intermediate import costs to labour costs is 0.376, implying that the zero profit condition underestimates the magnitude of the offshoring elasticity. Setting the labour demand elasticity σ_{WW} to -0.5 from the labour demand literature (Hamermesh, 1993) and assuming labour supply is specific to industries ($\sigma^S_{WW} = 0$), the inferred Hotelling elasticity is $\sigma_{WP^i} = -1.23$. This differs in sign from an elasticity of $+1$ implied by a Cobb-Douglas production function.

The offshoring literature generally finds offshoring elasticities that are small in magnitude and of varying signs across different papers (Hummels et al., 2018). In fact, there is more evidence for substitutability between workers and intermediate imports, perhaps because the instruments typically draw on increases in imports from rapidly growing developing countries like China and India. Instead, the results of complementarity are more in line with the study of Danish manufacturing workers of Hummels et al. (2014), which also finds complementarity between offshoring and (high-skilled) domestic workers. Under the assumption of iceberg transport costs, their implied Hotelling elasticity ranges between -0.44 to -1.82, which places our estimates within their central range.[32]

6. Conclusions

This paper presents evidence of the economic consequences of the large, unexpected depreciation of the British pound that occurred in the wake of the June 2016 vote to leave the European Union. The significant variation in the scale of the exchange rate depreciation across different currencies is leveraged to first study the consequences for trade prices, and then for labour market outcomes. The analysis is set up to study before/after referendum changes in these outcomes in a difference-in-differences shift share research design.

On trade prices, there is robust evidence of a cost shock resulting from higher intermediate import price increases in industries facing higher depreciations due to their pre-referendum import reliance. This was not offset by revenue gains for exporters, because the higher depreciation exporters were also those facing higher cost shocks. Adjustment to this cost shock occurred in the labour market as higher depreciation settings saw real wages decline in relative terms and in the aggregate.

As intermediate imports became more expensive, workers lost out in terms of real wages. Wage growth slowed down considerably and by more as it stagnated for workers in higher depreciation industries. When considered relative to a coherently defined counterfactual, this resulted in an aggregate fall in real wages, of the order of 3 to 3.6% lower cumulative growth over the three years after the referendum. So what actually happened was opposite to the pre-referendum position taken by Brexit advocates that leaving the EU would generate wage and income gains from new trade advantages and benefits from national sovereignty. The new dawn they had precipitously argued for faded away.

Declaration of competing interest

None.

Data availability

New Dawn Fades: Trade, Labour and the Brexit Exchange Rate Depreciation (Reference data) (Mendeley Data)

[31] The baseline wage-depreciation elasticity can be augmented to account for the normalisation by factor shares, often adopted in production theories. When the full set of interactions of the depreciation with intermediate import costs to labour costs is included, the estimated coefficients on the interaction of the post indicator with lnD^i is -0.451 (0.119), with intermediate import cost to labour cost ratio is -0.047 (0.822) and with both interacted together is -0.015 (0.299). The wage-depreciation elasticity is therefore highly similar to the baseline estimate at -0.445, evaluated at the median intermediate import cost to labour cost ratio.

[32] The wage-import IV elasticity for high-skilled workers is between 0.007 and 0.030 and for low-skilled workers between -0.01 to -0.02 in Columns 3 to 6 in Table 5 of Hummels et al. (2014), with an average of 0.002 to 0.015 for all workers. The import-transport cost first-stage elasticity is -18 in Table 4. Multiplying them together gives a range of -0.13 to -0.54 for the wage-transport cost elasticity for high-skilled workers and 0.18 to 0.36 for low-skilled workers and 0.04 to 0.27 for all workers. The summary statistics for employment, wage bill per worker, gross output and broad offshoring in Table 1 gives an intermediate import to labour costs ratio of 0.779 for all workers, 0.148 for high-skilled workers and 0.631 for low-skilled workers. Following a similar calibration of zero labour supply elasticity and a labour demand elasticity of -0.5 then gives a Hotelling elasticity of -0.44 to -1.82 for high-skilled workers and 0.14 to 0.29 for low-skilled workers.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jinteco.2024.103993.

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