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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 very large exchange rate depreciation occurring in June 2016 due to the UK electorate unexpectedly voting to leave the European Union. As news of a leave vote came in, the value of sterling plummeted, recording the biggest one day depreciation of any of the world's four major currencies since the collapse of Bretton Woods. The prospect of Brexit really 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 rate depreciations facing businesses in different industries. The paper first considers revenue and cost channels operating through trade price responses, offering evidence of a cost shock from the price of intermediate imports rising by more in higher depreciation industries, but with no revenue offset from exports. Workers were impacted by the increased cost pressures facing businesses, not in terms of job loss but through relative real wage declines and stagnation for workers employed in industries facing larger depreciations.

Key words: Brexit, exchange rate depreciation, trade prices, labour outcomes
JEL codes: J46; J68; L52; P25

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1. Introduction

Immediately after the UK electorate unexpectedly voted to leave the European Union on the night of June 23 2016, the British pound experienced its biggest one day loss since the introduction of free-floating exchange rates in the 1970s. In less than twenty four hours, the pound-dollar exchange rate fell by a massive 8 percent, and the pound-euro rate by 6 percent. The 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 different degrees against world currencies. This means that industries trading in different world markets faced sizable variations in the size of the sterling depreciation, and therefore in the magnitude of the cost and revenue shocks they experienced as a consequence of the exchange rate shift. This paper leverages this variation to study the trade and labour market consequences of the Brexit exchange rate depreciation.

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. Some early empirical studies provided evidence of a negative impact on workers' wages and/or employment from increases in import competition and an appreciation in the dollar in the 1980s (Grossman 1987; Revenga 1992).

Since that research, one key development in trade patterns that makes the conventional approach less relevant to 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, over and

above the revenue shocks from the two channels studied in the earlier work, 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 Campa and Goldberg 2001, Hummels 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 very large, unexpected, Brexit exchange rate depreciation. To do so, it considers how the sterling depreciation generated revenue and/or cost shocks by affecting trade prices, focusing on 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, as it reduced wages. The depreciation acted to impose extra costs on businesses, thereby making intermediate imports more expensive and 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 2.6 percent per annum compared to a counterfactual where pre-referendum real wage growth was maintained.

Whilst their specificity to the Brexit referendum setting needs to be made clear, these findings add to and advance what we know from several literatures. First of all, the exchange rate change we study is of unprecedented magnitude in research studying the four major world

currencies.[1] 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. As a consequence, variations in tariffs and exchange rates have often been too small to credibly study labour market impacts (see Liu and Trefler 2011; Ebenstein et al. 2014; Hummels et al. 2018 for discussion).

Moreover, above the sheer scale of the depreciation, the unexpected nature of the vote – which we discuss in more detail later – makes for a more credible exogenous variation 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 plausibly more exogenous to labour market outcomes than general exchange rate movements or other large shocks to exchange rates. One example would be exchange rate movements driven by monetary policy actions because they are often adopted during times of economic 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.

Secondly, the findings reported in the paper connect 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] We provide reduced form evidence of a significant impact of exchange rate

[1] 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).
[2] Key papers include: Feenstra and Hanson (2008); Trefler (2004); Helpman, Itskhoki, Redding (2010); Autor, Dorn and Hanson (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).

depreciations on wages and, because the referendum induced exchange rate depreciation provides variation in intermediate import prices, some structural estimates of the wage-intermediate import price elasticity. This offers a different counterpoint to existing work that shows a causal impact of trade on labour. We estimate a wage-intermediate import price elasticity because prices better capture shifts in services inputs and their sourcing, which are often difficult to measure as trade flows (Feenstra et al. 2010). It is also used in a calibration to determine the underlying labour-offshoring elasticity in production.

Thirdly, the large exchange rate depreciation provides variation in trade, including 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).

Finally, 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.[3] The new dawn referred to in the title of this paper did in

[3] 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; Breinlich et al.

fact fade for workers, despite the protestations that wages and incomes would improve under Brexit from those who advocated Leave.

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 (D-i-D) 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 considers the macroeconomic wage picture, showing there to be a permanent and sizable aggregate real wage reduction that occurred due to the exchange rate depreciation, together with variations around that aggregate fall due to differential exposure to a bigger depreciation. The implications of the core results are then discussed broadly in section 5. More skin is put on the bones by considering a wider range of estimates, both to assess the robustness of the core findings, but also place them better into the wider context of the literatures discussed above. One key feature of this is a structural interpretation of the impact of trade on the labour market by putting together the trade price and real wages reduced form results shown in the previous two sections. The resultant estimate of the structural elasticity – the elasticity of wages with respect to intermediate import prices - enables calibration of the underlying labour-offshoring elasticity in production. Section 6 concludes.

2022; Crowley et al. 2018; Bloom et al. 2019, Hassan et al. 2021; 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. The EU Referendum Vote and the Sterling Depreciation

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, that 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 10pm on June 23. A YouGov opinion poll released then suggested Remain were on course for victory with 52 percent and Leave on 48 percent. By 10.15pm, Farage conceded the Brexit campaign may be beaten and said Remain "will edge it."

The exchange rate movements then confirmed this expectation. Figure 1a shows the pound dollar and pound euro minute by minute exchange rates indexed to 1 at 10pm when the polls closed, so as to clearly show the before/after shifts, between 6pm and 11-25pm on June

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

23 (11-25 being the time the first result was reported). Sterling jumped at 10pm, 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 11-25pm were large. But they are just dwarfed by what followed. At 11-25pm, the first result came in, a big Remain vote from Gibraltar of 96 percent. 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 percent against 49.3 percent – which was nowhere near the margin many thought would occur.

Then twenty minutes later at 12-20am, 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 percent. Sterling plummeted, and went from being up, to within seconds an instantaneous near 4.7 percent drop. This alone, in seconds, was a bigger fall than the Black Wednesday crash in 1992.

Figure 1b shows the minute by minute exchange rate movements of the night, now in the time window from 6pm on June 23 and 8am on June 24. It makes very clear how the big gains up to 11-25pm look tiny compared to what subsequently happened. The precipitous drop triggered by the Sunderland vote is shown by the vertical line at 12-20am.

Sentiment changed immediately. Bookmakers' odds flipped and sharply reversed. People started to feel that Leave could be winning, and it showed in their Google searches in the next hour. Other Brexit wins followed and by 2-17am, Nigel Farage tweeted that he is "so

happy with the results in North East England".[5] A few big wins went to Remain subsequently, but in the next couple of hours 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 7am on June 24, the Leave campaign had officially won.

Figure 1b shows that, throughout the night, sterling's slide against the dollar and euro continued. By 8am on June 24, you got 1.36 dollars for a pound, 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 hour fall was a huge 8 percent against the dollar and 6 percent against the Euro.

This very big exchange rate depreciation, it's unexpected surprise nature, and its significant differences in magnitude against different currencies is the variation we study in this paper. That there is very big variation is shown in Table 1 for 26 exchange rates - the Bank of England's official set of currencies - in the 24 hour period surrounding the referendum. Sterling depreciated most against the Japanese Yen (11 percent) and the US dollar (8 percent). 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.[6] 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. 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.[7]

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

[6] 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 percent - 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 percent increase in traffic on its online purchase site compared to the same time the previous day.

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

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 Figure A1a and A1b of Appendix C). That said, it is noteworthy that the sterling depreciation turned out to be a permanent one that strongly persisted for at least two more years after, as shown in Figure A1c in Appendix C.[8] Thus, the Brexit depreciation produced a long-lasting drop in the value of the pound relative to other currencies.

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 $\mathcal{S}$ which is a vector of all relevant variables in the economy that can be viewed as fixed, and the public's best estimate of $\mathcal{S}$, denoted by $\tilde{\mathcal{S}}$ which changes with news that occurs in an event study window (see Andersen et al. 2003; Engel 2014). As an example, trade openness of the UK economy can be considered an economic fundamental which does not change with the news of the referendum, but the public's perception of UK's openness to the EU 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 $E_c = \phi_c(\mathcal{S}, \tilde{\mathcal{S}})$. For a given time window, linearising and time differencing gives $\Delta E_c = \phi_{1c}\Delta\mathcal{S} + \phi_{2c}\Delta\tilde{\mathcal{S}}$ where Δ is a difference operator 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 $\tilde{\mathcal{S}}$ and the surprise of the Brexit referendum news, B, the state variable changes by $\Delta\tilde{\mathcal{S}} = B$ and the

[8] 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 hour 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).

exchange rate consequently changes by $\Delta E_c = \phi_{2c} B$. 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 different industries buy and sell across various source and destination countries. For example, financial services purchases inputs primarily from the United States and experienced a larger cost shock than insurance services which buys 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 a shift-share measure of generic form $D_o = \sum_c S_{co} \Delta E_c$, where S_{co} is the economic linkage share of country c and ΔE_c is the shift (or sterling depreciation) against country c's currency. Analogous measures to this, with different shifts and shares definitions for the 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. More recently, there has been a surge of work on statistical inference when such shift share measures are used in difference-in-differences and in instrumental variable models (see the review by Wooldridge 2021). For our purposes, the key relevant issue in this literature is about computation of standard errors when D_o is a regressor, and we follow the two step procedures of Adao, Kolesar and Morales (2019) and Borusyak, Hull and Jaravel (BHJ) (2022) in our empirical analysis (reporting BHJ standard errors for shift-share variables where required).

On a practical level, there are various ways the share term can be measured. There are a range of possible economic linkages that industries have with different countries, but for the focus and interest of our paper the most natural one to consider is trade linkages. Thus, for most of the analysis in this paper, two trade shares 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 other measures of D_o.

To be more concrete, we use data on all 2-digit industries in the UK put together with 145 world currencies across 245 countries 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 sectors (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.

For each of these, and defining an output industry *o*, combining currency variations and trade shares produces the two trade weighted industry-level depreciation measures:

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

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

Higher values of ΔE_o^x and ΔE_o^i respectively correspond to bigger revenue and cost shocks. The two measures are constructed by weighting the currency depreciations – the shifts - with their country's shares in the industry's pre-referendum trade. As recommended by the new shift share literature, the source of the variations across the shift and share dimensions are broken out and shown in Figure A2 in Appendix C which plots the currency exchange rate shifts against their average industry weighted trade shares. These are not highly correlated, so

the shift-share design benefits from variation in depreciation shocks that are not driven just by the trade shares (a feature also confirmed by some robustness checks presented later in the paper).

The industry-country trade shares used to weight the exchange rates are based on pre-referendum data combining goods trade from UN COMTRADE, services trade from the International Trade in Services (ITIS) microdata and the Import Supply-Use Tables of the Office of National Statistics (ONS) for 2015. The 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 sectors 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 for over a decade 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 detail and high quality information on services trade patterns for most sectors in the UK. Trade patterns for a few sectors 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, 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_{ci} and the share of that input in the intermediate imports of the industry S_{io} : $S_{ico} = S_{ci} \times S_{io}$. After trimming currency shares of below 1 percent in an industry, 102 countries and

77 currencies are used to construct the exports weighted depreciation measure and 74 countries and 51 currencies are used to construct the intermediate imports weighted measure.[9]

Descriptives

Figure 3 shows the broad currency composition of the two depreciation measures, ΔE_o^x and ΔE_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 general patterns. Service industries tend to rank at the top of both of the measures. Manufacturing features in the bottom 4. The top four in each is characterised by more dollar trades, and the bottom four by euro trades. And the depreciations of the top 4 and bottom 4 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 percent from bottom to top for intermediate imports). This is the variation used in the empirical analysis to be reported.

More specifically, Cultural activities, Repairs and installation of machinery, Scientific research and development and Education export largely to the United States 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 and Water collection and treatment and Repair of personal and household goods export mostly to European countries and are the least affected in terms of exports.

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

The top and bottom four industries in terms of exports differ 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 among the bottom four for the intermediate imports-weighted depreciation.

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 analysis is undertaken using quarterly data for the four years prior to and the three years after the referendum. Thus, it runs from 2012Q3 to 2019Q2. The reduced form before/after referendum evolution of a given outcome Y is related to the industry depreciation measures $D_o = \left[\Delta E_o^x, \Delta E_o^i\right]$ for output industry o in time period qt, where q is quarter and t is year, as follows:

$$Y_{oqt} = \alpha_o + \alpha_{qt} + \beta \times \mathbb{1}(qt \geq Referendum_{qt}) \times D_o + \varepsilon_{oqt} \quad (1)$$

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

ε_{oqt} is an error term. If a log-log functional form is adopted for Y_{oqt} and D_o then the key parameter of interest, β, is an elasticity. For example, when Y is a trade price, then this is a passthrough parameter, like those used in the international prices and exchange rate literatures mentioned earlier.

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

$$Y_{oqt} = \alpha_o + \beta_a \times \mathbb{1}(qt \geq Referendum_{qt}) \times (D_0 > Median) + \beta_b \times \mathbb{1}(qt \geq Referendum_{qt}) \times (D_0 < Median) + \varepsilon_{oqt} \quad (2)$$

In (2), β_a is the estimated before/after change in the outcome for industries that face above median depreciation, and β_b the analogous measure for the below median depreciation industries. Therefore, $\beta \equiv \beta_a - \beta_b$ is the difference-in-differences estimand of interest that shows the relative change in Y before and after the referendum.

3. Trade Prices and the Brexit Exchange Rate Depreciation

In this section, Y is measured by trade prices, specifically export prices and intermediate import prices, which are related to the trade weighted exchange rate depreciations with an aim of empirically evaluating whether revenue or cost channel shocks (or both) occurred due to the Brexit exchange rate depreciation.

Trade Prices

Quarterly data on export and import price indices at the industry level come from price observations reported by firms to the ONS. We combine publicly available price indices with those for certain 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 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.

Descriptive Analysis

Starting with descriptive analysis, Figure 4 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 log 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.

Regression Estimates

Table 3 systematises these findings in the D-i-D model of equation (1), where a log-log specification is adopted. For export prices, there is no evidence of a before/after differential change in export prices (in sterling) in industries with a higher depreciation. Indeed, the D-i-D point estimate of interest is 0.096 with a standard error of 0.073. 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, and in line with the descriptive scatterplots, there is strong evidence in column (2) of Table 3 that the sterling depreciation had a significant price-increasing impact on intermediate imports, with an estimated elasticity of 0.478. A 10 percent higher depreciation (for example, a sterling depreciation of 6.6 percent as compared to the pound-euro fall of 6 percent) resulted in intermediate import prices going up by just under 4.8 percent. In column (3), the five non-traded export industries are excluded, and a similar, slightly reduced in magnitude but still large effect is seen. The sizable passthroughs of specifications (2) and (3) in the Table are in line with magnitudes seen in other work (e.g. Chen et al. 2021 with disaggregated goods customs data).

To provide a clearer sense of the magnitude of the trade price changes, Table 4 compares across industries that faced above or below median depreciations, as in the equation (2) specification of the previous section. Export prices did rise, but by a highly similar 10 percent or so in both the above and below median export depreciation industries, with there being no systematic difference between the two. But, changes in intermediate import prices did differ systematically across above and below median intermediate import weighted depreciation. Intermediate import prices rose by 8.4 percent among industries with above median depreciation compared to 5.4 percent for below median industries. This gives a D-i-D estimate of a 3 percent higher intermediate import price passthrough across the two sets of industries.

Pre-Trends

The estimates reported so far rely on there being no pre-referendum trend differences in the outcome of interest. To examine this is more detail, Figure 4 shows event study estimates of equation (2) for intermediate import prices where separate year specific estimates of β_a and

β_b are shown (with associated confidence intervals) for the three post-referendum periods (2016/17, 2017/18 and 2018H2) and two pre-referendum years (2014/15 and 2015/16).[10]

The event study chart on the left of Figure 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.[11] 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 the Table 3 specifications, 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. In practical terms, it does not make much difference, and if anything, the passthrough rises a little to 0.515 (from 0.478) for the intermediate imports elasticity. 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-trend and to possible announcement effects being at play.

[10] 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.

[11] 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.

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 D-i-D models. There is significant evidence, in column (1) that, export prices do indeed rise with the intermediate imports weighted depreciation for the industry. The passthrough is estimated at 0.278, much larger in magnitude than the passthrough of the exports weighted depreciation.

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.

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:

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

ii) Hours, H_{joqt} - hours worked in a week by worker j.

iii) Inflows of workers into the industry I_{oqt}.

iv) Outflows of workers from the industry O_{oqt} are also shown to examine employment shifts.

More detail on data construction, specific definitions and sources is given in Data Appendix B.

Descriptive Analysis

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

For all outcomes considered, the pattern in Figure 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 Figure 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).

Regression Estimates

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

Panel A of the Table makes it clear that real wage growth was 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 (-0.024 with an associated standard error of 0.071). There is a sizable wage-reducing effect of the intermediate imports weighted depreciation, with an estimated elasticity of -0.442.

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 magnitudes, Table 7 shows the discrete specification of equation (2). Real wages in industries with above median intermediate imports weighted depreciation grew only by 1.4 percent over the three years after the referendum. In the below-median industries, real wages grew by 4.8 percent, which results in a DiD coefficient between the above/below median industries of -3.4 percent.

Panel C 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 percent over the three years after the referendum. In contrast, the bottom four industries grew by 5.6 percent, resulting in a DiD coefficient of -4.9 percent 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 percent over the post-referendum period.

These results are confirmed further in column (2) of Table 5 where hourly wages of all workers - now including part-timers - are examined. The wage elasticities are slightly smaller in magnitude when all workers are considered but remain highly similar to the previous ones for fulltime workers.[12]

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. In the next subsection, we therefore focus on pre-trends in wages to ensure that the intermediate imports weighted depreciations are driving this slowdown.

Pre-Trends

Figures 6a and 6b 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

[12] 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.

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.

Real Wage Stagnation

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

But what about overall in the aggegate? It is possible to compare against a counterfactual of what would have happened to real wage growth in the absence of the vote to leave the EU. One such exercise is considered in Figure 7. The black solid line is real wage growth over the full sample period 2012Q2 to 2019Q2. Looking at the pre-referendum changes, it is clear that following a period at the start when real wages were actually falling in the UK after the financial crisis, the ten quarters before the referendum had shown a pick up in real wages which were starting to grow again at a modest, but relatively constant, rate of around 1.7 percent per year. As shown in Figure 7, projecting this forward beyond the referendum produces a counterfactual prediction – shown on the dashed black line - that average real wages would have grown by 5.1 percent cumulatively in the three years after the referendum had wage growth stayed on trend. In actual fact, they rose by quite a lot less, going up 2.3 percent. Aggregate real wage growth was therefore 2.8 percent lower than the pre-referendum projection cumulatively over the three years after the referendum.

When considering the depreciation, the real wage fall relative to the projected trend growth is bigger for workers in high depreciation industries (by a cumulative 4 percent). By contrast, there is only a modest fall in real wage growth of 1.4 percent for workers in the low

depreciation industries. These falls come about as a result of both lower than projected nominal wage growth and higher consumer price inflation in the post-referendum period (see also Breinlich et al. 2022 and Dhingra and Sampson 2022 for discussion).

For aggregate wages, the bottom line is a permanent real wage drop as the aggregate labour market never got back on the higher projected track that it was on before the Leave vote. Figure 8 shows this to be the case over a longer time period than our study period with the Office for National Statistics' aggregate average weekly earnings series (AWE) for all months from January 2000 up to June 2022. The AWE monthly headline figures are for wages paid by employers (from the Monthly Wages and Salaries Survey).

The Figure is useful first to show the longer run evolution of UK real wages before and after our sample period. The real wage path in black denotes the period covered by our sample, while the gray path shows the periods before and after that. The Figure makes it clear that real wage growth was returning to the UK labour market from the start of 2014 (two and half years before the referendum) after a torrid period of real wage falls from austerity in the early 2010s. Had aggregate wages continued to grow on this 2014 onwards trend, they would have followed the dashed black line which is above the actual real wage path in the post-referendum period. However, and confirming our sample period QLFS analysis, aggregate wage growth stagnated in the 6 to 8 quarters after the referendum, then picked up on a similar trend growth (abstracting from the Covid-19 drop in 2020), but has since never recovered to the projection from its pre-referendum trend, even after factoring in the bounce back from the pandemic. Calibrating the permanent drop down in average wages from the QLFS Figure 7 using a discount factor of 0.96 as in Dhingra et al. (2017), the present discounted value of the average real wage fall is 2.6 percent per year relative to the counterfactual pre-referendum prediction, or just over £800 of a full-timers' wage per year in 2016 prices.

5. Discussion and Interpretation

The main finding of section 4 is real wage reductions for workers employed in industries that experienced a larger cost shock from the Brexit exchange rate depreciation. In this section, we discuss extensions and refinements in the context of the quite wide-ranging literatures that the analysis undertaken so far can speak to. These include: the relation to previous work on trade and trade policy; deglobalisation and Brexit/Trump; the causal impact of trade on the labour market and; services trade.

Trade and Trade Policy

There are several refinements and extensions that the trade and trade policy literature suggest pursuing. We study their implications for the main finding of the paper by assessing how they affect the wage-intermediate import depreciation elasticity of -0.442, and also present and discuss the full results in additional Tables presented in Appendix C. Table 9 summarises results from these specification adaptations to show the baseline estimate changes for five sets of trade and trade policy related extensions:

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. An imports weighted depreciation can be defined as $\Delta E_o^m = \sum_c S_{co} \Delta E_c$ where S_{co} is the share of source country c in imports of goods and services that belong to output industry o and that are imported as final consumption or as intermediates by industries other than o.[13] Inclusion of this third depreciation measure, along with the exports and intermediate imports weighted depreciations considered earlier, makes little difference as is shown in Panel A of Table 9. Table A2 in Appendix C shows the full model including all

[13] It is worth noting that the import competition channel may still be partly capturing intermediate consumption from businesses reselling the imported goods and services to other sectors. 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.

three measures, with a negligible wage impact of -0.001 with respect to the imports weighted depreciation.[14]

2) Initial trade structure: Panel B of Table 9 shows the estimated elasticity when initial trade shares, measured in several ways and interacted with the post-referendum dummy, are additionally included. For six initial trade measures, the estimates of the main elasticity are strongly clustered near the core finding of -0.442. The trade share interactions with the post indicator are small and statistically insignificant on their own, which corroborates the earlier discussion that the shift-share instrument is driven by variation in the shifts from the currency depreciation rather than the trade shares themselves (see again Figure A2 of Appendix C).

3). Trade policy: 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. We examine the role of expected changes in trade barriers after Brexit by including interactions of the post period indicator with tariffs and services trade restrictiveness indices that would apply under hard and soft Brexit scenarios. To capture the 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 following the trade policy uncertainty literature (e.g., Limao and Maggi 2015; Pierce and Schott 2016).

We also examine indirect impacts from spillovers of trade barriers across sectors by including interactions of the post period with predicted industry-specific impacts for Gross Value Added under a soft or hard Brexit shock from a quantitative gravity model of trade (Dhingra et al. 2017). In another exercise, the full higher-order upstream and downstream depreciations for each industry are included following Acemoglu, Autor, Dorn and Hanson (2016).

[14] Entering the imports weighted depreciation on its own also shows no significant association with real wages, with an estimated coefficient (standard error) of -0.072 (0.073) as shown in Table A2 of Appendix C.

As shown in Panel C of Table 9, inclusion of Brexit trade barriers or the uncertainty over them makes little difference to the baseline wage estimate. But uncertainty after the Brexit vote was not confined to trade policy. Following Bloom et al. (2019), we therefore also consider the role of economic uncertainty in Figure A5 which 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.

4). Migration and FDI shares

Brexit was also expected to affect UK's international linkages through barriers to movement of people and capital with the EU and beyond. To account for this, we consider specifications with depreciations that are weighted by the country structure of migrants and FDI in the UK in Panel D. Just like currency exposure through trade, source country patterns of migration are used to construct a migration weighted depreciation for each industry. Further, source country shares of inwards FDI coming into an industry and the destination country shares of outwards FDI from an industry are used to determine inward and outward FDI weighted depreciations. We also follow the earlier exercise of including interactions of the post period indicator with the initial shares of migrants in the workforce and the initial shares of FDI across industries to examine if their initial structure affected wages.

5). Currencies

Finally, we conducted a few checks on the currency shocks in Panel E by altering the window to a week or two weeks and by assigning countries to major currencies (dollar and euro) according to their shares of vehicle currency invoicing in UK trade. Overall, the magnitude of the wage elasticity is tightly bound between -0.3 to -0.4 across various specifications that relate to previous work.

Causal Impact of Trade on Labour

Some of the trade and labour literature has utilised instrumental variable (IV) methods to study the causal impact of trade on labour. Prominent examples are: early work by Revenga (1992) which is closest to our analysis of instrumenting import prices in a labour equation, although new developments necessitate a focus on intermediate imports instead of final import competition in our setting; Autor, Dorn and Hanson's (2013) China shock paper where US import penetration is instrumented with import penetration of China in other advanced economies; and Hummels et al. (2014) using Danish administrative data to look at the impact of offshoring on wages using transport costs as instruments for intermediate imports.[15]

We are able to push the research design in the direction of unpacking a causal impact of trade on wages, by setting up a research design where we instrument trade prices on the right hand side of a structural wage equation. More specifically, sections 3 and 4 estimated equation (1) to provide estimates of the elasticities of both trade price and real wages with respect to the sterling depreciation. These can be utilised to obtain a causal impact of the trade price on wages, if one is willing to make 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 that would pose a threat to identification. Put differently, to offer a causal interpretation, this requires that the only way in which the depreciation impacts wages is by working through the cost channel from the higher intermediate price, making it a credible instrumental variable for the intermediate import price.

More formally, under this assumption one can think of the estimates presented earlier as coming from two reduced form relations between trade prices (the first stage) or wages and

[15] See also a growing literature that has been using shift-share variables for labour market impacts of globalisation, such as extensions of the China shock work summarised in Autor, Dorn and Hanson (2016) and a more recent discussion in Redding (2020).

depreciation (the reduced form), which can underpin the following structural form of the wage equation:

$$log(W_{joqt}) = \alpha_o + \alpha_{qt} + \theta \times log(P^m_{oqt}) + \varepsilon_{oqt} \quad (3)$$

where ε_{oqt} is an error term. When $log(P^m_{oqt})$ is instrumented with $\mathbb{1}(qt \geq Referendum_{qt}) \times D_o$ as in equation (1), then the estimated θ is the wage elasticity of intermediate import prices, which is the ratio of the wage reduced form coefficient to that of the first stage. This is often referred to as the offshoring elasticity (e.g. Hummels et al. 2018) and its sign determines whether offshoring is complementary to domestic workers ($\theta < 0$) or whether offshoring substitutes for workers at home ($\theta > 0$).

Table 10 shows the Instrumental Variables (IV) estimates of θ, together with the underlying reduced form specifications. The reduced form for wages is -0.442 while the reduced form for price passthrough is 0.479, now estimated for the same sample as the consistently defined price series. Their ratio gives the estimated wage-price elasticity of -0.938. A 1 percent higher price for imported inputs reduces wages by a little less than 1 percent, showing that offshoring is complementary to workers.

The finding of complementarity in our setting accords well with the nature of inputs that are imported into services industries. Table A10 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.

A further issue worth noting for whether structurally interpreting the results is plausible concerns their timing. Looking closely at the above/below median difference-in-differences charts in Figure 4 for intermediate import prices and Figure 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). As such, it seems like the staggered timing of the trade price and worker outcome responses, with a reasonable assumption reflecting the predetermined nature of the trade price change that predates the wage changes, acts to reinforce the causal pattern of results that run in the direction of higher import prices negatively impacting worker outcomes.

Services and Manufacturing

So far, we have looked at economy wide estimates and have only noted in passing our use of rich service sector data compared to many existing studies in the literature that look only at manufacturing sector workers. Does this matter? The answer is yes, as a study confined to manufacturing would not have found the average effects that we do.

This becomes evident since, when splitting the sample of workers by manufacturing and services, the wage coefficient with respect to the intermediate import weighted depreciation is -0.515 in services (with an associated standard error of 0.099), but within manufacturing it is 0.078 (0.139). The passthrough of the depreciation on intermediate import prices is relatively similar across manufacturing and services. But the negligible wage coefficient in manufacturing implies that the wage slowdown is entirely driven by services industries. The labour-offshoring elasticity is nor far away from -1 in services, and if anything is positive in manufacturing

industries. This is consistent with the common finding of substitutability between domestic workers and intermediate imports in studies that focus on manufacturing workers. For services, we find instead that domestic workers were complementary to intermediate imports affected by the Brexit depreciation.[16]

Calibration

The structural wage-intermediate import price elasticity, and the plausibility of its estimated value, can be appraised in light of theories of the elasticity of substitution or complementarity between factors of production (e.g. Allen 1934; Hicks 1970; Blackorby and Russell 1989; and see Stern 2011 for discussion). We focus on the Hotelling elasticity because it nests other frameworks and is defined in terms of prices.

In a general formulation where firms maximise profits, Hotelling's Lemma gives factor demand as the partial derivative of the profit function with respect to the factor price: $L_o^D = -\Pi_w\left(W_o, P_o^i, P_o^d, P_o^x, P_o^{uk}\right)$. The profit function depends on factor costs (wages, imported input prices and domestic input prices denoted by P_o^d) and on revenues (through output prices of exports and domestic sales, denoted by P_o^x, P_o^{uk} respectively, where the latter in turn depends on competing import prices P_o^m). Then the cross-price elasticity between workers and intermediate imports is defined as:

$$\varepsilon_{WP^i} \equiv \partial log L_o^D\left(W_o, P_o^i, P_o^d, P_o^x, P_o^{uk}\right)/\partial log P_o^i = \Pi_{WP^i} P_o^i/\Pi_W. \quad (4)$$

The Hotelling elasticity normalises equation (4) above with input shares to give the elasticity of substitution between labour and offshoring as

$$\sigma_{WP^i} \equiv -\Pi\Pi_{WP^i} P_o^i/\Pi_W \Pi_{P^i} = \varepsilon_{WP^i}/S_{P^i\Pi}$$

where $S_{P^i\Pi} \equiv P_o^i Q_o^i/\Pi$ is the share of intermediate import costs in profits. If instead firms' output and other costs cannot be immediately altered, then firms are cost minimisers and σ_{WP^i}

[16] Manufacturing refers to SIC 2-digit industries 1 to 33, where 1 to 9 are agriculture and mining activities (which have relatively) small sample sizes.

gives the familiar Allen-Uzawa elasticity (in price terms). Because there is no reduced form wage impact of revenue side depreciation measures, generalisation of the offshoring elasticity in the presence of import and export channels is relegated to a more detailed discussion, presented in Appendix D.[17]

Moving from the firm-level relationship to an industry elasticity, we specify the supply of labour to the industry as $L_o^S = L(W_o)$. Let $\varepsilon_{WW}^S \equiv WL'(W)/L(W)$ denote the elasticity of labour supply to the industry which is typically assumed to be weakly positive, with zero denoting industry-specific labour (at least in the short run). Assuming wages are set by market clearing and totally differentiating the labour market clearing condition then gives the equilibrium wage-import price elasticity as:

$$dlnW_o = \frac{\varepsilon_{WP^i}}{\varepsilon_{WW}^S - \varepsilon_{WW}} dlnP_o^i = \frac{\sigma_{WP^i}}{\sigma_{WW}^S - \sigma_{WW}} \frac{S_{P^i\Pi}}{S_{W\Pi}} dlnP_o^i \tag{5}$$

where $S_{W\Pi} \equiv WL/\Pi$ is the share of labour costs in profits, so that $S_{P^i\Pi}/S_{W\Pi}$ is the share of intermediate import costs to labour costs. The first equality in equation (5) takes account of own changes in wages when intermediate import prices change. Under industry-specific labour, this would simplify to $-\varepsilon_{WP^i}/\varepsilon_{WW}$. The second equality expresses the cross-price elasticities in their more familiar Hotelling form.

Under the additional assumption of zero profits in the industry, the RHS of equation (5) becomes just the negative of the ratio of intermediate import costs to labour costs: $lnW_o = -\left(S_{P^i\Pi}/S_{W\Pi}\right)dlnP_o^i$. In particular, the first term on the RHS turns out to be minus one $(\sigma_{WP^i}/(\sigma_{WW}^S - \sigma_{WW}) = -1)$. The zero profit condition therefore corresponds to a special case where increases in intermediate import prices reduce wages by the ratio of the intermediate

[17] In the presence of output effects from exports, competing imports and domestic sales, equation (3) would include industry output measures to allow for scale effects in the labour demand equation. Entering real gross value added (GVA) on the RHS of equation (3), the coefficient on intermediate imports weighted depreciation is almost unchanged at -0.433 (with an associated standard error of 0.074) and the coefficient on real GVA is small and statistically insignificant at -0.030 (with an associated standard error of 0.027).

imports to labour costs to maintain zero profits. In our empirical setting, the share of intermediate import costs to labour costs is 0.376.

This is smaller in magnitude than our estimated elasticity of -0.938 so we can back out the underlying Hotelling elasticity between domestic workers and intermediate imports σ_{WP^i} by calibrating the other parameters. The parameters we calibrate are zero for the labour supply elasticity σ_{WW}^{S} because this corresponds to the commonly used framework of factors that are specific to the industry over this period. The labour demand elasticity σ_{WW} is set to -0.5 from the literature (Hamermesh 1993). Then the Hotelling elasticity is $\sigma_{WP^i} = -1.25$ because

$$-0.938 = \frac{\sigma_{WP^i}}{0-(-0.5)}(0.376).$$

This can be compared to the study of workers in Danish manufacturing firms by 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 from -0.44 to -1.82, which puts our estimates in their central range.[18]

6. Conclusions

This paper presents evidence of the economic consequences of the very 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 facing different industries is leveraged to first study the consequences for trade

[18] The wage-import IV elasticity for high-skilled workers is between 0.007 to 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 latter range is directly comparable to our IV estimates under the assumption of iceberg transport costs. 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.

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. 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, mostly in the service sector where the exchange rate depreciated by more, workers lost out permanently in terms of real wages. Wage growth slowed down considerably and stagnated in higher depreciation industries through a cost shock that lasted up to two years following the referendum. So what actually happened was quite the opposite to the pre-referendum position taken by Brexit advocates who argued 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.

References

Acemoglu, D., Autor, D., Dorn, D., Hanson, G. and Price, B. (2016) "Import Competition and the Great US Employment Sag of the 2000s ", Journal of Labor Economics, 34, S141-S198.

Adao, R., Kolesar, M. and Morales, E. (2019) "Shift-Share Designs: Theory and Inference," Quarterly Journal of Economics, 134, 1949-2010.

Allen, R. (1934) "A Comparison Between Different Definitions of Complementary and Competitive Goods", Econometrica, 2, 168-175.

Amiti, M., Itskhoki, O., and Konings, J. (2014) "Importers, Exporters, and Exchange Rate Disconnect", American Economic Review, 104, 1942-78.

Andersen, T., Bollerslev, T., Diebold, F. and Vega, C. (2003) "Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange", American Economic Review, 93, 38-62.

Auer, R., Burnstein, A. and Lein, S. (2021) "Exchange Rates and Prices: Evidence from the 2015 Swiss Franc Appreciation", American Economic Review, 111, 652-86.

Autor, D., Dorn, D. and Hanson, G. (2013) "The China Syndrome: Local Labor Market Effects of Import Competition in the United States", American Economic Review, 103, 2121-68.

Autor, D., Dorn, D. and Hanson, G. (2016) "The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade", Annual Review of Economics, 8, 205-240.

Bartik, T. (1991) "Who Benefits from State and Local Economic Development Policies?," W.E. Upjohn Institute.

Berman, N., Martin, P. and Mayer, T. (2012) "How do Different Exporters React to Exchange Rate Changes?," The Quarterly Journal of Economics, 127, 437-492

Blackorby, C. and Russell, R. (1989) "Will The Real Elasticity of Substitution Please Stand Up? (A Comparison of the Allen/Uzawa and Morishima Elasticities)", American Economic Review, 79, 882-888.

Bloom, N., Bunn, P., Chen, S., Mizen, P., Smietanka, P. and Thwaites, G. (2019) "The Impact of Brexit on UK Firms," NBER Working Paper, w26218.

Borusyak, K., Hull, P. and Jaravel, X. (2022) "Quasi-Experimental Shift-Share Research Designs", Review of Economic Studies, 89, 181-213.

Breinlich, H., Leromain, E., Novy, D. and Sampson, T. (2022) "The Brexit Vote, Inflation and UK Living Standards", International Economic Review, 63, 63-93.

Burstein, A., Eichenbaum, M. and Rebelo, S. (2005) "Large Devaluations and the Real Exchange Rate", Journal of Political Economy, 113, 742-784.

Burstein, A. and Gopinath, G. (2014) "International Prices and Exchange Rates", in Gopinath, G., Helpman, E. and Rogoff, K. (eds.) Handbook of International Economics, Volume 4, Elsevier.

Campa, J. and Goldberg, L. (2001) "Employment Versus Wage Adjustment and the U.S. Dollar", The Review of Economics and Statistics, 83, 477-489.

Chen, N., Chung, W., and Novy, D.(2021) "Vehicle Currency Pricing and Exchange Rate Pass-Through", Journal of the European Economic Association, 20, 312-351

Cravino, J. and Levchenko, A. (2017) "The Distributional Consequences of Large Devaluations", American Economic Review, 107, 3477-3509.

Crowley, M., Exton, O. and Han, L. (2018) "Renegotiation of Trade Agreements and Firm Exporting Decisions: Evidence from the Impact of Brexit on UK Exports", Cambridge Working Papers in Economics, 1839.

Davies, R. and Studnicka, Z. (2018) "The Heterogeneous Impact of Brexit: Early Indications from the FTSE," European Economic Review, 110, 1-17.

De Soyres, F., Frohm, E., Gunnella, V. and Pavlova, E. (2021) "Bought, Sold and Bought Again: The Impact of Complex Value Chains on Export Elasticities", European Economic Review, 140, 103896.

Dhingra, S., Huang, H., Ottaviano, G., Pessoa, J., Sampson, T. and Van Reenen, J. (2017) "The Costs and Benefits of Leaving the EU: Trade Effects", Economic Policy, 32, 651-705.

Dhingra, S. and Sampson, T. (2022) "Expecting Brexit", Annual Review of Economics, 14, 495-519.

Dix-Carneiro, R., and Kovak, .B. (2017) "Trade Liberalization and Regional Dynamics", American Economic Review, 107, 2908-46.

Ebenstein, A., Harrison, A., McMillan, M. and Phillips, S. (2014) "Estimating the Impact of Trade and Offshoring on American Workers using the Current Population Surveys", Review of Economics and Statistics, 96, 581-595.

Engel, C. (2014), "Exchange Rates and Interest Parity", in Gopinath, G., Helpman, E. and Rogoff, K. (eds.) Handbook of International Economics, Volume 4, Elsevier.

Faccini, R. and Palombo, E. (2021), "News Uncertainty in Brexit United Kingdom", American Economic Review: Insights, 3, 149-64.

Fajgelbaum, P. and Khandelwal, A. (2022) "The Economic Impacts of the US–China Trade War", Annual Review of Economics, 14, 205-228.

Feenstra, R. and Hanson, G. (1997) “Foreign Direct Investment and Relative Wages: Evidence from Mexico’s Maquiladoras”, Journal of International Economics, 42, 371-393.

Feenstra, R. (1998) "Integration of Trade and Disintegration of Production in the Global Economy", Journal of Economic Perspectives, 12, 31-50.

Feenstra, R. and Hanson, G. (1999) “The Impact of Outsourcing and High-Technology Capital on Wages: Estimates For the United States, 1979–1990”, The Quarterly Journal of Economics, 114, 907–940.

Feenstra, R. and Hanson, G. (2008) "Global Production Sharing and Rising Inequality: A Survey of Trade and Wages", in Kwan Choi, E. and Harrigan, J. (eds.), Handbook of International Trade, Wiley.

Feenstra, R., Lipsey, R., Branstetter, L., Foley, C., Harrigan, J., Jensen, J., Kletzer, L., Mann, C., Schott, P. and Wright, G. (2010), “Report on the State of Available Data for the Study of International Trade and Foreign Direct Investment”, NBER Working Paper 16254.

Fisman, R. and Zitzewitz, E. (2019) “An Event Long-Short Index: Theory and Applications”, American Economic Review: Insights, 1, 357-72.

Goldberg, P. and Pavcnik, N. (2016) "The Effects of Trade Policy", in Bagwell, K. and Staiger, D. (eds.) Handbook of Commercial Policy, Volume 1, Elsevier.

Graziano, A., Handley, K. and Limao, N. (2021) “Brexit Uncertainty and Trade Disintegration”, Economic Journal, 131, 1150-1185.

Grossman, G. (1987) "The Employment and Wage Effects of Import Competition in the United States", Journal of Economic Integration, 2, 1-23

Grossman, G. and Rossi-Hansberg, E. (2008) "Trading Tasks: A Simple Theory of Offshoring", American Economic Review, 98, 1978-1997.

Grossman, G. and Rossi-Hansberg, E. (2012) "Task Trade Between Similar Countries", Econometrica, 80, 593-629

Hakobyan, S. and McLaren, J. (2016) "Looking for Local Labor Market Effects of NAFTA", Review of Economics and Statistics, 98, 728-741.

Hamermesh, D. (1993) “Labor Demand”, Princeton University Press.

Hassan, T., Hollander, S., Van Lent, L. and Tahoun, A., (2021) “The Global Impact of Brexit Uncertainty,” NBER Working Paper w26609.

Helpman, E. (2017) “Globalization and Wage Inequality”, Journal of the British Academy, 5, 125-162.

Helpman, E., Itskhoki, O., and Redding, S. (2010) “Inequality and Unemployment in a Global Economy”, Econometrica, 78, 1239–1283.

Hicks, J. (1970) “Elasticity of Substitution Again: Substitutes and Complements”, Oxford Economic Papers, 22, 289-296.

Hummels, D., Jorgensen, R., Munch, J. and Xiang, C. (2014) “The Wage Effects of Offshoring: Evidence from Danish Matched Worker-Firm Data”, American Economic Review, 104, 1597–1629.

Hummels, D., Munch, J. and Xiang, C. (2018) “Offshoring and Labor Markets”, Journal of Economic Literature, 56, 981-1028.

Javorcik, B., Stapleton, K., Kett, B. and O’Kane, L. (2020) “Unravelling Deep Integration: Local Labour Market Effects of the Brexit Vote”, CEPR Discussion Paper 14222.

Limao, N. and G. Maggi (2015) “Uncertainty and Trade Agreements,” American Economic Journal: Microeconomics, 7, 1-42.

Liu, R. and Trefler, D. (2011) "A Sorted Tale of Globalization: White Collar Jobs and the Rise of Service Offshoring", NBER Working Papers, 17559.

Lorenzoni, G. (2014) “International Financial Crises,” in Gopinath, G., Helpman, E. and Rogoff, K. (eds.) Handbook of International Economics, Volume 4, Elsevier.

Muendler, M. (2017) "Trade, Technology, and Prosperity: An Account of Evidence from a Labor-Market Perspective", WTO Staff Working Papers, 15.

O’ Rourke, K. (2019) “A Short History of Brexit: From Brentry to Backstop”, Pelican Books.

Pierce, R. and Schott, P. (2016) “The Surprisingly Swift Decline of US Manufacturing Employment”, American Economic Review, 106,1632-62.

Redding, S. (2020) “Trade and Geography,” NBER Working Paper 27821.

Revenga, A. (1992) “Exporting Jobs?: The Impact of Import Competition on Employment and Wages in U.S. Manufacturing”, The Quarterly Journal of Economics, 107, 255-284.

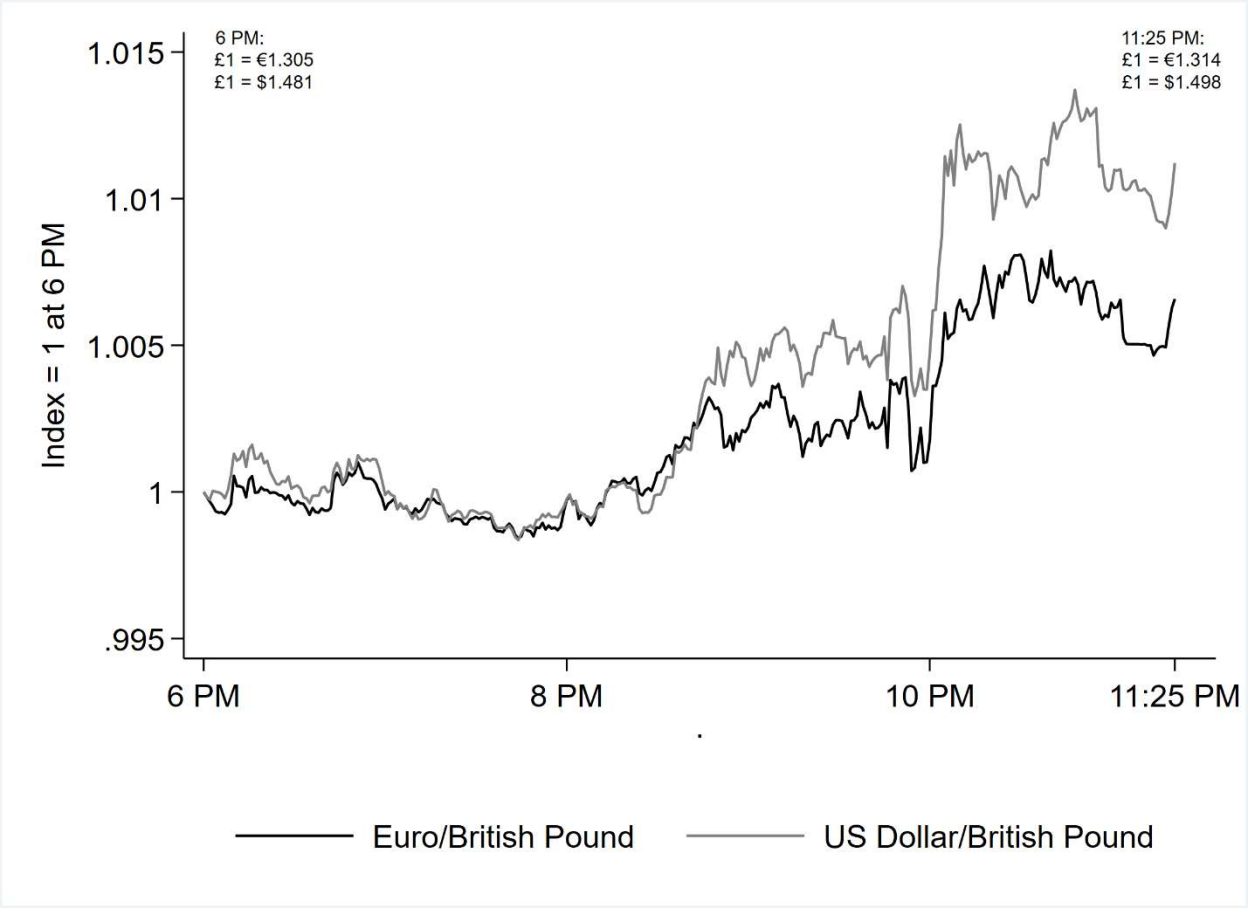
Stern, D. (2011) “Elasticities of Substitution and Complementarity”, Journal of Productivity Analysis, 36, 79-89.

Trefler, D. (2004) “The Long and Short of the Canada-U.S. Free Trade Agreement”, American Economic Review, 94, 870-895.

Wooldridge, J. (2021) “Two-Way Fixed Effects, the Two-Way Mundlak Regression, and Difference-in-Differences Estimators,” Working Paper.

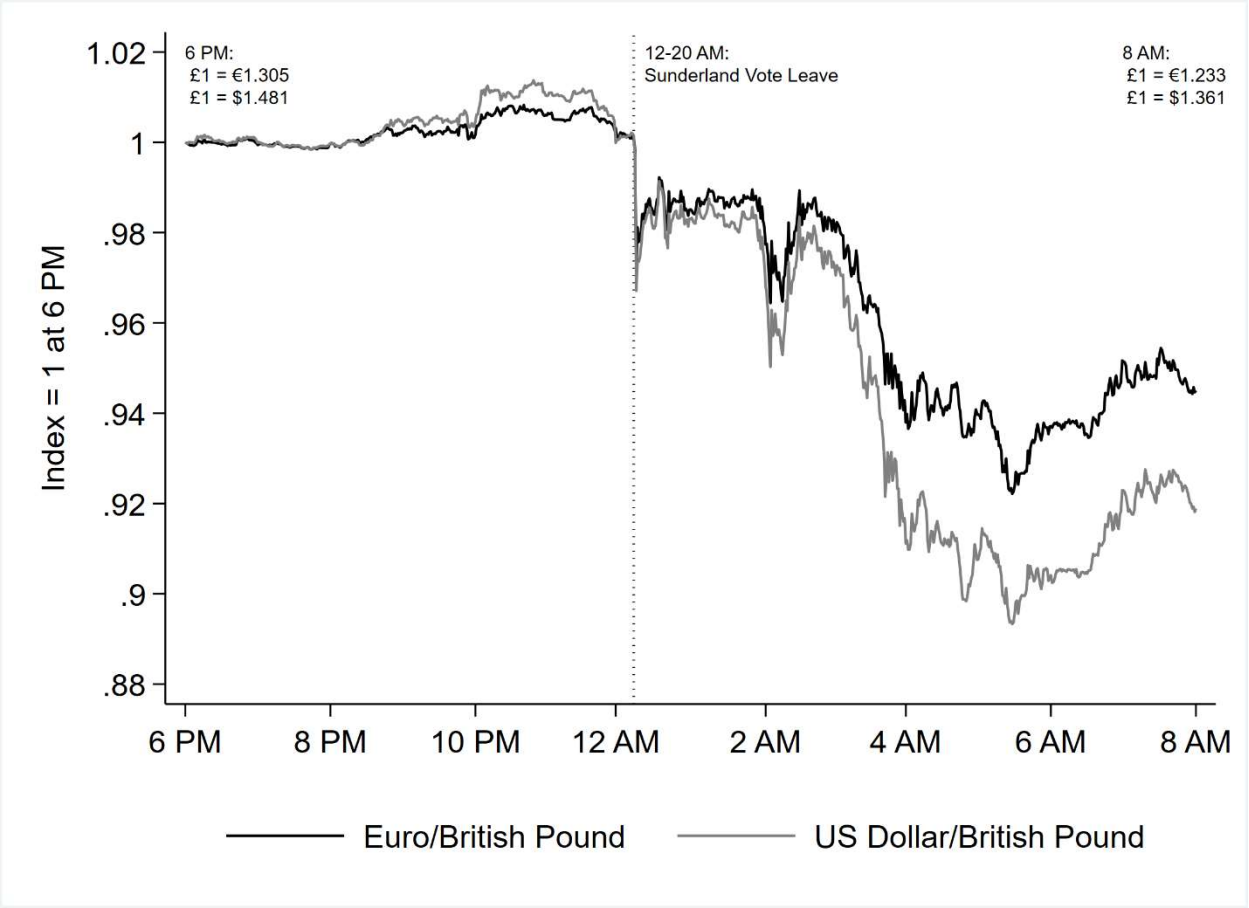
Yi, K. (2003) “Can Vertical Specialization Explain the Growth of World Trade?”, Journal of Political Economy, 111, 52-102.

Figure 1a: Exchange Rate Movements 6 PM To 11-25 PM, June 23 2016



Notes: Minute by minute exchange rates from HistData (FOREX).

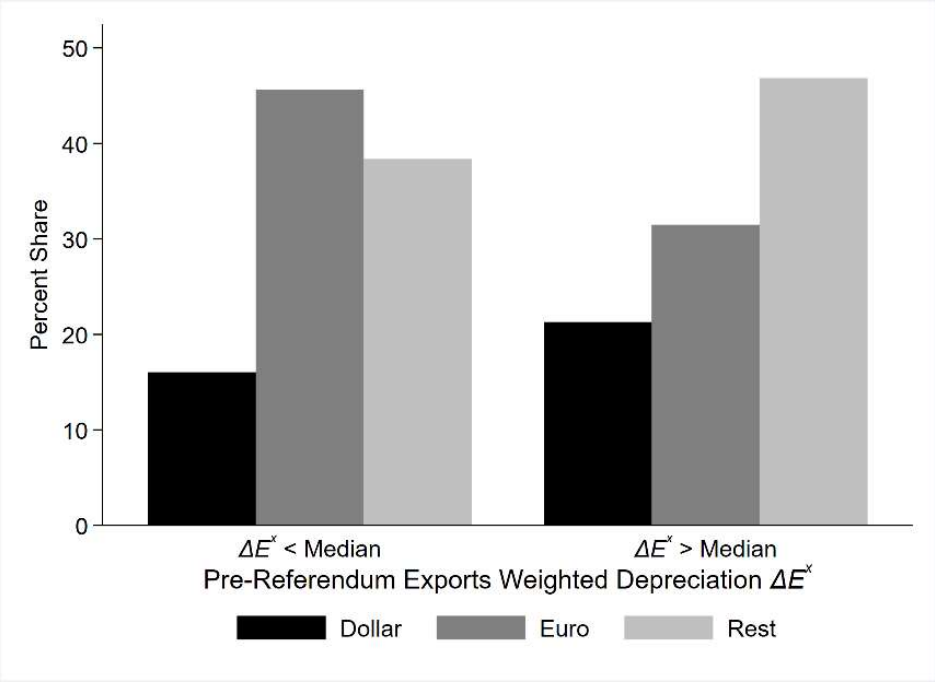
Figure 1b: Exchange Rate Movements 6 PM, June 23 2016, To 8 AM, June 24 2016



Notes: Minute by minute exchange rates from HistData (FOREX).

Figure 2: Currency Structures

Exports



Intermediate imports

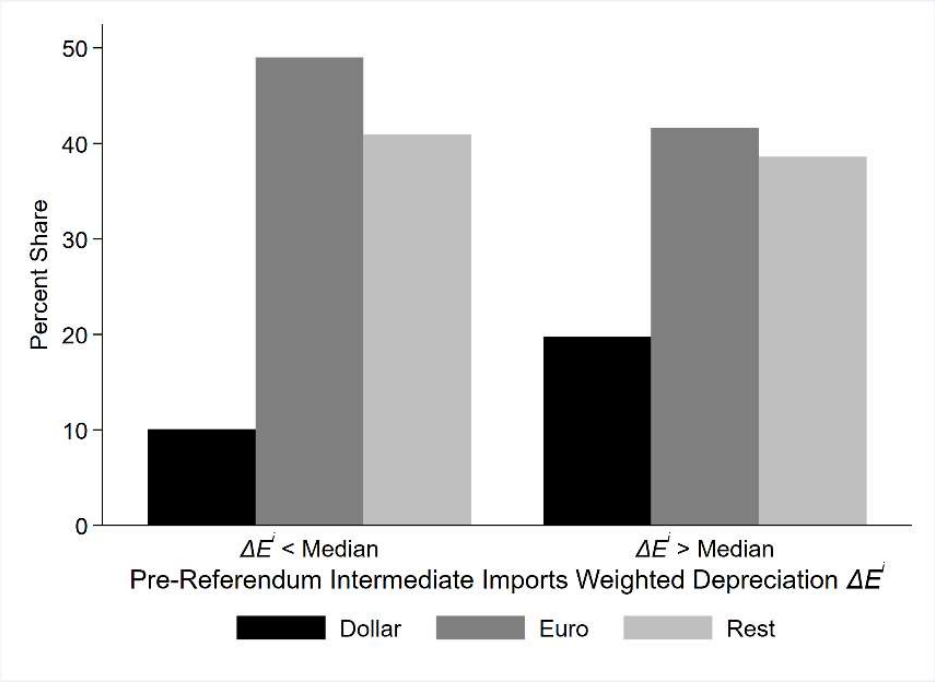


Figure 3: Scatters – Trade Prices And Depreciation

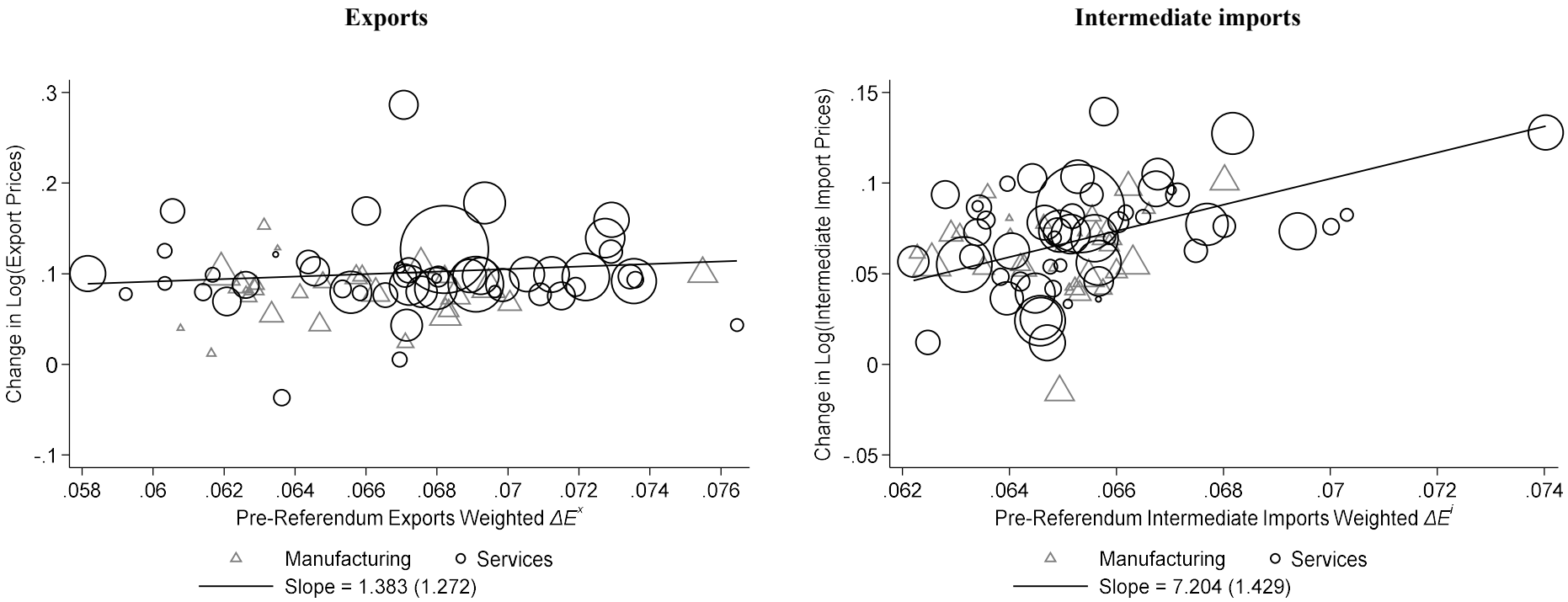
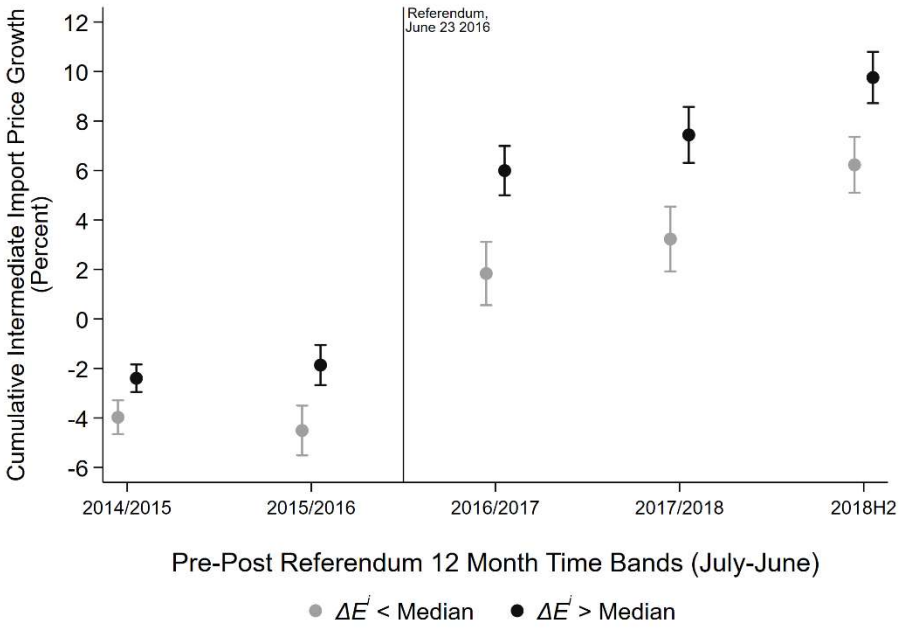


Figure 4: Event Study, Intermediate Import Prices And Intermediate Imports Weighted Depreciation

Pre/Post Referendum



Pre/Post Announcement and Referendum

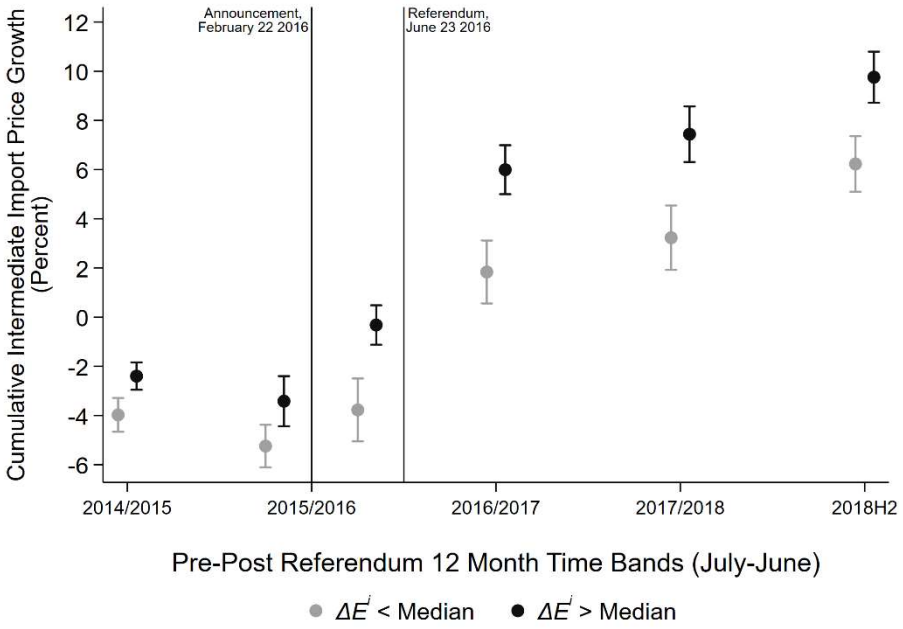


Figure 5a: Scatters – Real Wages, Hours And Employment, Exports Weighted Depreciation

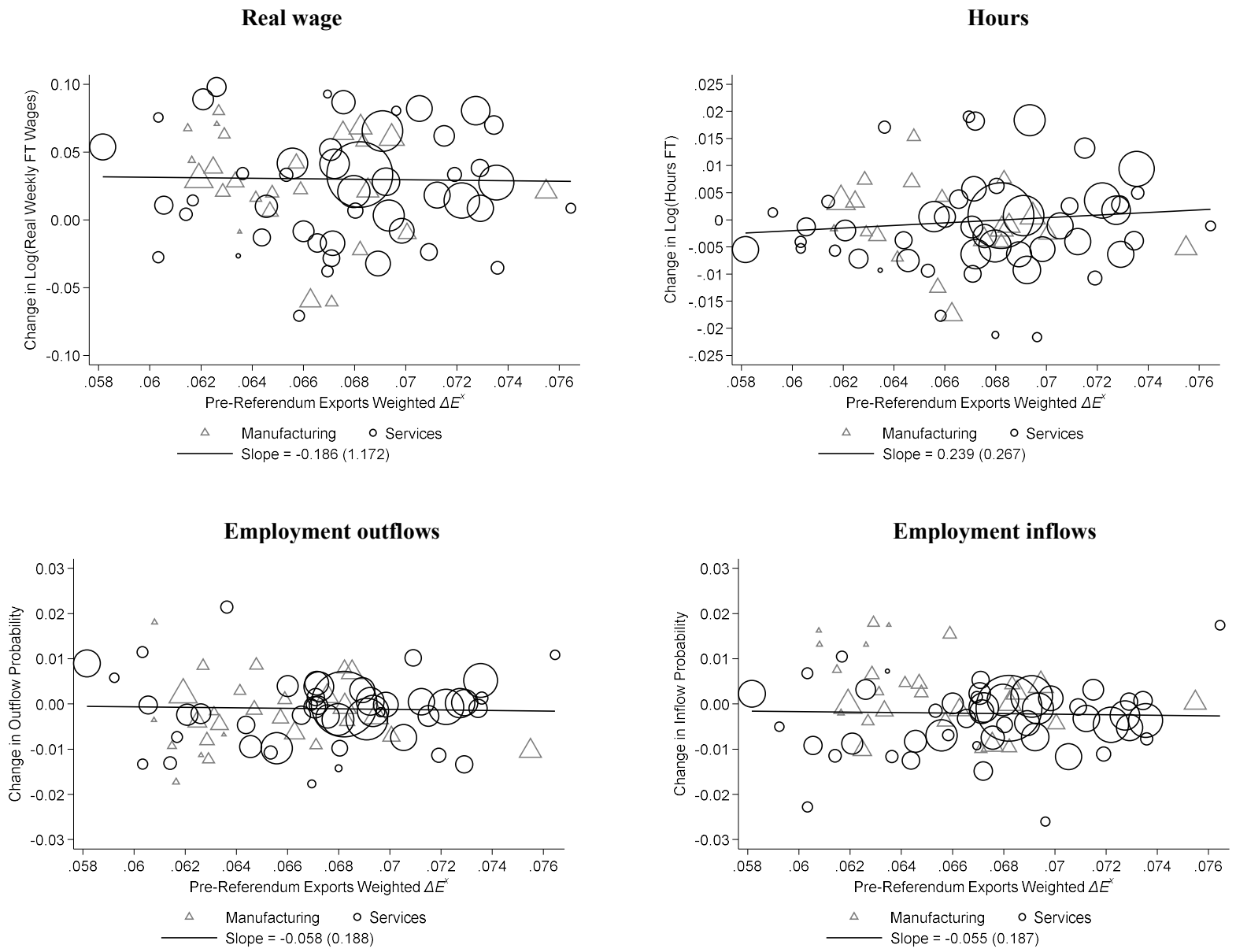


Figure 5b: Scatters – Real Wages, Hours And Employment, Intermediate Imports Weighted Depreciation

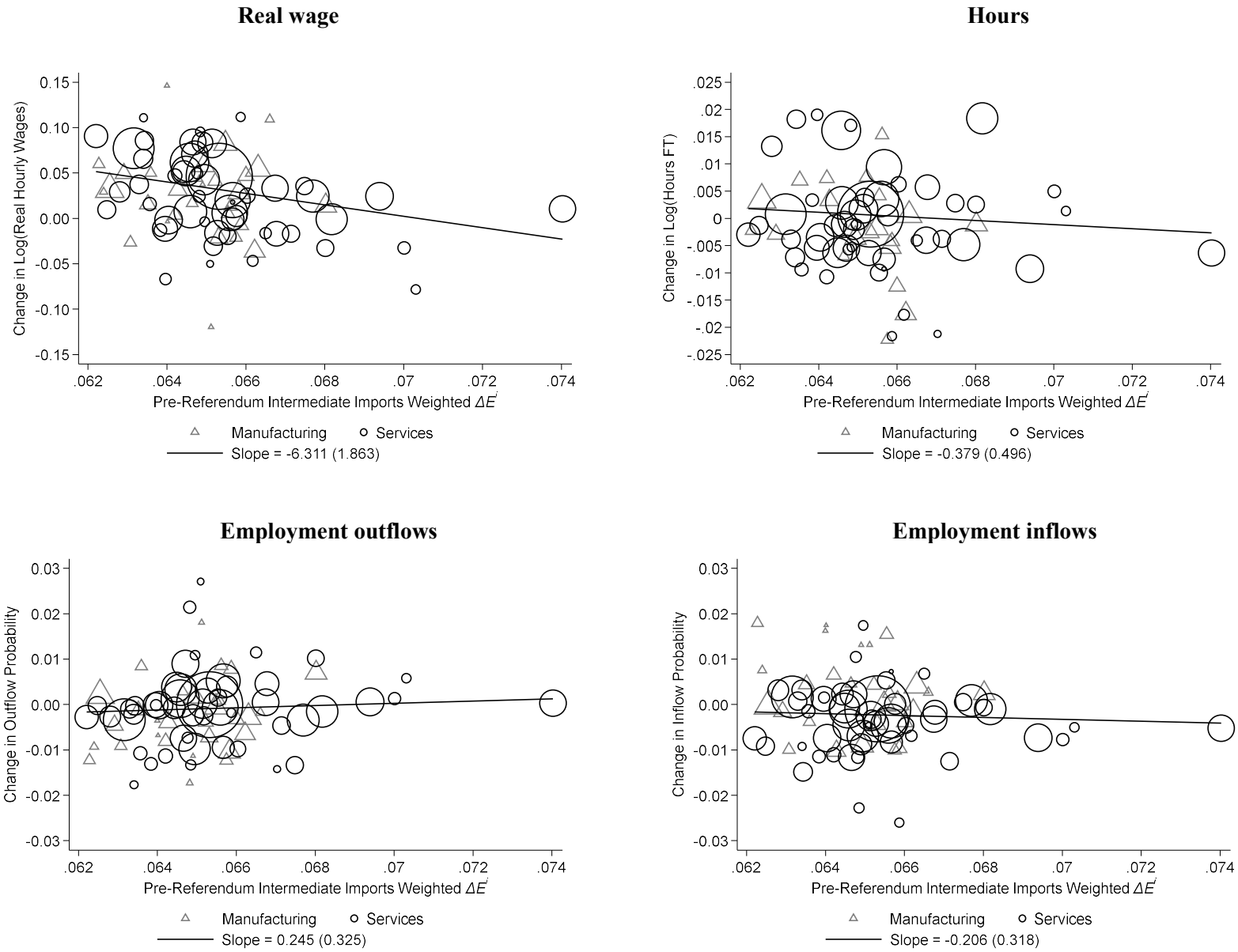


Figure 6: Event Study, Real Wages and Intermediate Imports Weighted Depreciation

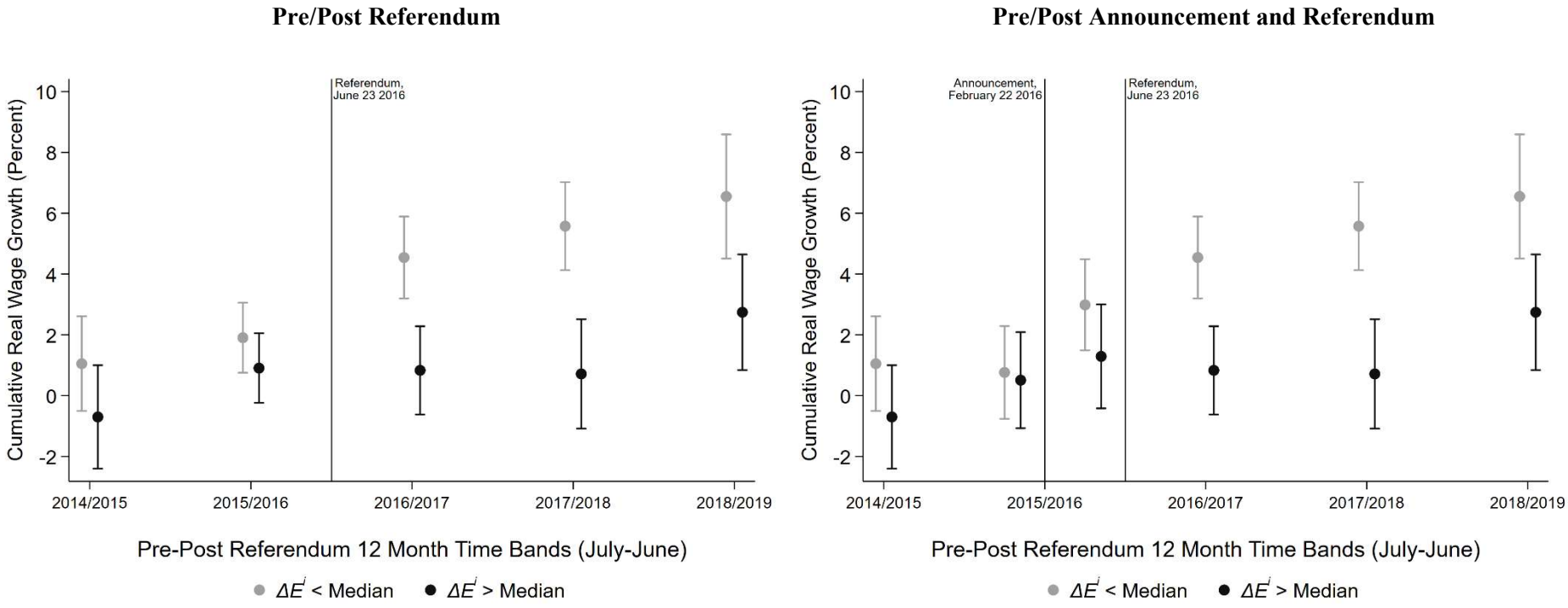


Figure 7: Post-Referendum Aggregate, Above Median and Below Median Real Wage Changes

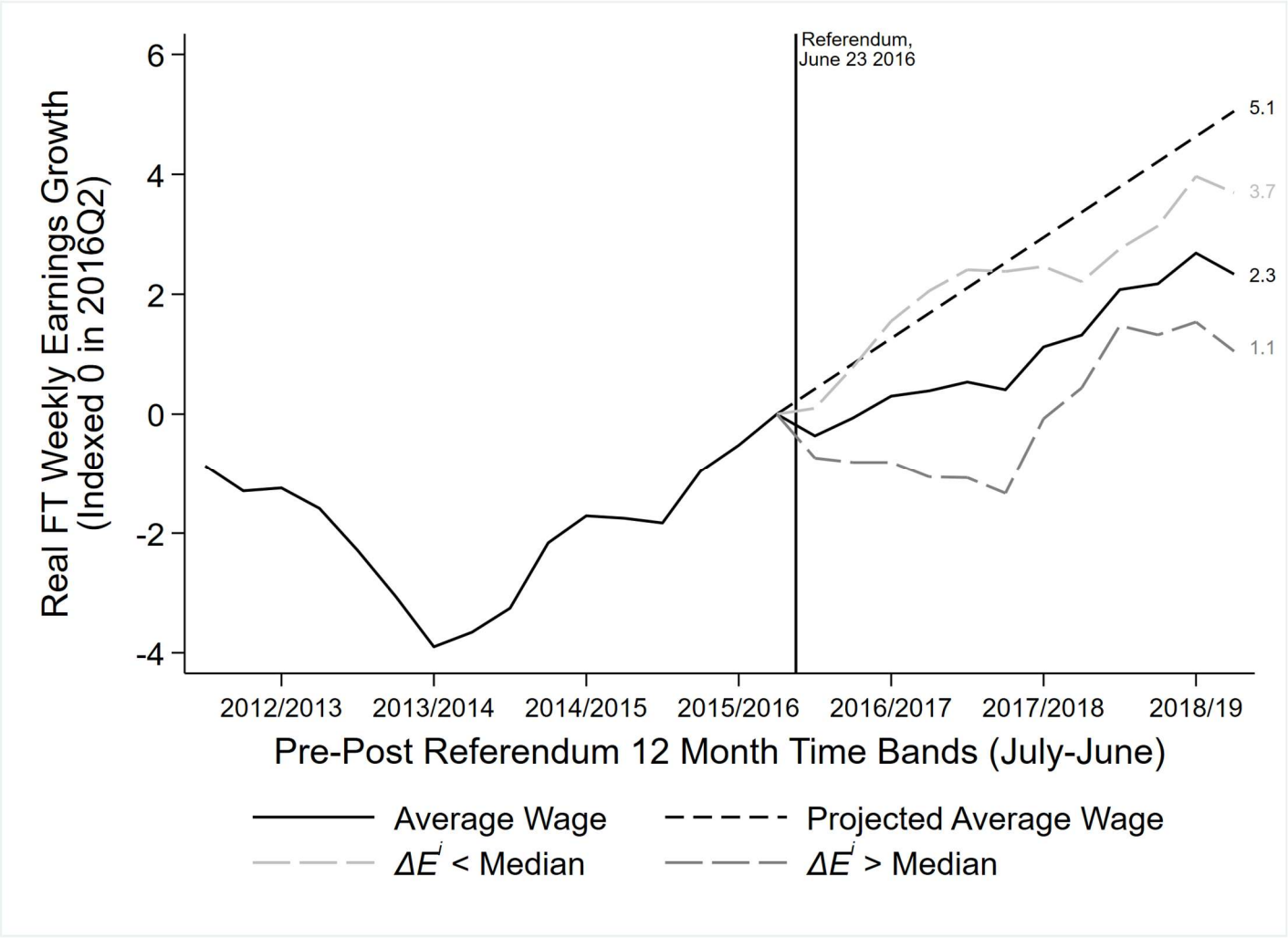


Figure 8: Post-Referendum Aggregate Real Wage Evolution

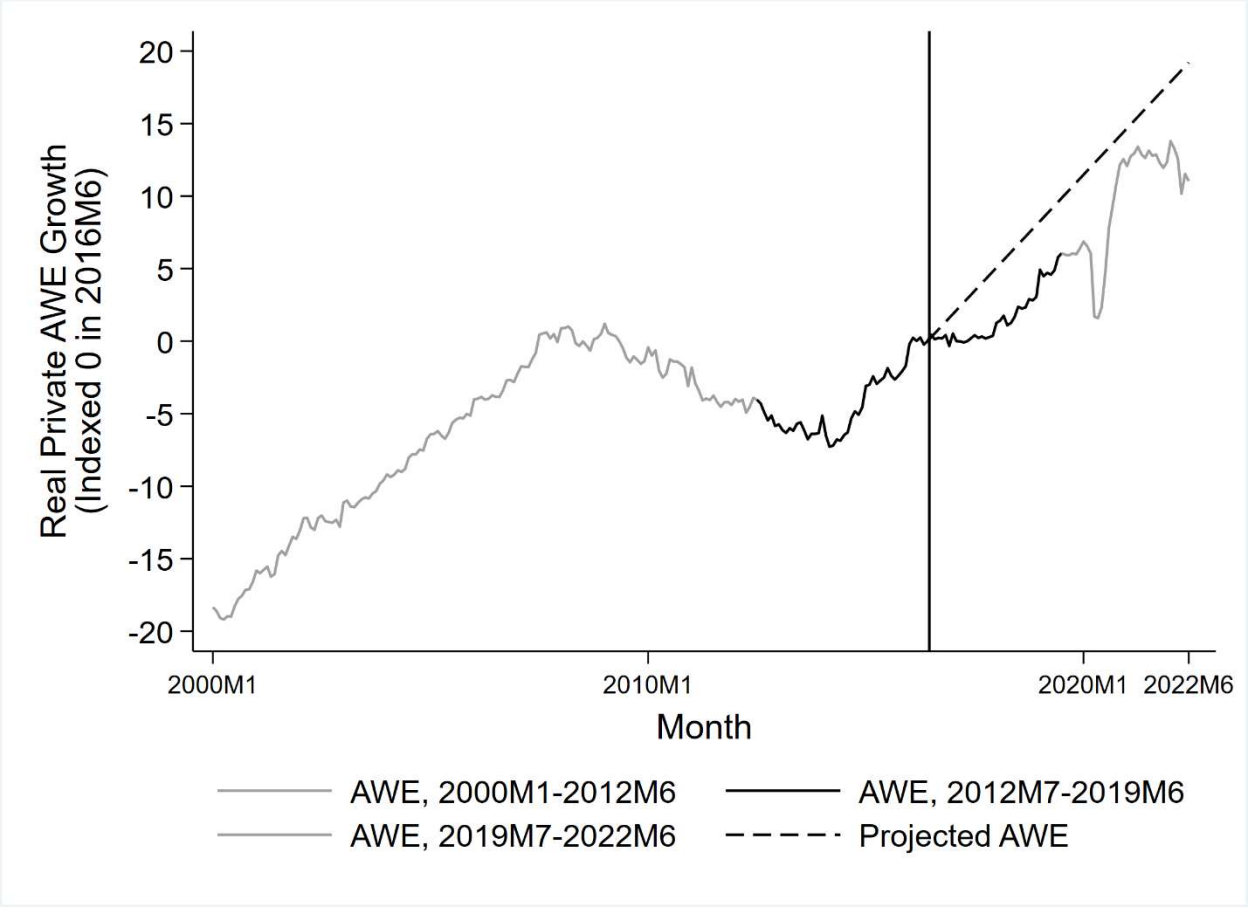


Table 1: EU Referendum Depreciation Of Sterling For Major Currencies

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	New Israeli Sheqel	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

Source: Daily spot exchange rates from Reuters Datastream.

Table 2: Top 4 and Bottom 4 Depreciation Industries

Exports, ΔE^x

Depreciation	Top 4 Industries (SIC)	Top 3 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	Scientific research and development (72)	USD (38), Euro (28), Swiss Franc (15)
7.35	Education (85)	USD (29), Euro (16), Yuan (11)
Depreciation	Bottom 4 Industries (SIC)	Bottom 3 Currencies (%)
6.03	Repair of Personal and Household Goods (95)	Euro (49), Swiss Franc (12), USD (8)
6.03	Water collection and treatment (36)	Euro (100)
5.92	Programming and broadcasting (60)	Euro (50), Zloty (10), Sweden Krona (6)
5.82	Wholesale and retail trade (45)	Euro (54), Sweden Krona (36), USD (9)

Intermediate Imports, ΔE^i

Depreciation	Top 4 Industries (SIC)	Top 3 Currencies (%)
7.40	Activities auxiliary to financial and insurance services (66)	USD (46), Euro (25), Yen (6)
7.03	Programming and broadcasting (60)	USD (54), Euro (41), Yuan (4)
7.00	Scientific research and development (72)	USD (38), Euro (31), Swedish Krona (10)
6.94	Architectural and engineering services (71)	Euro (35), USD (29), Yuan (7)
Depreciation	Bottom 4 Industries (SIC)	Bottom 3 Currencies (%)
6.25	Electricity, gas and other energy supply (35)	Euro (75), USD (8), Yuan (5)
6.24	Manufacture of 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 (12), USD (9)
6.22	Accommodation (55)	Euro (71), USD (7), Yuan (5)

Table 3: Trade Prices and Depreciation

	(1)	(2)	(3)
	Log(P^x)	Log(P^i)	Log(P^i)
A. Continuous			
Log(ΔE^x) x Post-Referendum	0.096 (0.073)		
Log(ΔE^i) x Post-Referendum		0.478 (0.120)	0.437 (0.107)
Industry and Time Dummies	Yes	Yes	Yes
Sample Size	2028	2158	2028
B. Above/Below Median			
(ΔE^x > Median) x Post-Referendum	0.108 (0.007)		
(ΔE^x < Median) x Post-Referendum	0.094 (0.008)		
(ΔE^i > Median) x Post-Referendum		0.084 (0.005)	0.084 (0.004)
(ΔE^i < Median) x Post-Referendum		0.054 (0.005)	0.058 (0.005)
Difference-in-Differences	0.014 (0.011)	0.030 (0.007)	0.026 (0.006)
Industry and Time Dummies	Yes	Yes	Yes
Sample Size	2028	2158	2028

Notes: Standard errors in parentheses, BHJ adjusted in Panel A.

Table 4: Trade Prices and Depreciation, Announcement Effects

	(1)	(2)	(3)
	Log(P^x)	Log(P^i)	Log(P^i)
A. Continuous			
Log(ΔE^x) x Post-Announcement	0.106 (0.074)		
Log(ΔE^i) x Post-Announcement		0.515 (0.133)	0.473 (0.152)
Industry and Time Dummies	Yes	Yes	Yes
Sample Size	2028	2158	2028
B. Above/Below Median			
(ΔE^x > Median) x Post-Announcement	0.098 (0.007)		
(ΔE^x < Median) x Post-Announcement	0.083 (0.009)		
(ΔE^i > Median) x Post-Announcement		0.072 (0.004)	0.073 (0.004)
(ΔE^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)
Industry Dummies	Yes	Yes	Yes
Sample Size	2028	2158	2028

Notes: Standard errors in parentheses, BHJ adjusted in Panel A.

Table 5: Trade Prices, Cost and Revenue Channels

	(1)	(2)
	Log(P^x)	Log(P^i)
Log(ΔE^x) x Post-Referendum	0.057 (0.061)	0.064 (0.046)
Log(ΔE^i) x Post-Referendum	0.285 (0.078)	0.402 (0.113)
Industry and Time Dummies	Yes	Yes
Sample Size	2028	2028

Notes: Standard errors in parentheses, BHJ adjusted.

Table 6: Real Wages, Hours And Employment

	(1)	(2)	(3)	(4)	(5)	(6)
	T = Post-Referendum			T = Post-Announcement		
A. Log(FT real weekly wage)						
Log(ΔE^x) x Post-T	-0.023 (0.071)		0.069 (0.057)	-0.040 (0.062)		0.047 (0.047)
Log(ΔE^i) x Post-T		-0.442 (0.078)	-0.486 (0.085)		-0.425 (0.053)	-0.456 (0.059)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	86108	86108	86108	86108	86108	86108
B. Log(Hours)						
Log(ΔE^x) x Post-T	0.018 (0.013)		0.024 (0.014)	0.012 (0.015)		0.018 (0.016)
Log(ΔE^i) x Post-T		-0.022 (0.024)	-0.028 (0.021)		-0.028 (0.014)	-0.032 (0.014)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	86108	86108	86108	86108	86108	86108
C. Outflow						
Log(ΔE^x) x Post-T	-0.004 (0.011)		-0.006 (0.012)	-0.002 (0.008)		-0.003 (0.009)
Log(ΔE^i) x Post-T		0.007 (0.013)	0.014 (0.013)		-0.003 (0.015)	0.003 (0.014)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	356244	356244	356244	356244	356244	356244
D. Inflow						
Log(ΔE^x) x Post-T	0.000 (0.011)		0.003 (0.012)	0.000 (0.008)		0.003 (0.009)
Log(ΔE^i) x Post-T		-0.013 (0.012)	-0.017 (0.015)		-0.009 (0.009)	-0.014 (0.011)
Industry and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	355510	355510	355510	355510	355510	355510

Notes: Standard errors in parentheses, BHJ adjusted.

Table 7: Real Wages Across The Depreciation Distribution

	(1)	(2)
	Log(FT real weekly wage)	Log(Hourly real wage)
A. Continuous		
Log(ΔE^i) x Post-Referendum	-0.442 (0.078)	-0.429 (0.069)
B. Above/Below Median		
(ΔE^i > Median) x Post-Referendum	0.014 (0.006)	0.022 (0.008)
(ΔE^i < Median) x Post-Referendum	0.048 (0.006)	0.048 (0.007)
Difference-in-Differences (Above - Below Median)	-0.034 (0.008)	-0.026 (0.010)
C. Top 4/Bottom 4		
(ΔE^i Top 4) x Post-Referendum	0.007 (0.011)	0.010 (0.009)
(ΔE^i Middle 75) x Post-Referendum	0.031 (0.005)	0.035 (0.005)
(ΔE^i Bottom 4) x Post-Referendum	0.056 (0.021)	0.060 (0.022)
Difference-in-Differences (Top 4 - Bottom 4)	-0.049 (0.024)	-0.050 (0.024)
Sample Size	86108	111600

Notes: Standard errors in parentheses, BHJ adjusted in Panel A.

Table 9: Elasticity of Real Wage to Intermediate Imports Weighted Depreciation inAdditional Specification Adaptations

Specification Adaptations: All x Post-Referendum	Real Wage Elasticity	Full Results Appendix C Table
A. Import Competition Channel		
Exports, Imports and Intermediate Imports Weighted Depreciations	-0.486 (0.089)	A2
B. Initial Trade Structure		
Intermediate Imports to Labour Costs	-0.456 (0.077)	A3
Intermediate Imports to Labour Costs x Depreciation*	-0.455 (0.141)	A3
Share of Imported Intermediates in Output	-0.449 (0.080)	A4a
Share of Imports in Intermediates	-0.450 (0.081)	A4a
Share of Exports in Demand	-0.399 (0.091)	A4b
EU Share of Intermediate Imports and EU Share of Exports	-0.472 (0.156)	A4b
C. Trade Policy		
Soft Brexit Trade Barriers (Tariffs and Services NTBs)	-0.348 (0.042)	A5
Hard Brexit Trade Barriers (Tariffs and Services NTBs)	-0.350 (0.077)	A5
Hard-Soft Brexit Trade Barriers	-0.362 (0.084)	A5
Gravity-Predicted GVA Changes from Brexit	-0.377 (0.090)	A6
Upstream Depreciation and Downstream Depreciation	-0.404 (0.083)	A6
D. Migration and FDI		
Migration Weighted Depreciation	-0.377 (0.076)	A7
Share of Migrants in Workforce	-0.433 (0.084)	A7
Share of EU Migrants in Workforce and Share of Non-EU Migrants in Workforce	-0.434 (0.094)	A7
Inward FDI Weighted Depreciation and Outward FDI Weighted Depreciation	-0.403 (0.074)	A8
Share of EU in Inward FDI and Share of EU in Outward FDI	-0.392 (0.073)	A8
E. Currency Depreciations		
7-days Brexit window	-0.396 (0.138)	A9a
15-days Brexit window	-0.344 (0.170)	A9a
Vehicle Currency Adjustment	-0.308 (0.119)	A9b
Vehicle Currency Adjustment for Exports, Imports and Intermediate Imports Weighted Depreciations	-0.322 (0.132)	A9b

Notes: * = Evaluated at the mean of Intermediate Imports to Labour Costs

Table 10: Structural Estimates For Real Wages And Intermediate Import Prices

	(1)	(2)	(3)
	All	Manufacturing	Services
A. IV			
Log(P^i)	-0.938 (0.223)	0.206 (0.401)	-1.078 (0.241)
B. Reduced Form			
Log(ΔE^i) x Post-Referendum	-0.449 (0.093)	0.078 (0.139)	-0.515 (0.099)
C. First Stage			
Log(ΔE^i) x Post-Referendum	0.479 (0.104)	0.379 (0.326)	0.478 (0.093)
F-Statistic	21.2	1.4	26.7
Industry and Time Dummies	Yes	Yes	Yes
Sample Size	79716	15587	64129

Notes: Standard errors in parentheses, BHJ adjusted.

Appendix A

Timeline

Thursday June 23, 2016:

10 PM - The last votes are cast and polling stations across the country close at the end of a day on which a record 46.5 million people were eligible to have their say. Ballot boxes are sent to 382 counting centres nationwide.

10 PM - A YouGov opinion poll released at the same time suggests Remain are on course for victory with 52% and Leave on 48%.

10-15 PM - Ukip's Nigel Farage concedes the Brexit campaign may be beaten and Remain "will edge it" - but promises "Ukip and I are going nowhere".

10-30 PM - Sterling surges against the US dollar on the back of the favourable opinion poll for Remain and Farage's comments, rocketing to 1.5 dollars, its strongest performance in 2016.

11-25 PM - Gibraltar is the first area to declare, with a predictable landslide for Remain at 96% of the vote.

Friday, June 24, 2016:

12-04 AM - The first big result is declared, with a narrow win in Newcastle for Remain with 50.7% against Leave on 49.3%. It was an expected win in Newcastle, but not by the margin many suspected.

12-20 AM - Sunderland votes to Leave by a significant margin, with 61% in the Tyne and Wear town in favour of Brexit compared with 39% backing Remain.

12-21 AM - Sterling instantly tumbles against the US dollar as jitters over a possible swing to Leave wipe earlier gains off the pound, with a near 4.7% drop - greater than the Black Wednesday crash in 1992.

1-30 AM – People started to sense that Leave would win, and it showed in their Google searches.

1-55 AM - The City of London count is announced as vote to Remain in the EU.

2-01AM - Swansea votes to Leave, with 61,936 backing a Brexit against 58,307 voting to remain.

2-17 AM - Nigel Farage, who earlier said he sensed Remain would take victory, tweeted that he is "so happy with the results in North East England".

2-30 AM – Remain went back ahead for the first time since the Sunderland announcement after big wins in Lambeth and Glasgow.

3-44 AM – But over the next hour the Leave campaign enjoyed gain across Wales, Northern Ireland, Yorkshire and the Midlands to dwarf the majority of Remain's support in Scotland and London.

3.27am - Sheffield comes out for Leave, backing an exit from the EU by little over 5,000 votes.

3-51 AM - Leave's lead stretches to 500,000 votes as results pass 200 out of 382.

3-57 AM - Sterling's precipitous slide against the dollar continues after victories consolidate a lead for Leave. Trading figures show the pound at 1.37 dollars, down from a high last night of over 1.5 dollars.

6-02 AM - The Leave campaign officially passes the estimated winning post 16,763,272 in the EU referendum.

7-01 AM - The Bank of England says it will take "all necessary steps" to ensure monetary and financial stability in the wake of the Brexit vote.

7-04 AM - The final count of the EU referendum shows Leave won 51.9% of the total vote to Remain’s 48.1%.

8-08 AM - The FTSE 100 falls more than 7% within minutes of the markets opening following Britain’s decision to leave the EU.

8-50 AM - Bank of England governor Mark Carney says "some market and economic volatility can be expected" in the wake of the Brexit vote, but the Bank is well prepared. It also has £250bn to support the UK economy.

Appendix B

Data Description

Exchange Rates

The minute-by-minute exchange rates shown in Figures 1a and 1b for a selected bundle of currencies against sterling are from HistData.

For the depreciation measures, daily exchange rates are from Reuters Datastream and refer to the spot price at 4pm UK time.[19] In the few cases for which no exchange rate against the pound was available, suitable conversion is based on its reported dollar exchange rate. Mapping of currencies to country of use is based on the official UN Operational Currency correspondence. The final dataset is composed of 234 countries[20] and 126 currencies. After trimming currency shares of below 1 percent in an industry, 102 countries and 77 currencies are used to construct the exports weighted depreciation measure and 74 countries and 51 currencies are used to construct the intermediate imports weighted measure.

To account for vehicle currency invoicing, the re-defined exchange rate measure changes from the source country depreciation ΔE_s to a weighted average of the source currency and a vehicle currency: $\Delta E^i_{o,vehicle} = \sum_i \sum_s S_{iso}\left(S^{PCP}_{USA}\Delta E_s + \left(1 - S^{PCP}_{USA}\right)\Delta E_v\right)$ where the weight S^{PCP}_{USA} is the share of producer currency pricing in UK imports. Note that local currency pricing would have a depreciation of zero so it is not included. The invoicing shares are taken from Chen et al. (2021) for China, East and Southeast Asia, Eurozone, Europe excluding the EU, India, United States, Other Americas and Others. Japan is proxied with the United States shares. Chen et al. find 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.[21]

Trade Prices

Quarterly time-series of goods import and export trade values (current price measure) and volumes (chained volume measure) are made available by ONS for 2 digit UK SIC industries in sections A, B and C: Agriculture, Forestry and Fishing; Mining and Quarrying; and Manufacturing. Those are supplemented by services trade values and volumes for 14 aggregates of services product-industry: Manufacturing and Maintenance, Sea Transport, Air Transport, Other Transport, Postal & Courier, Travel, Construction, Insurance, Financial, Intellectual Property, Telecommunications, Computer & Information, Other Business Services, Personal, Cultural & Recreational and Government. Import Price Indexes (IPI) and Export Price Indexes (EPI) are calculated as the weighted average of the product-specific IPIs and EPIs after mapping them to their industries of export and import use.

Import and export flows are collected from the annual import values for 2015 taken from UN COMTRADE for goods and from the International Trade in Services Survey (ITIS) of the ONS for services. For services and sectors that are not covered by the ITIS, trade flows by country and product are obtained through freedom of information requests to the ONS for the same time period.

The International Trade in Services Survey is a unique source of data on international trade in services. ITIS collects yearly data on import and export services trade at firm level for a range of 52 services products by trade partner. ITIS includes around 16,000 businesses each year, including a panel of core contributors and larger firms. The sampling inclusion criteria ensures that firms reporting a total value of services trade above a certain threshold are surveyed in following years. Some sectors are not part of the sample of ITIS: financial, transport, travel and higher education sectors are not sampled. However, trade in products produced in these sectors and imported by UK firms in other sectors will be recorded: for example, records of a UK based R&D firm that imports financial service products from France will be present. The focus

[19] According to Reuters Datastream, the WM Refinitiv Closing Spot rates are fixings calculated by Refinitiv based on Refinitiv Matching, EBS, Currenex and Refinitiv multi-contributor data over a five minute fixing window around 16:00 in London. This time reflects the middle of the 'global day' and the time of highest liquidity in the foreign exchange market. Daily updates are published in Refinitiv Datastream product series by 16:45 each day. The rates are based on snapshots of U.S. dollar market data, or Euro for a subset of the currencies. The Euro subset includes Czech Koruna, Danish Krone, Hungarian Forint, Norwegian Kroner, Polish Zloty, Romanian Leu, Swedish Krona, and Swiss Franc. The snapshots are taken from the Refinitiv Market Data system during the five minute fixing window around 16:00 and median rates are then calculated for each currency. This is done independently for bid and offer rates. When the rates have been validated WMR derive cross rates to GBP and EUR (or GBP and USD). Mid rates are calculated as the arithmetic mean of bids and offers.

[20] 5 of these countries correspond to unallocated residual groups by continent: Africa, America, Asia, Europe and Oceania.

[21] They also find further using detailed customs data for non-EU transactions that UK exports are much less likely to be priced in vehicle currencies than imports (25% compared to 55% share), so that the lack of export price passthrough is not driven by invoicing. Even when the vehicle currency is used, unit values of intermediate imports respond systematically but export responses are mostly erratic and insignificant.

of the survey is on producer services, particularly, on the import flows which in the case of our analysis is of most relevance in studying the intermediate import cost channel. The remainder uncovered services and sectors are recorded separately and obtained from the ONS.

Trade barriers data for tariffs is from WITS and from the OECD for services trade restrictiveness indices for 2015. Industry-level trade barriers are arrived at in the same way as the depreciation measures with country trade shares as weights. Correspondence between COMTRADE HS-2012 (Harmonized Code 2012) product codes and UK SIC 2007 industry codes was obtained using a two-step crosswalk procedure. Firstly, we use Peter Schott's HS-2012 to NAICS 2012. Secondly we map NAICS 2012 to NACE 2 using the Eurostat official correspondence table. ITIS is matched directly to the UK firm register hence identifying the industry of activity of the firm exporting or importing the services.

Input-Output Tables

Import use of services is from the 2015 ITIS microdata which identifies the using industry. Data on import use for goods and uncovered services or sectors is from the import use tables (product by industry) of the ONS for 2015. Intermediate import shares, intermediate shares and export shares in demand are from the 2015 IO tables published by the ONS.

Labour Force Survey Data

Labour force data refer to all employed individuals aged 18 to 65 working in the private sector and not in fulltime education, and are taken from the UK Quarterly Labour Force Survey (QLFS) 2012Q3 to 2019Q2.

Wages are defined for full-time private sector workers, based upon the wage questions asked in quarter 1 of the QLFS (Quarter 5 wage responses are not included to avoid attrition bias). Hours worked is the weekly hours for private sector workers, including part-time workers. The focus is on fulltime workers because of the well-known concerns over measurement error in wages of part-time workers, though we later also examine hourly wages for all workers.

Top-coded wages in the QLFS are adjusted using the mean weekly wages above the LFS top-coding threshold by sex-region-year cells from Annual Survey of Hours and Earnings (ASHE). When measuring hourly wages, we use directly reported hourly rates by individuals in LFS, if no hourly rate is reported then the hourly wage is calculated as the ratio between weekly wages and total weekly hours worked. The hourly wages are censored at the lowest UK minimum wage (the minimum wage applicable to workers under 18 years of age in the relevant quarter). Wage measures are deflated to be expressed in real terms using the Consumer Prices Index including owner occupiers' housing costs (CPIH). For some of the aggregate analysis the monthly Average Weekly Earnings data derived from the Monthly Wage and Salaries Survey are used, again with the wage measures deflated by CPIH.

The QLFS interviews the same individual for 5 consecutive quarters, so inflows of individuals into an industry and outflows of individuals from an industry can also be computed. An inflow is a worker who enters the industry after having been employed in a different industry or having been unemployed or inactive in the previous quarter. The inflow rate is defined as the weighted number of inflows divided by the employment count in the previous quarter. Similarly, an outflow is a worker who leaves the industry to either work in a different industry or to become unemployed or inactive in the next quarter. The outflow rate is defined as the weighted number of outflows divided by the employment count in the current quarter.

Industry Classification

The industry classification follows the UK 2007 Standard Industrial Classification (SIC) which is based on the International Standard Industrial Classification of All Economic Activities (ISIC) Rev 4 and NACE Rev 2. We exclude section T "Activities of households as employers; Undifferentiated goods and services-producing activities of households for own use" and section U "Activities of extraterritorial organisations and bodies" due to their small samples. Additionally, to avoid small sample measurement errors, we follow ONS official statistics and aggregate industry divisions 6 - Extraction of crude petroleum and natural gas and 7- Mining of metal ores, and 11 - Manufacture of beverages and 12 - Manufacture of tobacco products into two aggregate industries (6&7 and 11&12). As a result of these sample restrictions and aggregations the number of industries used in analysis totals 83 distinct industries.

Migrant and FDI Shares

Migrant shares are calculated from the QLFS for 2013-2015 based on industry of the main job and country of birth. FDI shares are calculated from the Annual Inquiry into Foreign Direct Investment (AFDI) microdata of the ONS for 2015.

Business expectations

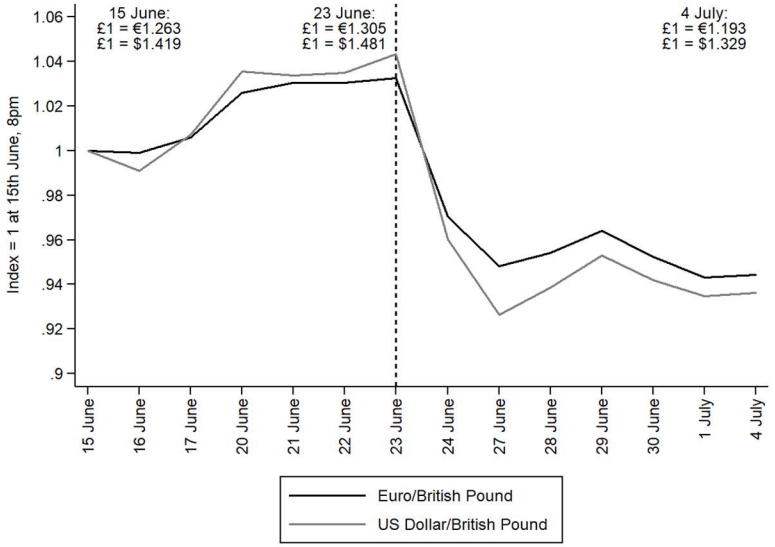
The Confederation of British Industry (CBI) is a UK business organisation that represents 190,000 businesses in total and whose trade associations account for one third of private sector employment. It undertakes monthly and quarterly surveys of its members and non-members in four broad industrial groupings: Industrial Trends Survey (ITS); Service Sector Survey (SSS); Financial Services Survey (FSS); Distributive Trades Survey (DTS). The quarterly surveys have larger sample sizes and greater question coverage and are used in this paper for the period 2012 Q3 to 2019 Q2. The quarterly ITS takes place in January, April, July and October; the quarterly SSS and DTS in February, May, August and November; and the quarterly FSS in March, June, September and December. The following question is consistently asked in three of the four surveys, the ITS, SSS and FSS: "Are you more, or less optimistic than you were three months ago about the overall business situation in your sector?". Three responses are permitted in a tick box set up: More; Same; Less. Coverage compared to the analysis of the rest of the paper is reduced, because the DTS does not have a comparable question on optimism and because the CBI does not survey some industries (notably in agriculture, mining, waste recycling, construction and largely public sector industries). The answers to the question are used to determine changes in business expectations, which Bloom et al. (2019) show is a better measure of economic uncertainty during this episode. They use the Bank of England Decision Makers' Panel (DMP) to measure uncertainty in a similar way, but the DMP does not have pre-referendum observations so cannot be used for our pre/post referendum analysis.

Appendix C:

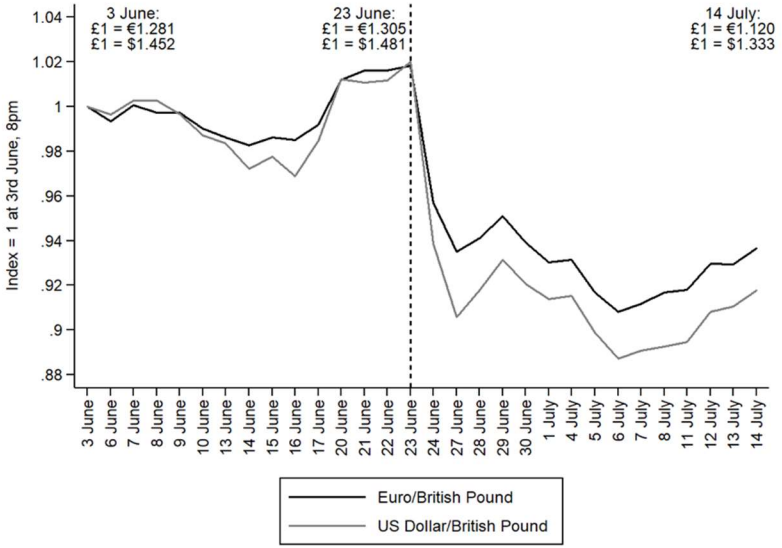
Additional Tables and Figures

Figure A1: Exchange Rate Movements over Time

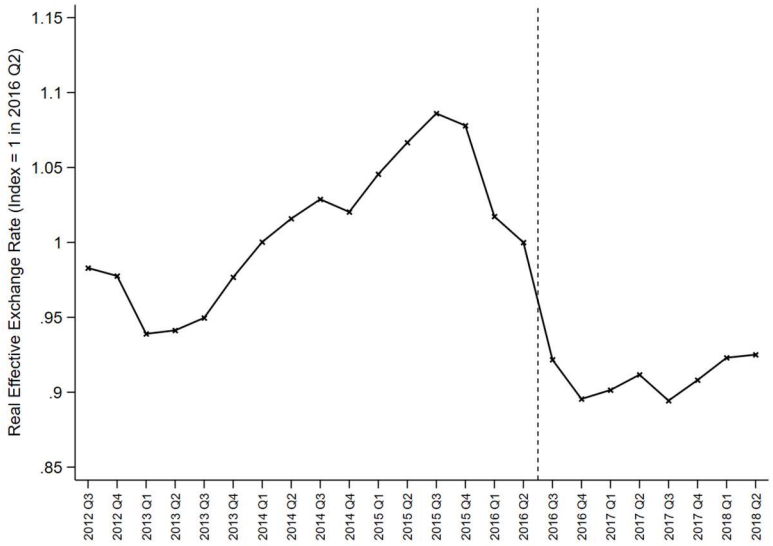
7 days window



15 days window

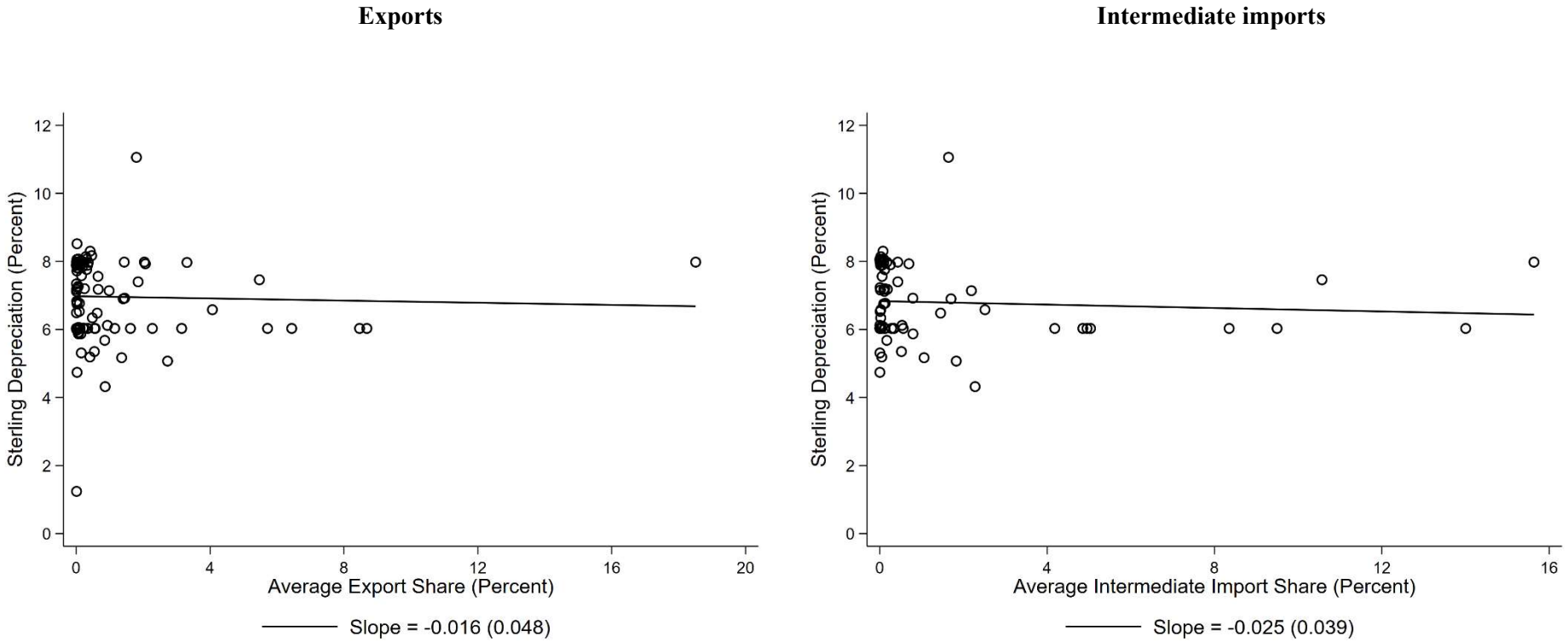


2012Q3 to 2018Q2



$$\text{Real effective exchange rate: } \log(\text{REER}_{qt}) = \underset{(0.017)}{-0.101}\text{Post}_{qt} + \varepsilon_{qt}$$

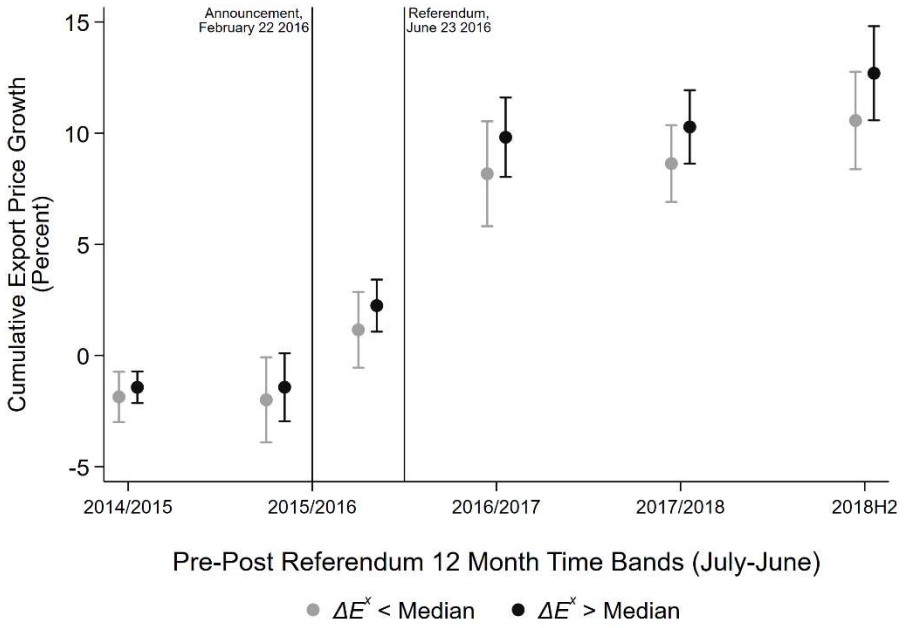
Figure A2: Currency Depreciation Shocks and Average Trade Shares by Country



Notes: The depreciation shocks (shifts) are measured by country (and respective currency) specific sterling depreciations, and trade shares are the average country-level pre-referendum at the country level as per BHJ (2022).

Figure A3: Event Study, Export Prices And Exports Weighted Depreciation

Pre/Post Referendum



Pre/Post Announcement and Referendum

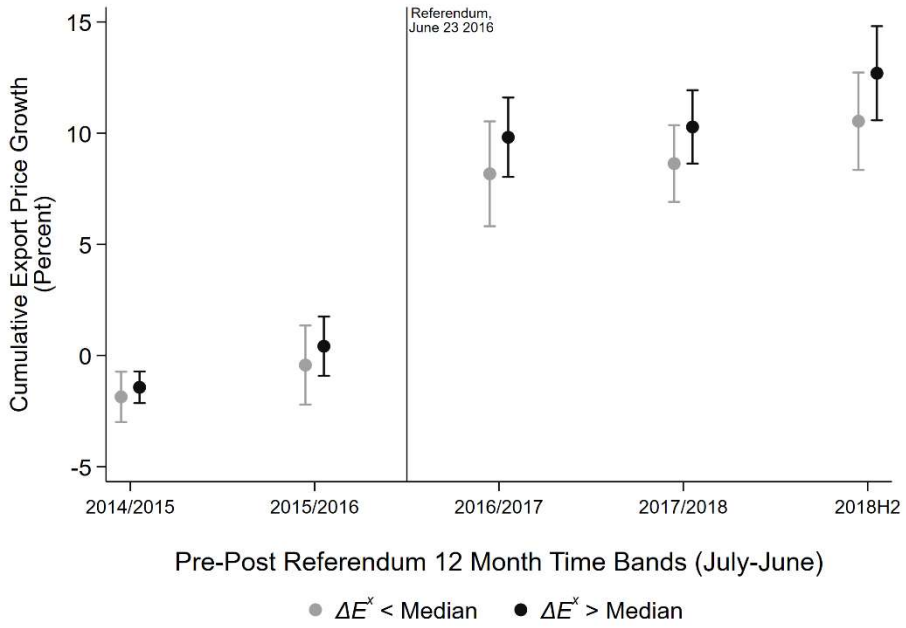
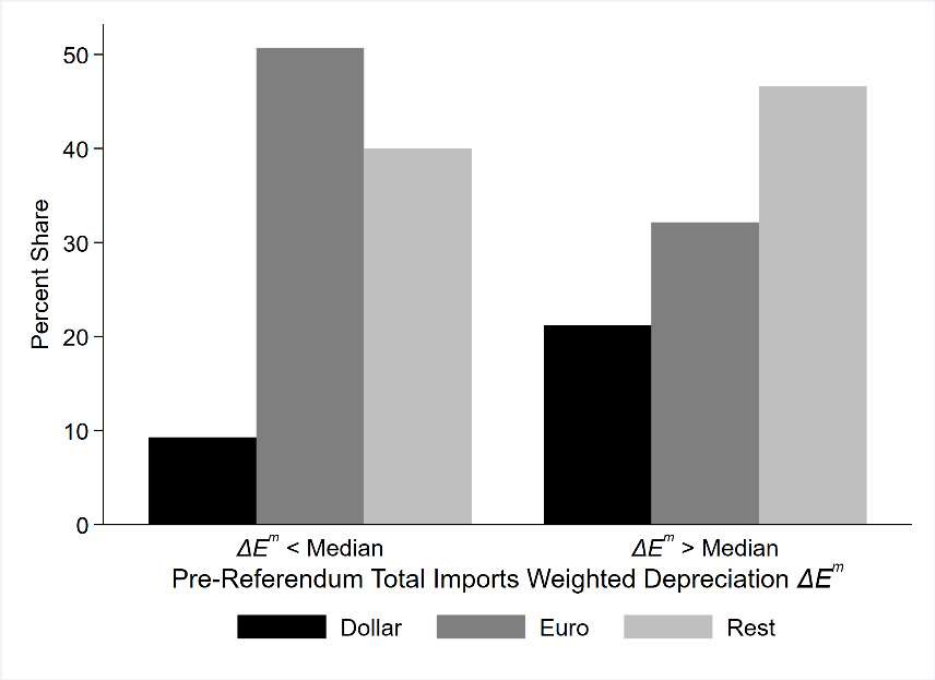


Figure A4a: Import Competition, Currency Structure and Import Prices

Currency Structure



Import Prices

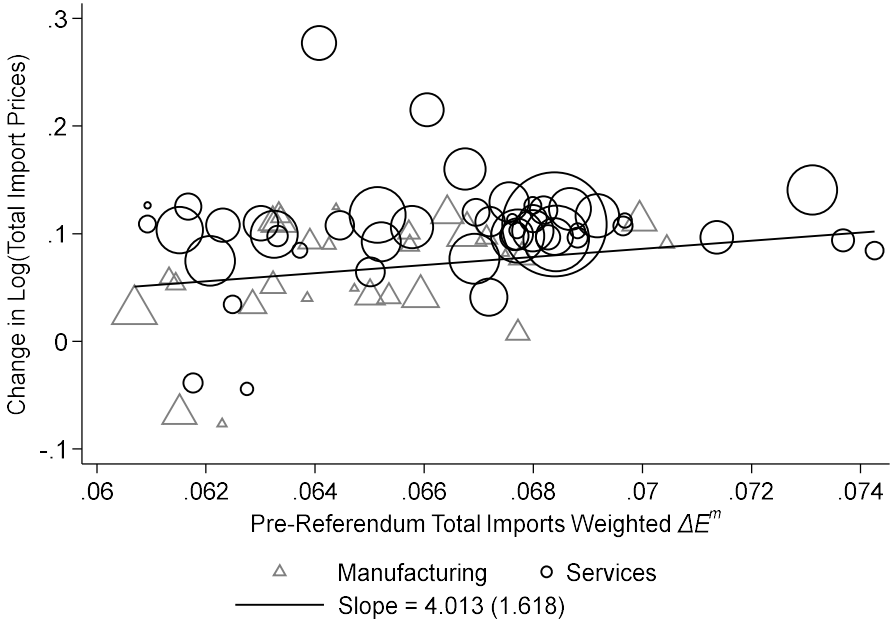


Figure A4b: Scatters – Real Wages, Hours And Employment, Imports Weighted Depreciation

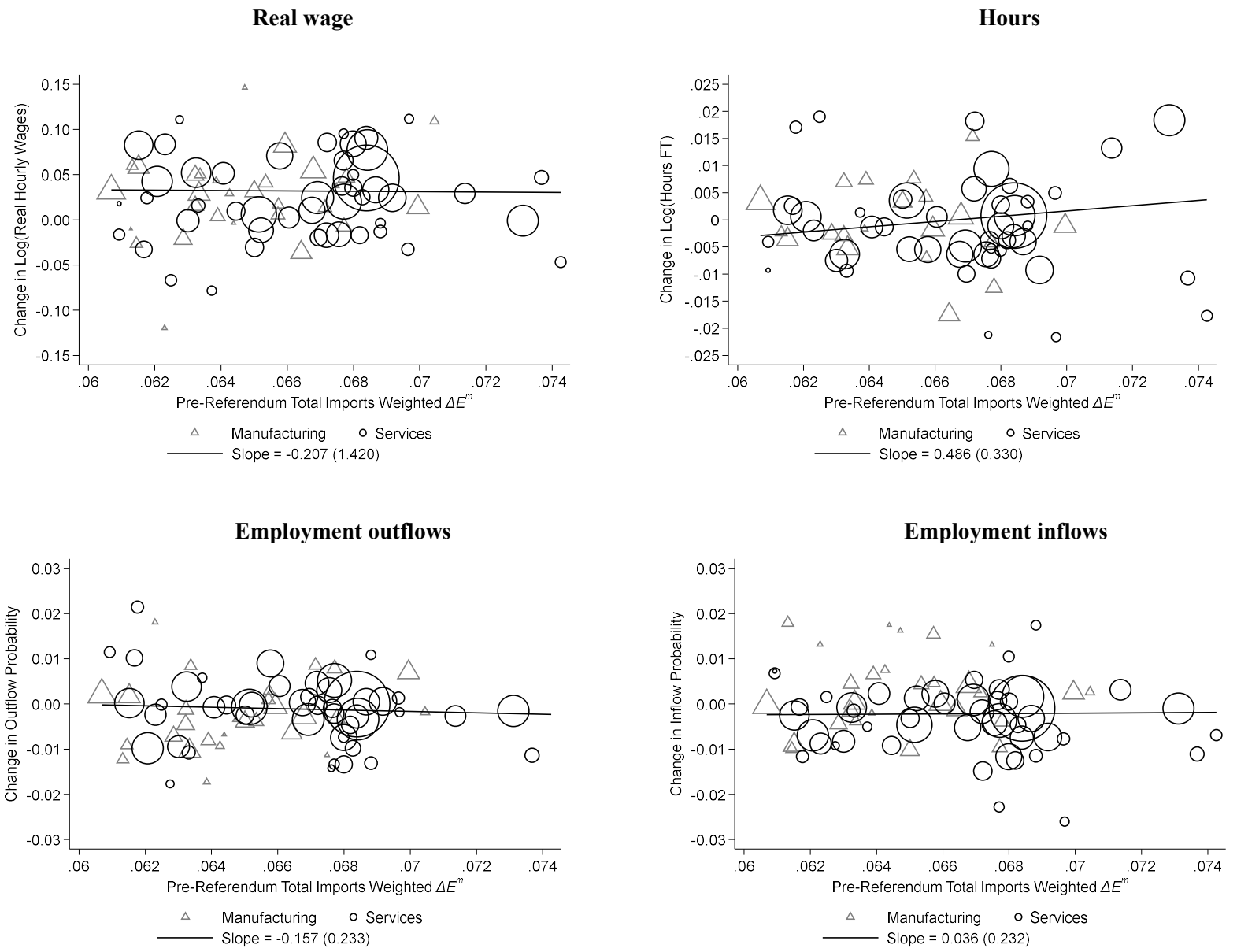
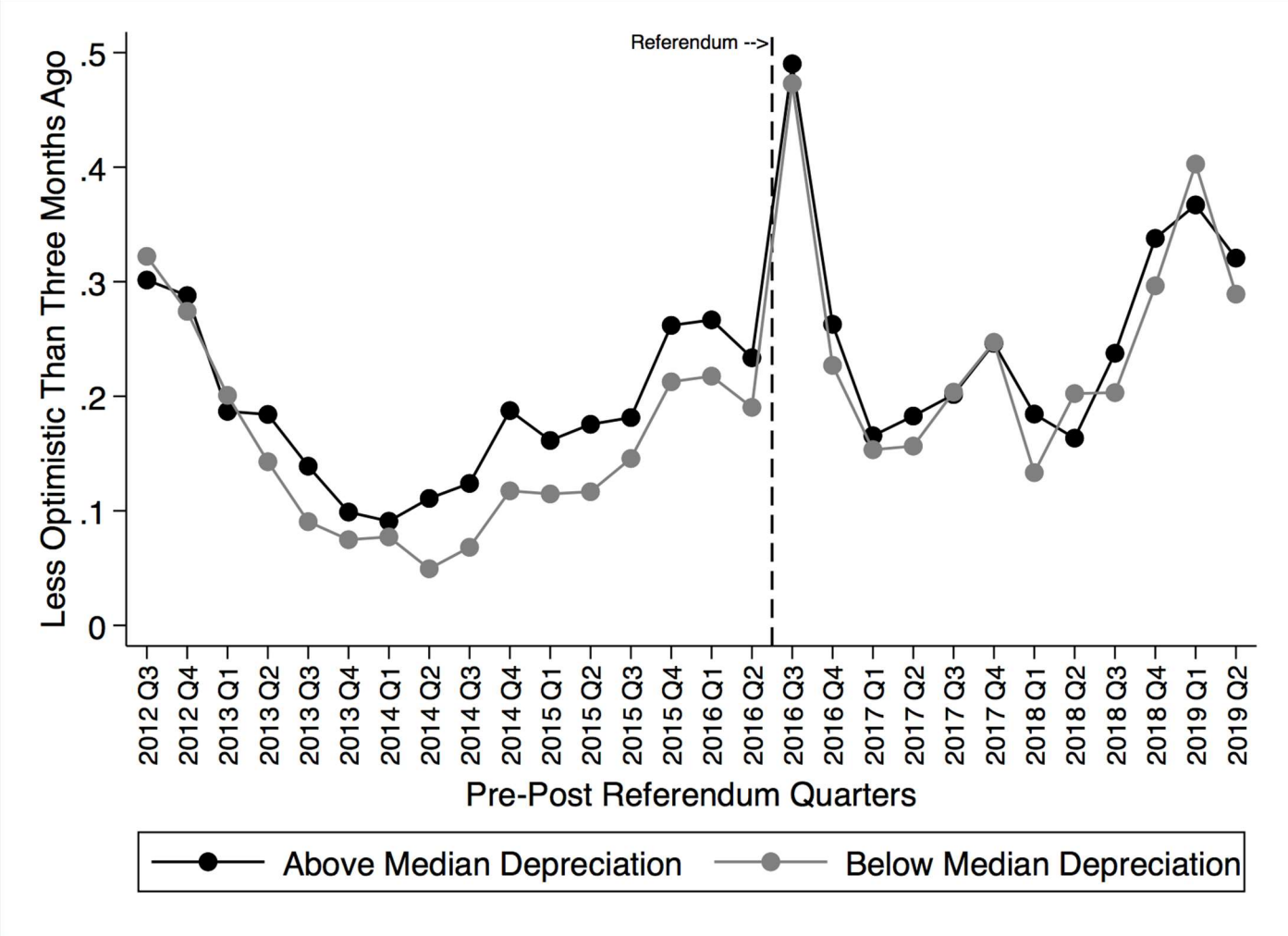


Figure A5: Event Study, Business Expectations and Intermediate Imports Weighted Depreciation



Notes: The y-axis plots the share of firms with less optimistic expectations of business conditions by above/below median intermediate imports weighted depreciation for their main industry. Source: Quarterly surveys of the Confederation of Business and Industry (CBI).

Table A1: EU Referendum Depreciation Of Sterling For Major Currencies

Country	Currency	Depreciation (Percent)	
		Spot	Forward 1 year
Japan	Japanese Yen	11.1	10.9
United States	US Dollar	8.0	8.5
Saudi Arabia	Saudi Riyal	8.0	7.7
Hong Kong	Hong Kong Dollar	7.9	7.7
Thailand	Thai Baht	7.6	7.4
China	Chinese Yuan	7.5	7.3
Singapore	Singapore Dollar	7.4	7.1
Taiwan	Taiwan Dollar	7.2	7.1
Russia	Russian Ruble	7.2	6.8
India	Indian Rupee	7.1	7.0
New Zealand	New Zealand Dollar	7.1	7.0
Australia	Australian Dollar	6.9	6.7
Canada	Canadian Dollar	6.9	6.7
Israel	New Israeli Sheqel	6.8	6.6
Switzerland	Swiss Franc	6.6	6.9
Turkey	Turkish Lira	6.5	6.1
Malaysia	Malaysian Ringgit	6.3	6.2
Denmark	Danish Krone	6.1	6.0
Euro Zone	Euro	6.0	5.9
Czech Republic	Czech Koruna	5.9	5.7
South Korea	Korean Won	5.7	5.5
South Africa	South African Rand	5.3	5.0
Hungary	Hungarian Forint	5.2	5.0
Norway	Norwegian Krone	5.2	5.0
Sweden	Swedish Krona	5.1	4.9
Poland	Polish Zloty	4.3	4.2

Source: Daily spot and forward exchange rates from Reuters Datastream.

Table A2: Real Wages With All Depreciations

	(1)	(2)
A. Log(FT real weekly wage)		
Log(ΔE^x) x Post-Referendum		0.069 (0.060)
Log(ΔE^m) x Post-Referendum	-0.072 (0.073)	-0.001 (0.029)
Log(ΔE^i) x Post-Referendum		-0.486 (0.089)
Industry and Time Dummies	Yes	Yes
Sample Size	86108	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A3: Real Wages and Initial Intermediate Import Structure

	(1)	(2)
A. Factor Shares		
Log(ΔE^i) x Post-Referendum	-0.456 (0.077)	-0.451 (0.119)
$(Intermediate\ Import\ Costs/Labour\ Costs)_o$ x Post-Referendum	-0.005 (0.008)	-0.047 (0.822)
$(Intermediate\ Import\ Costs/Labour\ Costs)_o$ x Log(ΔE^i) x Post-Referendum		-0.015 (0.299)
Industry and Time Dummies	Yes	Yes
Sample Size	86108	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A4a: Real Wages and Initial Trade Structure

	(1)
A. Share of Imported Intermediates in Output	
Log(ΔE^i) x Post-Referendum	-0.449 (0.080)
Share of Imported Intermediates in Output x Post-Referendum	-0.022 (0.053)
Industry and Time Dummies	Yes
Sample Size	86108
B. Share of Imports in Intermediates	
Log(ΔE^i) x Post-Referendum	-0.450 (0.081)
Share of Imports in Intermediates x Post-Referendum	-0.030 (0.037)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A4b: Real Wages and Initial Trade Structure

	(1)
A. Share of Exports in Demand	
Log(ΔE^i) x Post-Referendum	-0.399 (0.091)
Share of Exports in Demand x Post-Referendum	-0.017 (0.022)
Industry and Time Dummies	Yes
Sample Size	86108
B. Share of EU Trade	
Log(ΔE^i) x Post-Referendum	-0.472 (0.156)
EU Share of Intermediate Imports x Post-Referendum	0.005 (0.040)
EU Share of Exports x Post-Referendum	-0.029 (0.018)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A5: Real Wages and Trade Policy

	(1)
A. Soft Brexit	
Log(ΔE^i) x Post-Referendum	-0.348 (0.042)
Intermediate Import Goods Tariffs x Post-Referendum	2.878 (1.350)
Export Goods Tariffs x Post-Referendum	1.375 (0.583)
Intermediate Import Services NTB x Post-Referendum	-0.498 (0.188)
Export Services NTB x Post-Referendum	0.053 (0.156)
Industry and Time Dummies	Yes
Sample Size	86108
B. Hard Brexit	
Log(ΔE^i) x Post-Referendum	-0.350 (0.077)
Intermediate Import Goods Tariffs x Post-Referendum	1.403 (0.338)
Export Goods Tariffs x Post-Referendum	-0.143 (0.081)
Intermediate Import Services NTB x Post-Referendum	-0.364 (0.199)
Export Services NTB x Post-Referendum	0.327 (0.173)
Industry and Time Dummies	Yes
Sample Size	86108
C. Hard-Soft Brexit	
Log(ΔE^i) x Post-Referendum	-0.362 (0.108)
Hard-Soft Intermediate Import Goods Tariffs x Post-Referendum	1.557 (0.327)
Hard-Soft Export Goods Tariffs x Post-Referendum	-0.152 (0.088)
Hard-Soft Intermediate Import Services NTB x Post-Referendum	0.188 (0.336)
Hard-Soft Export Services NTB x Post-Referendum	0.139 (0.235)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A6: Real Wages and Sectoral Spillovers

	(1)
A. Gravity Model Predicted Sectoral GVA Change from Brexit	
Log(ΔE^i) x Post-Referendum	-0.377 (0.090)
Sectoral GVA Prediction for Hard Brexit x Post-Referendum	0.094 (0.036)
Sectoral GVA Prediction for Soft Brexit x Post-Referendum	0.181 (0.146)
Industry and Time Dummies	Yes
Sample Size	86108
B. Upstream and Downstream Weighted Depreciation	
Log(ΔE^i) x Post-Referendum	-0.404 (0.083)
Log($\Delta E^{upstream}$) x Post-Referendum	0.003 (0.003)
Log($\Delta E^{downstream}$) x Post-Referendum	-0.006 (0.009)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A7: Real Wages and Migration

	(1)
A. Share of Migrants in Workforce	
Log(ΔE^i) x Post-Referendum	-0.433 (0.084)
Share of Migrants in Workforce x Post-Referendum	0.042 (0.062)
Industry and Time Dummies	Yes
Sample Size	86108
B. Share of EU and Non-EU in Migrants	
Log(ΔE^i) x Post-Referendum	-0.434 (0.094)
Share of EU Migrants in Workforce x Post-Referendum	0.038 (0.117)
Share of Non-EU Migrants in Workforce x Post-Referendum	0.045 (0.096)
Industry and Time Dummies	Yes
Sample Size	86108
C. Migrant Source Weighted Depreciation	
Log(ΔE^i) x Post-Referendum	-0.377 (0.076)
Log($\Delta E^{migrant}$) x Post-Referendum	-0.095 (0.061)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A8: Real Wages and Foreign Direct Investment (FDI)

	(1)
A. Share of EU in Inward and Outward FDI	
Log(ΔE^i) x Post-Referendum	-0.392 (0.073)
Share of EU in Inward FDI x Post-Referendum	-0.003 (0.019)
Share of EU in Outward FDI x Post-Referendum	0.016 (0.014)
Industry and Time Dummies	Yes
Sample Size	86108
B. Inward and Outward FDI Weighted Depreciation	
Log(ΔE^i) x Post-Referendum	-0.403 (0.074)
Log(ΔE^{inward}) x Post-Referendum	-0.009 (0.023)
Log($\Delta E^{outward}$) x Post-Referendum	-0.012 (0.011)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, BHJ adjusted.

Table A9a: Real Wages and Currency Depreciation Windows

	(1)
A. 7 Days Sterling Depreciation Window	
Log($\Delta E^{i}_{7\ days}$) x Post-Referendum	-0.396 (0.138)
Industry and Time Dummies	Yes
Sample Size	86108
B. 15 Days Sterling Depreciation Window	
Log($\Delta E^{i}_{15\ days}$) x Post-Referendum	-0.344 (0.170)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, BHJ adjusted

Table A9b: Real Wages and Vehicle Currency Adjustments

	(1)
A. Vehicle Currency Adjustment	
Log($\Delta E^{i}_{vehicle}$) x Post-Referendum	-0.308 (0.119)
Industry and Time Dummies	Yes
Sample Size	86108
B. Vehicle Currency Adjustments for All Depreciations	
Log($\Delta E^{i}_{vehicle}$) x Post-Referendum	-0.322 (0.132)
Log($\Delta E^{x}_{vehicle}$) x Post-Referendum	-0.007 (0.104)
Log($\Delta E^{m}_{vehicle}$) x Post-Referendum	0.030 (0.081)
Industry and Time Dummies	Yes
Sample Size	86108

Notes: Standard errors in parentheses, clustered by industry.

Table A10: Top 3 Intermediate Imports of High Intermediate Import Depreciation Industries

Intermediate Imports, ΔE^i

Depreciation	Top 4 Industries (SIC)	Top 4 Intermediate Imports (%)
7.40	Activities auxiliary to financial and insurance services (66)	Financial services (46), Other business services (36), Telecom, computer and information services (6), Insurance services (4)
7.03	Programming and broadcasting (60)	Intellectual property services (39), Personal, recreational and cultural services (16), Goods from Creative, arts and entertainment activities (10), Goods from Motion picture, video and television programme production, sound recording and music publishing activities (6)
7.00	Scientific research and development (72)	Other business services (54), Other transport equipment (9), Computer, electronic and optical products (7), Machinery and equipment n.e.c. (5)
6.94	Architectural and engineering services (71)	Other business services (47), Other transport equipment (14), Government services (8), Construction services (4)
Depreciation	Bottom 4 Industries (SIC)	Bottom 4 Intermediate Imports (%)
6.25	Electricity, gas and other energy supply (35)	Extraction of crude and natural gas (40), Mining of coal (14), Electrical equipment (8), Electricity, gas, steam and air conditioning supply (8)
6.24	Manufacture of coke and petroleum products (19)	Extraction of crude and natural gas (73), Mining of metal ores (10), Chemicals and chemical products (9), Machinery and equipment n.e.c. (3)
6.23	Manufacture of paper and paper products (17)	Paper and paper products (66), Chemicals and chemical products (11), Machinery and equipment n.e.c. (7), Rubber and plastic products (4)
6.22	Accommodation (55)	Beverages and tobacco (63), Food Products (6), Other business services (4), Air transport services (4)

Appendix D: Theory

Profits are $\Pi_o = \Pi\left(W_o, P_o^i\left(P_{iso}(E_s)\right), P_o^d(1), P_o^x\left(P_{do}(E_d)\right), P_o^{uk}\left(P_o^m\left(P_{so}(E_s)\right)\right)\right)$ where W_o are sectoral wages. P_o^i and P_o^d are intermediate input prices from abroad and at home. The former in turn depends on the prices of input i from source country s, labelled $P_{iso}(E_s)$. The intermediate import prices depend on prices which are converted into sterling through the source currency exchange rate E_s. The domestic input price depends on the value of sterling which is normalised to one. P_o^x and P_o^{uk} are output prices for exports and domestic sales of the output. The export prices depend on the prices received in sterling when they have been converted from the destination-denominated prices through the exchange rate E_d. Domestic output competes with imports of that output coming into the UK. Home output prices for the industry therefore depend on the prices of competing importers, summarised by the import price index P_o^m, which consists of source-specific import prices P_{so} that are converted into sterling through the source country exchange rate with sterling E_s.

The partial derivative $\partial \ln P_o^i\left(P_{iso}(E_s)\right)/\partial \ln E_s$ denotes the passthrough of the sterling depreciation (with respect to the currency of a source country s) to the intermediate import price index. Similarly, the partial $\partial \ln P_o^x\left(P_{do}(E_d)\right)/\partial \ln E_d$ is the passthrough of sterling's depreciation with respect to the currency of destination d into prices received in sterling by UK firms. Note that prices are denominated in sterling without loss of generality, implying a passthrough of 1 corresponds to full passthrough on the intermediate import side and no passthrough on the export side of UK firms. Finally, when sterling depreciates, it affects the import prices charged by foreign competitors of UK's output industry o and the partial $\partial \ln P_o^{uk}\left(P_o^m\left(P_{so}(E_s)\right)\right)/\partial \ln E_s$ is the indirect passthrough of sterling's depreciation to output prices charged by UK firms in that industry. This is the import competition channel faced domestically by UK producers.

By Hotelling's Lemma, labour demand in the sector is $L^D = -\Pi_W\left(W_o, P_o^i\left(P_{iso}(E_s)\right), P_o^d(1), P_o^x\left(P_{od}(E_d)\right), P_o^{uk}\left(P_o^m\left(P_{so}(E_s)\right)\right)\right)$. Denote the cross-price elasticity between factors i and j as $\varepsilon_{ij} \equiv \Pi_{P_iP_j}P_j/\Pi_{P_i} = Q_i'P_j/Q_i$ where Q_i is the quantity of input i demanded. The Hotelling elasticity of substitution is $\sigma_{ij} \equiv -\Pi\Pi_{P_iP_j}P_j/\Pi_{P_i}\Pi_{P_j}$. Therefore, the Hotelling elasticity is $\sigma_{ij} = \varepsilon_{ij}/S_{j\Pi}$ where $S_{j\Pi} \equiv P_jQ_j/\Pi$ is the share of input costs for j in profits.

Labour demand must equal the supply of labour to the sector: $L_o^S = L(W_o)$. Denote the labour supply elasticity by $\varepsilon_{WW}^S \equiv WL'(W)/L(W)$ which would be zero in a specific factors model. More generally, let ε_{WW}^S summarise the labour supply elasticity which is weakly positive. Labour market clearing implies that labour demand of an industry must equal the labour supply to the industry.

Totally differentiating the labour market clearing condition $L(W_o) = -\Pi_W$ and supressing the o subscripts for brevity then gives:

$$
\begin{aligned}
(\varepsilon^S_{WW} - \Pi_{WW}W/\Pi_W)d\ln W &= \sum_s\sum_i\left(\Pi_{WP^i}P_{is}/\Pi_W\right)d\ln P_{is} + \sum_d(\Pi_{WP^x}P_d/\Pi_W)d\ln P_d + \sum_s\left(\Pi_{WP^{uk}}\Pi_{P^{uk}P^m}P_s/\Pi_W\right)d\ln P_s \\
(\varepsilon^S_{WW} - \varepsilon_{WW})d\ln W &= \sum_s\sum_i\varepsilon_{WP^i}d\ln P_{is} + \sum_d\varepsilon_{WP^x}d\ln P_d + \varepsilon_{WP^{uk}}\sum_s\varepsilon_{P^{uk}P^m}d\ln P_s \\
(\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC})d\ln W &= \sigma_{WP^i}\sum_s\sum_i S_{P_{is}C}d\ln P_{is} + \sigma_{WP^x}\sum_d S_{P_dR}d\ln P_d + \sigma_{WP^{uk}}S_{P_{uk}R}\sigma_{P^{uk}P^m}\sum_s S_{P_sE}d\ln P_s
\end{aligned}
$$

The subscripts C , R and E in the last line denote total costs, revenues, and domestic expenditures on the industry. S_{WC} is therefore the labour share in total costs C and $S_{P_{is}C}$ is the share of input i from source s in total costs. On the revenue side, S_{P_dR} is the share of exports to destination d in total revenues R while $S_{P_{uk}R}$ is the share of domestic sales in revenues of the industry. UK firms compete with foreign firms for outputs produced by the industry. S_{P_sE} is the share of UK expenditure on industry outputs from source country s. Summing across all foreign sources, the share of imports in UK expenditures on the industry is $S_{P^mE} = \sum_{s\neq uk}S_{P_sE}$.

Let β denote the price passthrough of the composite exchange rate. Then solving for the wage change, it can be re-written in terms of Hotelling elasticities and currency shocks as:

$$
\begin{aligned}
d\ln W &= \frac{\sigma_{WP^i}S_{P^iC}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}d\ln P^i + \frac{\sigma_{WP^x}S_{P^xR}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\,d\ln P^x + \frac{\sigma_{WP^{uk}}S_{P^{uk}R}\sigma_{P^{uk}P^m}S_{P^mE}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\,d\ln P^m \\
&\equiv \frac{\sigma_{WP^i}S_{P^iC}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\beta^i\left(\sum_s S_{P_{is}C}d\ln E_s\right) + \frac{\sigma_{WP^x}S_{P^xR}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\,\beta^x\left(\sum_d S_{P_dR}d\ln E_d\right) + \frac{\sigma_{WP^{uk}}S_{P^{uk}C}\sigma_{P^{uk}P^m}S_{P^mE}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\,\beta^m\left(\sum_s S_{P_sE}d\ln E_s\right) \\
&\equiv \frac{\sigma_{WP^i}S_{P^iC}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\beta^i\,\Delta E^i + \frac{\sigma_{WP^x}S_{P^xR}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\,\beta^x\,\Delta E^x + \frac{\sigma_{WP^{uk}}S_{P^{uk}C}\sigma_{P^{uk}P^m}S_{P^mE}}{\sigma^S_{WW}S_{WC} - \sigma_{WW}S_{WC}}\,\beta^m\Delta E^m
\end{aligned}
$$

For firms that are cost minimisers, the cost function is $C_o = C\left(W_o, P^i_o\left(P_{iso}(E_s)\right), P^d_o, Q^x_o(Q_{do}), Q^{uk}_o\left(Q^m_o(Q_{so})\right)\right)$. Then the change in wages is similarly derived from Shephard's Lemma as $d\ln W \equiv \frac{\varepsilon_{WP^i}}{\varepsilon^S_{WW}-\varepsilon_{WW}}\,d\ln P^i + \frac{\varepsilon_{WQ^x}}{\varepsilon^S_{WW}-\varepsilon_{WW}}\,d\ln Q^x + \frac{\varepsilon_{WQ^{uk}}}{\varepsilon^S_{WW}-\varepsilon_{WW}}\,d\ln Q^m$. Letting ε_{QP} denote the demand elasticity, the change in wages can also be re-written as $d\ln W \equiv \frac{\varepsilon_{WP^i}}{\varepsilon^S_{WW}-\varepsilon_{WW}}\,d\ln P^i + \frac{\varepsilon_{WQ^x}\varepsilon_{QP}}{\varepsilon^S_{WW}-\varepsilon_{WW}}\,d\ln P^x + \frac{\varepsilon_{WQ^{uk}}\varepsilon_{QP}}{\varepsilon^S_{WW}-\varepsilon_{WW}}\,d\ln P^{uk}$. Comparing with changes in wages from Hotelling's Lemma, the elasticities in the cost minimisation wage change comes from the cost functions instead of the profit function. Finally, for firms that must satisfy zero profits, $\sum_d P_dQ_d d\ln P_d - WLd\ln W - \sum_s\sum_i P_{is}Q_{is}d\ln P_{is} = 0$. Therefore, the change in wages is

$$
d\ln W \equiv -\left(\frac{S_{P^iC}}{S_{WC}}\right)d\ln P^i + \left(\frac{S_{P^xR}}{S_{WC}}\right)\,d\ln P^x + \left(\frac{S_{P^{uk}R}}{S_{WC}}\right)d\ln P^{uk}.
$$

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