Trade and Worker Deskilling: Evidence from the Brexit Vote

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January 2019

PRELIMINARY, Please do not cite without authors' permission.

Abstract

This paper presents new evidence on the impact of international trade on worker outcomes, by examining a big world event that produced an unprecedentedly large shock to the UK exchange rate. In the 24 hours in June 2016 during which the UK electorate unexpectedly voted to leave the European Union, the value of sterling plummeted. It recorded the biggest depreciation that has ever occurred in any of the world's four major currencies since the collapse of Bretton Woods. Exploiting this variation, the paper studies the impact of trade on wages and future earnings potential measured by job related education and training. Wages and training fell for workers employed in sectors where the intermediate import price rose by more as a result of the massive sterling depreciation. Calibrating the estimated wage elasticity with respect to intermediate import prices to theory uncovers evidence of complementarity between workers and intermediate imports. This provides new direct evidence that, in the modern world of global value chains, the cost of intermediate imports acts as an important driver of the impact of globalization on worker welfare.

Acknowledgements. The CEP has no institutional views, only those of its individual researchers. CEP's Brexit work is funded by the UK Economic and Social Research Council. As a whole the CEP receives less than 5% of its funding from the European Union. The EU funding is from the European Research Council for academic projects and not for general funding or consultancy.

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1 Introduction

Recently, and especially in the wake of the Great Recession, real wages and productivity have stagnated across the developed world. Some commentators have argued that globalization has been systematically connected to a worsening of economic performance (see for example De Long (2017), Mishel (2015)). Empirical studies in international trade and labour economics have attempted to connect the two, looking at a number of research areas including the impact of import competition on manufacturing jobs and wages, the differential evolution of skilled versus unskilled wages in response to offshoring, trade and labour reallocation and the changing employment shares of skilled workers over time.[1] While much progress has been made, a number of fundamental questions - like the impact of offshoring on domestic workers - remain far from resolved.[2]

This paper offers complementary new evidence on connections between trade and the labour market. It approaches the question in a rather different way to existing work by studying a big world event that sent shock waves globally about the future of international trade and trade policy. More specifically, we study what happened in the UK before and after the Brexit referendum vote of June 23, 2016. The focus is on trade and worker outcome responses to the sizable depreciation of sterling that arose because of the unanticipated nature of the leave vote. The result itself came as a big surprise to almost all observers, and had big and quickly realised effects on foreign exchange, equity and commodity markets.

Immediately following the UK electorate's unexpected referendum vote to leave the European Union, sterling suffered its biggest one day loss since the introduction of free-floating exchange rates in the 1970s. The pound-dollar exchange rate fell by a massive 8 percent to $1.33 on June 24, 2016. This was a much bigger drop than the one on Black Wednesday when the UK withdrew from the Exchange Rate Mechanism and even bigger than its drop during the height of the financial crisis in 2008 (The Guardian, 2016; Financial Times, 2016). In fact, the Brexit sterling drop is the biggest drop that has ever occurred in any of the world's four major currencies that make up the bulk of

[1] See, inter alia, Feenstra and Hanson (1999); Trefler (2004); Autor et al. (2013); Pierce and Schott (2016); Hakobyan and McLaren (2016). For recent surveys, see Goldberg and Pavcnik (2016a) and Helpman (2017).

[2] For example, in developed countries usual sources of exogenous variation, like economic policy shocks, are scarce as trade policies have recently remained fairly stable. In their Handbook chapter, Goldberg and Pavcnik (2016b) very much stress the limits to knowledge arising from endogeneity of trade policy and anticipation, arguing they are "first-order" concerns for identifying credible causal effects of globalisation on workers.

global hard cash reserves since the collapse of Bretton Woods (Reuters, 2016).

A key feature of the event was that the pound depreciated to different degrees against different world currencies. For example, for the UK's two major trade partners (the US and the EU) the pound-dollar exchange rate fell by 8 percent overnight on June 23/24 while the pound-euro exchange fell by 6 percent. Because imports and exports differ in their source and destination countries, industries trading in different world markets face a different sterling depreciation. This permits a before/after referendum study of what happened to individuals working in industries that face different cost and revenue shocks because of currency variations in the unexpected sterling depreciation.

In international trade theory, a rise in exports is expected to benefit workers but, at the same time, the impact of a rise in imports on workers is controversial. Early studies reported a negative impact of imports on workers, which is consistent with the theoretical literature that highlights the import-competing effects on domestic firms (Grossman 1987; Revenga 1992). But the key development in trade patterns in the last few decades has been the huge rise of trade in intermediate goods and services, often referred to as offshoring. Intermediate inputs today account for two thirds of international trade and imported content is estimated to make up 30 percent of world exports (Johnson and Noguera 2012; Datt et al. 2011). Trade in intermediates changes the likely effects of trade and trade policy – for example, tariffs on imports need not protect domestic producers when they rely on imports as intermediate inputs into their production (Antras and Staiger 2012).

Because of this, traditional conclusions for the impacts of trade on worker outcomes are nowhere near as straightforward as they were when the earlier literature studied final goods trade arising from factor price differences across countries. As in the earlier literature, imports have negative impacts on domestic workers when they have to compete with offshore sources of supply of tasks they perform. But, domestic workers can also benefit from cheaper foreign inputs when cost savings abroad raise the productivity or scale of domestic production. Such opposing forces from trade in intermediates imply that its impacts on workers have become increasingly nuanced and depend on various factors such as the costs of offshoring, the mix of trade partners and the extent of scale economies (Grossman and Rossi-Hansberg 2008, 2012). The question of how trade in intermediate inputs affects workers therefore requires careful empirical examination.

The unique natural experiment studied in this paper provides evidence that trade matters, by showing that a depreciation induced rise in the price of imported inputs hurts workers. The focus on a large, unexpected exchange rate depreciation offers the opportunity to study a potentially exogenous variation that impacts worker outcomes

through trade price movements due to revenue or cost shocks.[3] Other economic shocks that move exchange rates are less plausibly exogenous than the referendum induced exchange rate depreciation of the pound. One example would be if an exchange rate depreciates due to oil price shocks, so that changes in worker outcomes incorporate the direct substitution effects between energy and labour along with indirect impacts through changes in trade. A second example would be if exchange rate movements instead were driven by macroeconomic crises, then worker outcomes are likely to reflect the underlying sources of the crises, rather than responses to exchange rate shocks per se. Similar endogeneity concerns arise when looking at changes in worker level outcomes with respect to many feasible instruments, like tariffs, monetary policy and exchange rate devaluations during crises, which are often adopted to bolster employment outcomes.

Exploiting the sharp drop in the value of the pound from the unexpected leave vote enables progress to be made in identifying the impacts of trade on a broad set of workers (i.e. not just in manufacturing). Trade policy in most developed countries has remained stable so that variations in tariff and exchange rates are often too small to change offshoring by firms (Hummels et al. 2018, p.37). Further, in developed countries today, the bulk of the workforce is in industries where instruments for imports are hard to come by (Liu and Trefler 2011; Ebenstein et al. 2014). For example, there are no tariffs in services industries and data on non-tariff barriers is scant. The UK experience around the referendum provides a unique setting to study worker impacts using high quality (and relatively scarce in international terms) services trade data along with exogenous variation in services trade resulting from the large depreciation.

Empirical estimates based upon the differential exposure of industries to foreign sources of intermediate inputs produces findings showing that workers suffered when the prices of imported intermediates rose more in response to the Brexit sterling depreciation. A 1 percent increase in the price of intermediate imports of an industry lowered wages by somewhere between 0.35 and 0.55 percent. The results are from a different setting, but do differ from some of the offshoring literature, which typically finds negative, or positive but small, effects of offshoring on domestic workers' wages.[4] However,

[3]The focus on sizable exchange rate movements has some commonalities with the emerging literature on exchange rates that examines large depreciation episodes, often arising from currency devaluations during large declines in output, consumption and imports. See for example, Cravino and Levchenko (2017) which examines the price impacts of an unexpected Mexican peso crisis, and the price evolution studies of Burstein et al. (2005); Burstein and Gopinath (2014); Auer et al. (2018).

[4]Early evidence from Revenga (1992) suggested that increased import competition resulted in losses to employment and wages in US manufacturing, though the associated import price elasticities were relatively low, in particular for wages. Later work by Campa and Goldberg (2001) expands the analysis

as suggested by Harrison et al. (2011) in their survey, complementarity between workers and intermediate imports could be masked by a stronger negative labour supply effect of offshoring, especially as most studies focus on offshoring to low-wage-countries like China and India. Indeed, the estimated wage elasticity from the Brexit vote shock is similar to previous work on the UK labour market. In a rare study, Criscuolo and Garicano (2010) examine services industries and find substantial complementarity between imports of services and those in licensed occupations dedicated to the production of those services. In their analysis, a one percent increase in exposure to imports is associated with a decrease of 0.2 percent in wages of nonlicensed occupations and 0.5 percent increase in wages of licensed occupations.[5]

Workers in industries more exposed to the sterling depreciation experienced a bigger rise in the price of their intermediate imports and suffered bigger reductions in earnings. These negative effects on wages were further compounded by a cutback in

to intermediate imports but continues to find similar wage elasticities. Similarly, Goldberg and Tracy (2001) estimate a wage elasticity of -0.014 with respect to import-weighted exchange rate depreciation (which is statistically insignificant) for 2-digit SIC industries in US manufacturing from 1971-1995 (Appendix Table 2). Within international trade, Feenstra and Hanson (1999) is the starting point for much of the work on inequality effects of offshoring in US manufacturing. They find that real wages of production workers were largely unaffected by offshoring activities of US firms (with elasticities ranging between -0.01 to 0.02 percent) while the real wages of non-production workers changed by 0.06 to 0.10 percent with respect to a change in the share of imports in intermediate inputs. Sitchinava (2008) updates the Feenstra and Hanson paper to 1996 and also takes into account the possibility of services offshoring. Sitchinava finds that most of the increase in the relative wages of nonproduction relative to production workers can be explained by technical change, which is proxied with the share of high-technology equipment in the capital stock (Harrison et al. 2011). Using more recent BEA multinational data for the nineties and 2000s, Boehm et al. (2017) find newly multinational establishments in the U.S. experienced job losses, while their parent firms increased input imports from abroad. A few papers have moved beyond manufacturing and find that workers benefit from trade in intermediate inputs though the effects are small even over long periods of time (Amiti and Konings (2007); Liu and Trefler (2008, 2011); Ebenstein et al. (2014)). They find however that exports improve labour market outcomes, while imports can often have negative or mixed effects (Geishecker and Gorg (2013); Crino (2010)). For example, Liu and Trefler (2008) find a "tiny" effect of intermediate service imports from China and India on earnings of US workers, with an estimated earnings elasticity of -0.0001 with respect to imports.

[5]In related work, Sethupathy (2013) finds that after the Mexican peso crisis of 1994, average domestic wages of US manufacturing multinational firms that already offshored to Mexico rose 6% more than other firms in the US, suggesting complementarity between domestic workers and offhsoring. Using country-year variation in economic activity to construct Bartik instruments, Desai et al. (2009) find a positive relationship between earnings of domestic and foreign employment outcomes of US multinational firms. As our cross-country variation comes from the Brexit vote depreciation, we are closer to Kovak et al. (2017) which uses bilateral tax treaties (BTTs) as an instrument for employment at foreign affiliates. During their time period, BTTs were negotiated mainly with developing and transition countries so the first-stage relationship between BTTs and affiliate employment is only present in high differentiation industries. For these workers in the US, Kovak et al. estimate a positive employment elasticity - a 1 percent BTT-induced increase in affiliate employment drives a 0.18 percent increase in employment at the U.S. parent firm.

job-related education and training, suggesting losses in future earning potential. this is an important finding as investments in skills provide wage growth to workers and productivity gains for businesses (see for example Lynch 1992; Dearden et al. 2006). It has also become widely recognized that investments in skills are key to overcoming economic stagnation, especially because intangible assets like human capital are easier to scale up and have greater spillovers than other sources of growth like physical capital (Haskel and Westlake 2018).[6] Training is therefore a major component of investments that raise economic growth. It is also highly complementary to the success of R&D and other innovation activities (Brynjolfsson et al. 2002).

Beyond its contribution to economic growth, investment in skills can be an important lever to cushion workers during changes in their economic environment. The offshoring literature has recognised the importance of training in redistributing the gains from globalization to workers who are hurt by it. For example, the Trade Adjustment Assistance programme of the United States and the Globalization Adjustment Fund of the European Union provide public support for training of workers who are hurt by imports. While temporary relief can provide unemployment insurance, displaced individuals need skills to transition into jobs that are growing, and this is particularly important for workers who are hurt by offshoring (Hummels et al. 2012). Yet research on trade and training remains scarce, at least in part because the data requirements - observing wages, training and offshoring shocks together - have been said to be "onerous" (Hummels et al. 2018). Consequently, most papers rely on data from public training programmes for displaced workers to shed light on the prospects for future earnings of workers impacted by trade.[7]

The focus on training also relates to a nascent literature on globalization and human capital accumulation. Studies on human capital accumulation have largely examined

[6] A substantial fraction of investment in skills takes place through job-related education and training of workers. Although internationally comparable statistics are scarce, the OECD estimated that, on average, over a third of employed adults participate in job-related training, with countries like the UK, US and New Zealand showing much higher rates (Oecd (n.d.)). In many developed countries, job-related education and training makes up the single-largest component of investments in intangibles, higher than software and databases, R&D or brand equity (example, van Ark et al. 2009).

[7] A few recent papers find a link between rise in imports and training in the manufacturing sector. Kosteas (2017) finds US workers in industries with rising import penetration were less likely to enrol in career advancement training. Hogrefe and Wrona (2015) find instead that workers in industries with rising imports from low-income countries were more likely to enrol in training in Germany, where these investments have risen during the crisis period (unlike many other advanced countries). Cross-sectional evidence from Norway shows that manufacturing firms that report facing high competition in international markets invest more in training their workers, but this is not true for non-manufacturing firms (Schone 2007). Looking at training provided by Brazil's national services, Bastos et al. (2016) finds that manufacturing firms that are induced to export from exchange rate movements, have higher shares of low-skilled workers in training.

the impact of trade on schooling and found mixed results (Edmonds and Pavcnik 2005; Edmonds et al. 2010).[8] Much of the literature on trade and skills has focused on the impacts of trade and trade policy on shares of skilled workers and skill premia, often finding a positive relation between trade and skills.[9] We show that these effects of trade on skills is amplified through the channel of investments in education and training of workers.

Finally of relevance to the subject matter of this paper is the growing literature on the potential and actual impacts of the Brexit vote. Overall, the wage and training results are qualitatively similar and sit well with the counterfactual predictions of the likely negative economic consequences of leaving the EU. The dominant approach to date has been to infer the impact of leaving the EU on national GDP and on the household income distribution using standard models and estimated elasticities from international trade (for example, Dhingra et al. (2017), see Sampson (2017); Van Reenen (2016) for a survey). More recently, a few studies have started to look at post-referendum data on entry and exit of exporters of merchandise goods, stock market valuations of firms, prices of imported commodities, economic uncertainty and trade policy uncertainty.[10] To the best of our knowledge, we provide the first evidence on actual worker-level outcomes from the current surge in nationalist policies, including the Brexit vote.

Our main finding of reduced wages and human capital investment because of the Brexit vote has important welfare and policy implications. The UK fiscal system has clear incentives in place to increase firm level investment in R&D through a policy of tax credits. But unlike many other countries, it lacks a counterpart for human capital investment (Costa et al. 2018). In the absence of credits for human capital accumulation, it is likely that reduced on-the-job training will not reverse and will potentially translate into permanent income losses for workers. Furthermore, the impacts on aggregate productivity are also likely to be important, especially for the UK which has an output per hour worked that is 15.1 percent below the average for the rest of the

[8]Edmonds et al. (2010) finds lower increases in schooling in Indian districts where employment was concentrated in industries with bigger tariff reductions. In contrast, Edmonds and Pavcnik (2005) finds school attendance for girls rises and child labour falls more in Vietnamese regions that experience greater increases in the price of their primary exports of rice.

[9]See, for example, Verhoogen (2008); Bustos (2005); Brambilla et al. (2012).

[10]For example, Davies and Studnicka (2018) and Breinlich et al. (2018) examine the stock market valuations of firms with different levels of EU exposure. Bloom et al. (2018) find that Brexit is reported to be one of the top three sources of uncertainty for around 40 per cent of UK businesses in the two years after the vote and that perceived uncertainty is higher for businesses that are more dependent on trade with the EU. Crowley et al. (2018) and Graziano et al. (2018) study the reduction in bilateral exports after the vote and relate it to trade policy uncertainty.

G7 economies.

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. Section 3 presents the theoretical framework and Section 4 describes the research design that is adopted along with the data sources. Section 5 describes the results, together with a discussion of their wider relevance. Section 6 concludes.

2 Context: The EU Referendum Vote

The United Kingdom is one of the most open economies in the world. Its exports and imports were over 30 per cent of UK GDP each last year. The European Union (EU) is the UK's largest trade partner. Around a half of the UK's trade is with the EU. Prior to the UK joining the European Economic Community (EEC) in 1973, around one third of UK trade was with the EEC. In 2014, the 27 other EU members accounted for 45 percent of exports and 53 percent of imports (Dhingra et al. 2017).

As a member of the EU, the UK is in a customs union and a single market with EU members. A customs union means that all tariff barriers have been removed within the EU and that members pursue trade policies through the EU, and not independently. Member states charge the same tariffs to countries outside the EU. Importantly, membership implies the existence of a 'single market' that reduces non-tariff barriers. The latter include a wide range of measures that raise the costs of trade such as border controls, rules of origin checks, cross-country differences in regulations over things like product standards and safety, and threats of anti-dumping duties.

While membership lowers the costs of doing business between member states, they are required to coordinate on trade policy, including tariffs and non-tariff barriers and other trade-related policies like migration and foreign investment. Many political groups in the UK see this as a constraint on national sovereignty, and this motivated calls for a referendum to allow the UK electorate to vote on whether to remain in the EU in the future or to leave. This campaign was heavily stepped up by Nigel Farage, leader of the UK Independence Party, then a single issue party campaigning for Britain's exit from the EU. Because of these pressures, UK Prime Minister David Cameron pledged to hold an in or out referendum if his Conservative Party won the 2015 election.

After the party's win, June 23, 2016 was set as the date for a referendum on "Should the United Kingdom remain a member of the European Union or leave the European Union?" The possible answers were: "Remain a member of the European Union" or "Leave the European Union" (Baldwin 2016). About 72% of eligible voters cast a

ballot and 52% of these chose 'Leave'. Few had expected this result, especially in the foreign exchange and betting markets. In the run-up to the referendum, most polls and bookmakers had predicted a win for the Remain campaign, albeit with a small margin. Even up to polling day, Nigel Farage admitted that Remain was likely to edge a win (Independent 2016a, 2016b). The forex market exhibited similar uncertainty over the result of the Brexit vote. A full timeline of the events is given in Appendix A, and here we summarize the main episodes.

The last referendum votes were cast and polling stations across the country closed at 10 pm on June 23. A YouGov opinion poll released at the same time suggested Remain were on course for victory with 52 percent and Leave on 48 percent. By 10.15pm, UKIP's Nigel Farage conceded the Brexit campaign may be beaten and Remain "will edge it." Sterling surged 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. Soon after midnight, the first big result was declared, with a narrow win in Newcastle for Remain with 50.7 percent against Leave on 49.3 percent. It was an expected win in Newcastle, but not by the margin many suspected, and shortly afterwards the odds of Leave winning the vote was slashed by bookmakers. The big upset came at 12.20am on June 24. Sunderland voted to Leave by a significant margin, with 61 percent in the Tyne and Wear town in favour of Brexit compared with 39 percent backing Remain. By 12.30am, sterling tumbled against the US dollar, with an instantaneous near 4.7 percent drop - greater than the Black Wednesday crash in 1992.

People started to sense that Leave would win, and it showed in their Google searches after an hour. Bookmakers changed their odds in favour of Leave winning the referendum. Other Brexit wins followed and by 2.17am, Nigel Farage tweeted that he is "so happy with the results in North East England". A few big wins went to Remain subsequently, but in the next couple of hours, the Leave campaign enjoyed gains across Wales, Northern Ireland, Yorkshire and the Midlands to dwarf the majority of Remain's support in Scotland and London. Sterling's slide against the dollar continued, and the pound dropped to 1.37 dollars, down from a high the previous night of over 1.5 dollars. Investors reacted by moving from the sterling to other currencies and avenues for investment, as reflected in the sterling value against major foreign currencies in Figure 1. Table 1 gives more detail on the quite wide discrepancies in the percentage fall that sterling experienced against different currencies in the 24 hour period surrounding the referendum.

After 7am on June 24, the Leave campaign had officially won and we use this overnight exchange rate drop from 6pm on June 23 to 8am on June 24 as the unantic-

ipated depreciation shock to the sterling against other currencies in our analysis. The pattern of sterling's depreciation against other currencies reflects a safe haven flight from the pound. Sterling depreciated most against the Japanese Yen and the US dollar which are considered safe haven assets by forex traders and analysts (CNBC 2016a, 2016b).[11] In contrast, sterling depreciated relatively less against EU currencies like the Euro and the Polish Zloty, which are perceived to be more exposed to the political and economic fallout of the Brexit vote. Being one of the major currencies of the world, the flight from sterling also changed the value of a whole host of minor currencies as forex traders looked for new avenues and trades (Euromoney 2016).[12] The sterling depreciation therefore provides variation in export and import prices for a range of different currencies.

The view 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. The day after the Brexit vote saw a gold price rise of over 5% - the highest surge since the depth of the 2008 financial crisis- and the Royal Mint reported a 550 percent increase in traffic on its online purchase site compared to the same time the previous day (Coin World 2016).[13] Within a day, prices of safe assets like silver, precious metal ETFs and 10-year US Treasury bonds rose sharply (Forbes 2016).[14] The sterling depreciation can therefore be viewed as an unexpected news shock consistent with greater economic and policy uncertainty over subsequent years (Bloom et al. 2018; Graziano et al. 2018).

While sterling continued to decline in subsequent months, the analysis uses just the overnight decline to minimise endogeneity concerns arising from subsequent actions taken by the Bank of England (very soon after) and other market players in hedging economic losses and bolstering the UK economy. This is borne out by observing the pattern of exchange rate movements that later occurred. Figures A1 of the Appendix shows this for the three main currencies over a window of 7 and 15 days after the referendum. The 7-day window Figure does not show much difference, but more discrepancies start to arise relative to the 24 hour movements for the 15 day window (and for other longer windows we have considered, but do not show in the paper). As with event studies

[11] https://www.cnbc.com/2016/06/22/if-uk-votes-leave-in-brexit-referendum-pound-sterling-will-likely-tumble-dollar-surge.html and https://www.cnbc.com/2016/06/26/pound-sterling-set-to-fall-further-as-brexit-uncertainty-continues.html

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

[13] https://www.coinworld.com/news/precious-metals/2016/06/brexit-vote-european-union-gold-price-surge-kitco.all.html

[14] https://www.forbes.com/sites/maggiemcgrath/2016/06/24/global-markets-in-turmoil-after-the-u-k-votes-to-leave-the-european-union/#76b991053994

looking at exchange rate movements more generally (and indeed event studies looking at stock price movements) this is obviously because other news that occurs shapes the observed shifts. Clearly the use of a wider window would raise endogeneity concerns not present in the 24 hour window that measures exchange rate shifts that pre-date the several news and announcements following the referendum result that could be seen as direct reactions to the exchange rate drop. Some of these are listed in the Brexit timetable in the Appendix to the paper. The first is the Governor of the Bank of England Mark Carney's 8:50 am statement on June 24 about the readiness on the part of the Bank of England to use monetary policy to support the UK economy. And soon after this, the Bank of England strengthened its position and started some quantitative easing operations. The extent to which these operations could have been targeted to industries with higher trade exposure and/or larger exchange rate drops makes the movements in exchange rates past the 24 hour window potentially endogenous.

One concern with using the overnight exchange rate movement is that it may not capture the full extent of the the Brexit news shock if markets have not had time to factor this in. As we show later, this does not turn out to be a concern in identifying the causal mechanisms as we find strong persistent responses in real labour market outcomes. This is consistent with results using higher frequency data which finds one-off persistent price responses to the Brexit vote news. For example, the top five performers on the UK stock exchange the day after the Brexit vote were all mining companies and the bottom performers included air transport, financial services and real estate firms, that were expected to fare worse from policy changes after Brexit. The pattern of price changes these firms experienced were substantial, persistent and likely reflected a one-off Brexit news shock because the pattern was not repeated each time there was subsequent news on the Brexit process (Davies and Studnicka 2018; Breinlich et al. 2018). To a substantive degree then, the overnight sterling depreciation factors in the news shock over the future the UK economy following the Brexit vote.

3 Theoretical Framework

This section provides a theoretical framework for use in interpreting the empirical findings and their relation to work on trade, labour and exchange rates. For clarity, use s to denote the source country of UK's input suppliers and d to denote the destination country of firms located in the UK. Further, bold letters are used to indicate economy-wide vectors of prices, quantities and expenditures in each country. The starting point is a description of the economy and the market equilibrium, after which the exposition

proceeds to a discussion of the possible impacts of the sterling depreciation.

Output Prices

Let $Q\left(P_{od}, \boldsymbol{P_d}, I_d\right)$ be the quantity demanded from output industry o in the UK by a representative consumer in destination country d. P_{od} denotes the unit price charged for output o in destination d. $\boldsymbol{P}_d$ summarizes the set of all prices for goods and services in the destination market and I_d is the income of the representative consumer in destination d. Firms take the demand function as given and maximize profits. Markets are segmented and firms choose prices to maximize the profit from each destination: $\left(P_{od}/\tau_{od} - C_o/E_d\right) Q\left(P_{od}, \boldsymbol{P_d}, I_d\right)$. E_d is the exchange rate that converts foreign denominated values into sterling. Firms have a homothetic production function which results in unit cost C_o. Domestic sales do not entail trade costs but foreign sales entail iceberg transport costs $\tau_{od} \geq 1$.

Production requires workers L, intermediate inputs M from different industries and the numeraire good. Workers are industry-specific, at least in the short run and W_o denotes the wage rate of workers who are employed in output industry o. Intermediate inputs can be sourced at home or abroad and P_{si} denotes the price of input i from source country s. As is standard, we assume that firms can price discriminate across locations but not across different buyers within a location. Then the unit cost function can be written as $C_o = C\left(W_o, P_{Mo}\left(\boldsymbol{P_i}\left(\boldsymbol{P}_{si}\right)\right)\right)$ where P_i summarizes the import price index from intermediate industry i and P_M summarizes the import price index across all intermediates.[15]

We assume firms are monopolistically competitive and choose prices to maximize profits. As in standard monopoly problems, the optimal price of output o in destination d is $P_{od} = \mu\tau_{od}C_o/E_d$ where $\mu \equiv 1/\left(1 + 1/\left(\partial \ln Q\left(P_{od}, \boldsymbol{P}_d, I_d\right)/\partial \ln P_{od}\right)\right)$ is the inverse demand elasticity. We assume constant markups as we will not be able to decompose prices into markups and costs.[16]

[15] In principle, the cost function is $C_o = C\left(W_o, P_{Mo}\left(\boldsymbol{P_i}\left(\boldsymbol{P}_{si}\right)\right), 1\right)$ where 1 denotes the price of the numeraire good which for brevity, we write without the third argument.

[16] More generally, under variables markups, our estimated coefficients would incorporate the elasticity of markups to expenditures. Under oligopoly, the markup would include the sensitivity of the aggregate price index to own prices. For a detailed exposition of such effects in a general framework, see Amiti et al. (forthcoming).

Input Prices

Input suppliers combine the numeraire good from their own location and from the location of the using output industry. Suppliers need c_s and c_l units of the numeraire good from the source and the output location countries to provide a unit of their intermediate. Then $C_s = p_s c_s + c_l/E_s$ is the unit cost of providing the intermediate, where p_s is the price of the numeraire good in the foreign country. We incorporate $c_l > 0$ as it is a standard way of adding distribution costs in the exchange rate literature and E_s converts source country values into sterling.

As above, input suppliers can price discriminate across locations but not across buyers within a location. They choose prices to maximize profits from each market and he profit from supplying to the UK is $\left(P_{si}/\tau_{si}E_s - C_s\right) M_{si}$ where $\tau_{si} \geq 1$ is the iceberg transport cost incurred for intermediate inputs by UK firms. $M_{si} \equiv \left(\partial C\left(W_o, P_{Mo}\right)/\partial P_{si}\right)\left(\sum_o \tau_{od} Q_{od}/E_d\right)$ is the derived demand for inputs from all industries which is a function of factor prices and the scale of production in the UK. Suppliers are monopolistically competitive and choose optimal prices $P_{si} = \mu_i \tau_{si} C_{si} E_s$ where as earlier $\mu_i \equiv 1/\left(1 + 1/\left(\partial \ln M_{si}/\partial \ln P_{si}\right)\right)$ is the inverse derived demand elasticity of input i which we assume is constant.

Industry Wage

Labour market clearing sets the industry-specific wage rate. In equilibrium, the industry-specific supply of labour in the UK, $\bar{L}_o$, exactly equals the demand for labour from that industry, $\sum_d L_{od}$. By Shephard's lemma, labour market clearing implies $\bar{L}_{lo} = C_W\left(W_o, P_{Mo}\right) \sum_d \tau_{od} Q_{od}/E_d$ where C_W is the partial derivative of unit costs C with respect to the wage rate. Having specified the market equilibrium, we next discuss how equilibrium outcomes change with a depreciation of the exchange rate.

3.1 Impacts of the Brexit Referendum Sterling Depreciation

This sub-section starts with a discussion of the Brexit news shock on the exchange rate, and then determines the impacts on trade, imported intermediates and wages.

Sterling Depreciation

Following the international finance literature summarized in **?**, we will look at the narrow window of the Brexit referendum night to determine the news shock from the EU referendum results. This literature examines exchange rate changes over very short

time intervals following news announcements. Over these intervals, the economic fundamentals that determine exchange rates do not change much or at all, so that the primary driver of the exchange rate change is the news itself. With forward-looking asset prices, the change in the asset price is driven by news and not the fundamentals.

The key news that is announced during our 24 hour window from 8am on June 23, 2016 to 8am on June 24, 2016 is the news of the Brexit referendum by voting areas. The exchange rate changes over this 24 hour window cover the news of the Brexit referendum result, which can be written in terms of this literature as follows. As in Faust et al. (2007), let $\mathcal{S}$ be the vector describing all variables in the economy that can be viewed as fixed in the time period of the results announcement.[17] Let $\tilde{\mathcal{S}}$ be the public's best estimate of $\mathcal{S}$. Then the equilibrium exchange rate of the pound with respect to country c can be written as $E_c = \phi_c\left(\mathcal{S}, \tilde{\mathcal{S}}\right)$ where the c subscript allows the exchange rate to depend on country-specific factors such as trade costs or prices that vary by country, in addition to state variables that need not have a country dimension like the state of the aggregate world economy.

Linearizing S and then time differencing the result during the 24 hour window, $\Delta E_c = \phi_{1c}\Delta\mathcal{S} + \phi_{2c}\Delta\tilde{\mathcal{S}}$ where Δ is the 24 hr difference operator and ϕ_{1c}, ϕ_{2c} are the partial derivatives. Assuming the state variable does not change in this narrow window (when most markets except the forex market in London were closed), $\Delta\mathcal{S} = 0$ and $\Delta\tilde{\mathcal{S}}$ gives the marginal effect on the currency of a change in the public's perception of the state variable. Conditional on the information at the beginning of the window $\tilde{\mathcal{S}}$ and the Brexit referendum news B, the estimate of the state variable changes by $\Delta\tilde{S} = gB$. Therefore, the depreciation from the Brexit referendum news can be summarized by $\Delta E_c = \phi_{2c}gB$.

Trade Impacts

We determine how the sterling depreciation affected trade, prices and wages. Following the exchange rate literature, let $1-\kappa$ denote the probability that a firm cannot adjust its price following an exchange rate shock. Incorporating this sticky price mechanism, we discuss the changes in equilibrium outcomes here and relegate details to an Appendix. The level changes in any variable Z are denoted by $\Delta Z \equiv Z\left(E_c + \Delta E_c\right) - Z\left(E_c\right)$ and the percentage changes by $\hat{Z} \equiv \Delta Z / Z\left(E_c\right)$.[18]

[17] This includes traditional state variables like productivity and variables such as prices in other financial markets that need not be fixed over the time period beyond the window.

[18] For simplicity, we do not have a dynamic model that builds in the exact exchange rate determination rule. The framework can be extended to multiple periods to illustrate that, in the presence

Input Prices

From the supplier's optimal price equation, the change in the price of intermediates from industry i in source country s is $\hat{P}_{si} = \kappa^M \left(\hat{E}_s + \hat{C}_{si}\right)$ where κ^M is the probability of adjustment for suppliers of intermediate imports. Let $\delta \equiv c_s / \left(c_l / E_s + c_s\right)$ denote the share of source country costs in the total costs of the input supplier. Then the intermediate supplier's costs change by $\hat{C}_{si} = -\left(1-\delta\right)\hat{E}_s + \delta\hat{p}_s$ and the price of imported intermediate increases by $\hat{P}_{si} = \delta\kappa^M \left(\hat{E}_s + \hat{p}_s\right)$. A sterling depreciation ($\hat{E}_s > 0$) works like an increase in trade costs and raises the prices of imported intermediates. The exchange rate pass-through is $\delta\kappa^M$ which captures the share of source country costs and the probability of price adjustment.

Output Prices

From the industry's optimal price equation, the change in output price is $\hat{P}_{od} = \kappa\left(-\hat{E}_d + \hat{C}_o\right)$. The unit costs change by $\hat{C}_o = S_{WC_o}\hat{W}_o + S_{P_MC_o}\sum_i \sum_s S_{P_{si}P_i} S_{P_iP_M} \hat{P}_{si}$ where S_{WC} and S_{P_MC} are the shares of labour and imported intermediates in the industry's factor costs while $S_{P_{si}P_i}$ and $S_{P_iP_M}$ are the shares of source s and intermediate i in the respective intermediate costs of the industry.

Defining S_d as the share of total costs incurred for sales to destination d and using the optimal price and cost relationship, the change in scale across all destinations is $\sum_d S_d(\hat{PQ})_{od}$. Re-writing in terms of the demand-side elasticity $\sigma \equiv \mu / \left(\mu - 1\right)$, the expenditures in a destination change by $S_d(\hat{PQ})_{od} = \left(1/\left(1-\mu\right)\right) S_d \hat{P}_{od} + \boldsymbol{A}_d$ where $\boldsymbol{A}_d$ is an aggregate economy-wide shifter that contains the changes in the price index of the destination market and related income effects.[19]

Separating out home sales from exports, we can also define an export price index for UK firms. The change in the export price index is $\hat{P}_{Xo} \equiv \sum_{d \neq uk} S_{dx} \hat{P}_{od} = \kappa \sum_{d \neq uk} S_{dx} \left(-\hat{E}_d + S_{WC}\hat{W}_o + S_{P_MC}\hat{P}_{Mo}\right)$ where $S_{dx} \equiv S_d / \sum_{d \neq uk} S_d$ is the share of

of some degree of wage stickiness, the change in expectations about the future state of the economy would impact trade prices and wages through them. If factor prices and output prices can be adjusted before the actual Brexit event, the trade price responses to the exchange rate are likely to reflect trade policy uncertainty and economic uncertainty arising from the vote (as in the trade policy uncertainty literature of Handley and Limao 2015, 2017; Pierce and Schott 2016). In fact, Bloom et al. (2018) find that UK businesses report the lack of clarity over the transition and future arangements as a key source of economic uncertainty. If wages cannot be re-adjusted before the actual Brexit event, then the expectations over the future state of the economy would already encompass the expected changes in economic variables after Brexit, and not just the associated uncertainty and transition phases.

[19] Let $\epsilon_{o'}$ denote the cross-price elasticity with industry o' and let $S_{o'd}$ denote the share of industry o' in destination d expenditures. Then $\boldsymbol{A}_d = S_d\left(\sum_{o'} \epsilon_{o'd} S_{o'd} \hat{\boldsymbol{P}}_d + \epsilon_I \hat{I}_d\right)$ where $\hat{I}_{uk} = 0$ as it is defined in terms of the numeraire while $\hat{\boldsymbol{P}}_d = \hat{I}_d = 0$ for $d \neq UK$ when the UK is a small open economy.

destination d in exports of UK firms.

Wage Impacts

From labour market clearing, the change in wages is given by $0 = \left(\sigma^C_{WW} - 1\right) S_{WC}\hat{W}_o + \left(\sigma^C_{WP_M} - 1\right) S_{P_MC}\left(\sum_i S_{P_iP_M} \sum_s S_{P_{si}P_i}\hat{P}_{si}\right) + \sum_d S_d(\hat{PQ})_{od}$ where σ_{XY} denotes the Allen-Uzawa elasticities of substitution between X and Y. Specifically, $\sigma^C_{WW} \equiv \epsilon_{WW}/S_{WC}$ is the own elasticity of labour demand where $\epsilon_{WW} \equiv C_{WW}W/C_W$, $C_W > 0$ is the partial derivative of the unit cost function with respect to wages and $C_{WW} < 0$ is the second order partial derivative of the unit cost function with respect to wage. From Shephard's lemma, C_W is the equilibrium labour demand in the industry. Similarly, $\sigma^C_{WP_M} \equiv \epsilon_{WP_M}/S_{P_MC}$ is the Allen-Uzawa elasticity of substitution between workers and imported intermediates. The elasticity of labour demand with respect to the price of imported intermediates is $\epsilon_{WP_M} \equiv C_{WP_M}P_M/C_W$ which is less than zero for Allen-Uzawa complements and greater than zero for Allen-Uzawa substitutes.

For brevity, let $S_{sio} \equiv S_{P_{io}P_M}S_{P_{sio}P_{io}}$ denote the share of intermediates of industry i from source county s in the factor expenditures of output industry o. Combining all inputs used in the industry, the change in the imported intermediate price of output industry o is $\hat{P}_{Mo} \equiv \sum_i \sum_{s\neq uk} S_{sio}\hat{P}_{si}$. Substituting the import price index change in the wage change equation, the change in industry wage is

$$\left(1 - \sigma^C_{WW}\right) S_{WC}\hat{W}_o = -\left(1 - \sigma^C_{WP_M}\right) S_{P_MC}\hat{P}_{Mo} + \sum_d S_d(\hat{PQ})_{od} \tag{3.1}$$

where the sum on the RHS determines whether workers and intermediate imports are substitutes or complements. The first term on the RHS of Equation 3.1 determines the net complementarity or substitutability of workers with imported intermediates. When $\sigma^C_{WP_M} < 1$, an increase in the price of imported intermediates drives down the wage rate of workers in the industry and has the direct effect of reducing the absolute cost share of workers (because $\partial \ln S_{WC}/\partial \ln P_{Mo} = -S_{P_MC}\left(1 - \sigma^C_{WP_M}\right) < 0$ iff $\sigma^C_{WP_M} < 1$). The second term on the RHS determines the wage response to the scale of production. An increase in the scale of production raises the wage rate and the gross substitutability or complementarity between workers and imported intermediates depends on the relative strength of the direct substitution effect and the indirect scale effect. Solving further for the domestic price changes in Equation 3.1, we arrive at the estimating equations in the next sub-section.

3.2 Estimating Equations

Having determined changes in the labour market clearing condition, we can derive the structural equations for the empirical application to the Brexit news shock. The details are relegated to an Appendix and here we highlight the structural relationship in terms of changes in wages, imported intermediate prices and exports that we can take to the data. Our choice of trade measures are intermediate import price index and the export price index which determine wages. This is based on the reasoning by Grossman (1987) that prices are preferable to other commonly used measures of trade like the share of intermediate imports in domestic consumption because the latter captures changes in domestic supply and not just changes in foreign supply conditions. In their Report on the State of Available Data, Feenstra et al. (2010) explain further that prices are important for better capturing shifts in source countries by firms and for covering services inputs, which are often difficult to measure as trade flows. We therefore focus on deriving estimating equations using prices. As price data are scarce and much of the literature uses import shares, we also report results using the value of imports in an Appendix to provide comparable estimates.

Substituting for $\left(\hat{PQ}\right)_{uk}$, the change in wage rate from Equation 3.1 can be written in terms of imported intermediate prices and exports as

$$\begin{aligned}\left(1-\sigma^{C}_{WW}+\kappa S_{uk}\left(\sigma-1\right)\right)S_{WC}\hat{W}_{o} = &-\left(1-\sigma^{C}_{WP_{M}}+\kappa S_{uk}\left(\sigma-1\right)\right)S_{P_{M}C}\hat{P}_{Mo}\\ &-\left(1-S_{uk}\right)\left(\sigma-1\right)\hat{P}_{Xo}+\boldsymbol{A}_{uk}\end{aligned}$$

where S_{uk} is the share of sales at home. Combining this structural relationship with the changes in the import price index, we arrive at the structural and reduced form equations that can be estimated with data on wages, prices and trade during the Brexit vote-induced sterling depreciation.

The structural equation is:

$$\hat{W}_{o} = \alpha_{W}+\beta^{W}_{M}\hat{P}_{Mo}+\beta^{W}_{X}\hat{P}_{Xo} \tag{3.2}$$

The reduced form equations that underpin this are:

$$\begin{aligned}\hat{W}_{o} =&\alpha_{WW}+\left(\beta^{W}_{M}\beta_{MM}+\beta^{W}_{X}\beta_{MX}\right)\hat{E}_{Mo}+\beta^{W}_{X}\beta_{XX}\hat{E}_{Xo}\\ \hat{P}_{Mo} =&\alpha_{M}+\beta_{MM}\hat{E}_{Mo}\\ \hat{P}_{Xo} =&\alpha_{X}+\beta_{XX}\hat{E}_{Xo}+\beta_{MX}\hat{E}_{Mo}\end{aligned}$$

where α denote economy-wide shifters containing $\boldsymbol{A}_{uk}$ and for brevity, we define the weighted exchange rate measures as $\hat{E}_{Mo} \equiv \sum_i \sum_{s \neq uk} S_{sio} \hat{E}_s$ and $\hat{E}_{Xo} \equiv \sum_{d \neq uk} S_{dxo} \hat{E}_d$. The coefficients β measure the model parameters of interest and we proceed to explaining them in terms of the theoretical framework. The instruments are similar to the input cost shock that Goldberg et al. (2009) construct using tariffs for their study of product adoption from reduction in intermediate inputs tariffs in India.

3.2.1 First stage: Trade prices

We start with the change in trade arising from the sterling depreciation. The change in intermediate import prices is straightforward while the change in exports is more subtle as it contains the direct revenue effect and the indirect cost effect of the depreciation on UK firms.

The intermediate import price index change can be instrumented by the imported intermediate weighted exchange rate $\hat{E}_{Mo}$. As sterling depreciates, $\hat{E}_M > 0$ and prices of intermediate imports rise for $\beta_{MM} > 0$. The estimated exchange rate pass through to import prices is $\beta_{MM} \equiv \delta \kappa^M$ which incorporates the share of source country resources used in the provision of the intermediate δ and the probability of price adjustment in importing κ^M.

The change in export price index can be instrumented by the export weighted sterling appreciation $\hat{E}_{Xo}$. As sterling depreciates, $\hat{E}_X > 0$ and UK goods and services become cheaper for foreign consumers. This is the direct expenditure switching channel of the exchange rate depreciation which makes UK exports cheaper for foreign consumers, $\beta_{XX} \equiv -\kappa \frac{1-\sigma^C_{WW}+S_{uk}\kappa(\sigma-1)}{1-\sigma^C_{WW}+\kappa(\sigma-1)} < 0$ for downward sloping labour demand ($\sigma^C_{WW} < 0$). The extent to which this occurs depends on the probability of price adjustment in the output market κ and the indirect effect through wage changes incorporated in σ^C_{WW} and S_{uk}.

Export prices are cheaper in the export market on account of the direct effect of the depreciation. But the costs rise fall due to a rise in the price of intermediate imports when $\beta_{MX} > 0$. The estimated coefficient $\beta_{MX} \equiv \kappa S_{P_M C} \frac{\sigma^C_{WP_M}-\sigma^C_{WW}}{1-\sigma^C_{WW}+\kappa(\sigma-1)}$ is the exchange rate pass through of intermediate import costs to exports, and it incorporates the export price pass through $\kappa(\sigma-1)$, the intermediate import price pass through $\beta_{MM} S_{P_M C}$ and the indirect effects through wages which is captured in the elasticities of substitution $\frac{\sigma^C_{WP_M}-\sigma^C_{WW}}{1-\sigma^C_{WW}+\kappa(\sigma-1)}$. The denominator of the fraction is positive so the sign of the imported intermediate weighted exchange rate depreciation depends on the difference in the elasticity of substitution of workers with intermediate imports relative to own wages ($\sigma^C_{WP_M} - \sigma^C_{WW}$). When workers and intermediate imports are Allen-Uzawa substitutes, $\sigma^C_{WP_M} > 0 > \sigma^C_{WW}$ and export prices rise with the sterling depreciation through the

rise in intermediate import costs and increased substitution towards labour. Under complementarity, the relative magnitudes of the elasticities of substitution determine the direction of change in factor costs of UK firms and hence the cost channel through which the sterling depreciation affects exports. This is because the rise in price of intermediate imports from the sterling depreciation also reduces the demand for labour and has a countervailing effect on firm's factor costs through reduced wages. The net magnitude depends on the elasticities and the shares of each factor. It is reasonable to think that the cross elasticity of demand for labour is smaller in magnitude than the own elasticity of demand for labour. But the difference in the elasticities of substitution is positive for small enough labour shares relative to intermediate shares in factor costs, and vice-versa. Export prices therefore rise with the sterling depreciation through the cost channel when workers and intermediates are not complementary enough to reduce the total factor costs of exporters.

Summing up, the revenue channel of the sterling depreciation lowers export prices through its direct impact of cheaper output for foreign consumers. The cost channel of the sterling depreciation raises export prices through a rise in factor costs, as long as workers and intermediates are not complementary enough to reduce the overall factor costs of UK firms.

3.2.2 Second stage: Worker outcomes

The sterling depreciation changes worker outcomes in the industry through its impact on the costs of intermediate imports and sales to export markets. Wages fall with an increase in the intermediate import price index when workers and intermediate imports are Allen-Uzawa complements. The coefficient $\beta_M^W \equiv -\frac{\left(1-\sigma_{WP_M}^C+S_{uk}\kappa(\sigma-1)\right)S_{P_MC}}{\left(1-\sigma_{WW}^C+S_{uk}\kappa(\sigma-1)\right)S_{WC}}$ measures the gross elasticity of wages with respect to intermediate import prices. It incorporates Allen-Uzawa complementarity through $1-\sigma_{WP_M}$, the relative importance of workers and intermediates through their factor cost shares (S_{P_MC}, S_{WC}), and the expenditure elasticity with respect to own price of the industry through $\sigma-1$.

In a perfectly competitive setting, $\sigma = 1$ and the coefficient is just the relative Allen-Uzawa elasticities of substitution and factor shares. Then the coefficient is the change in the absolute cost shares of workers with a change in intermediate prices, relative to a change in wages because $\beta_M^W = -\frac{\left(1-\sigma_{WP_M}^C\right)S_{P_MC}}{\left(1-\sigma_{WW}^C\right)S_{WC}} = -\frac{\partial \ln S_{WC}/\partial \ln P_M}{\partial \ln S_{WC}/\partial \ln W}$. In an imperfectly competitive setting, the coefficient β_M^W captures the difference between the production elasticity and the demand elasticity (which determines the scale effects arising from domestic sales). This difference between the production side and demand

side elasticities in β_M^W is similar to Antras et al. (2017). They show that the difference between the output and the intermediate elasticities of substitution determines the sequential complementarity or substitutability of intermediate suppliers with earlier stages of the value chain of production.

For $\sigma_{WP_M}^C < 1$, the absolute cost share of workers rises with an increase in the price of intermediate imports and the wages of workers fall through the intermediate import cost channel of the exchange rate depreciation ($\beta_M^W < 0$). When workers and intermediate imports are Allen-Uzawa complements, the coefficient is always negative, and its magnitude is less than the ratio of intermediate shares to labour shares iff the earlier assumption of higher labour demand elasticity with respect to wages relative to intermediate import prices holds ($\sigma_{WP_M}^C - \sigma_{WW}^C > 0$).

While the first term in Equation 3.2 is the intermediate import channel of the sterling depreciation, the second term is the export channel which captures the effects of a rise in scale through foreign sales on wages. The coefficient $\beta_X^W \equiv \frac{(1-S_{uk})(\sigma-1)}{\left(1-\sigma_{WW}^C+S_{uk}\kappa(\sigma-1)\right)S_{WC}}$ measures the pass through of higher export prices into wages, which is positive for downward sloping labour demand.

To sum up, the sterling depreciation raises intermediate import prices and export revenues. When workers and intermediate imports are Allen-Uzawa complements, the sterling depreciation induced rise in intermediate import prices lowers wages in industries that experience greater intermediate imports weighted depreciation. In contrast, the rise in export revenues induced by a sterling depreciation raises wages in industries that experience greater export-weighted appreciation.

3.3 Generalizing to Human Capital

In the previous Section, we focused on inelastic labour supply to industries and allowed for one margin of adjustment in workers outcomes - wage rates. Wage contracts are often sticky too. When wages are downward sticky, our estimation strategy would still capture the impact on workers through slower wage growth when comparing across industries that are more or less exposed to the sterling depreciation. If worker contracts cannot be re-negotiated in response to the Brexit news, then we would not be capturing the margins of adjustment in labour demand. We therefore generalize our theoretical framework to examine alternative ways in which industries can adjust their labour costs in response to the Brexit news shock.

Let the unit cost function be $C = C\left(R\left(W_o, W_H\right), P_M\left(P_i\left(P_{si}\right)\right)\right)$ where labour choices now take a nested form consisting of industry-specific labour demand and hu-

man capital which costs W_H per unit to provide job-related education and training to workers. We assume that training and overtime costs do not change with the Brexit news, though the model can be easily extended to accommodate them. Human capital is accumulated by investing in training workers, and the firm's optimal choice is

$$H_o = C_R\left(R\left(W_o, W_H, W_T\right), P_M\left(P_i\left(P_{si}\right)\right)\right) R_{W_H}\left(W_o, W_H, W_T\right) \sum_d \tau_{od} Q_{od} / E_d$$

where C_R is the partial derivative of the unit cost function with respect to labour costs R and R_{W_H} is the partial derivative of the labour costs with respect to the human capital costs W_H. Firms cannot immediately hire and fire workers, but they can employ their workers to perform overtime work.

Putting together all the worker outcomes - wages, human capital and training, we can express the structural equations for $Y_o \in \{W_o, H_o\}$ as follows:

$$\hat{Y}_o = \alpha_Y + \beta_M^Y \hat{P}_{Mo} + \beta_X^Y \hat{P}_{Xo} \tag{3.3}$$

The coefficients for the wage equation are $\beta_M^W \equiv -\frac{\left(1-\sigma_{RP_M}^C + S_{uk}\kappa(\sigma-1)\right)S_{P_M C}}{\left(1-\sigma_{RR}^C - \sigma_{WW}/S_{RC} + S_{uk}\kappa(\sigma-1)\right)S_{RC}S_{WR}}$ and $\beta_X^W \equiv -\frac{(1-S_{uk})(\sigma-1)}{\left(1-\sigma_{RR}^C - \sigma_{WW}/S_{RC} + S_{uk}\kappa(\sigma-1)\right)S_{RC}S_{WR}}$. Compared to the baseline framework, the main change is that the elasticities of substitution are expressed in terms of total labour costs R rather than just the wage rate. The coefficients for the human capital equation are $\beta_M^H \equiv \beta_M^W S_{WR}\left(\sigma_{W_H W}^R - \sigma_{WW}^R\right)$ and $\beta_X^H \equiv \beta_X^W S_{WR} S_{WR}\left(\sigma_{W_H W}^R - \sigma_{WW}^R\right)$. Under the earlier assumption that own elasticities are large in magnitude than cross elasticities of substitution, the expected signs of human capital and overtime changes are the same as for wages.

Finally, the reduced form equations implied by the structural equations are

$$\hat{Y}_o = \alpha_{YY} + \beta_M^{YY} \hat{E}_{Mo} + \beta_X^{YY} \hat{E}_{Xo}. \tag{3.4}$$

$$\hat{P}_{Mo} \equiv \alpha_M + \beta_{MM} \hat{E}_{Mo} \tag{3.5}$$

$$\hat{P}_{Xo} \equiv \alpha_X + \beta_{XX} \hat{E}_{Xo} + \beta_{MX} \hat{E}_{Mo} \tag{3.6}$$

where $\beta_M^{YY} \equiv \beta_M^Y \beta_{MM} + \beta_X^Y \beta_{MX}$ and $\beta_X^Y \equiv \beta_X^Y \beta_{XX}$ for brevity. The next Section estimates the structural equations 3.3 and the reduced form equations 3.4 using cross-industry variation in worker outcomes, intermediate import prices, export prices and the related sterling depreciation measures.

4 Research Design and Data

Data

A combination of individual-level and industry-level data sources from the UK, supplemented by trade data from various sources, are used. Information on individual worker outcomes comes from the quarterly Labour Force Survey (LFS), a large-scale representative survey of around 38,000 responding households in each quarter. The quarterly survey has a longitudinal design with households staying in the sample for five consecutive quarters, and a fifth of the sample replaced each quarter (which generates an 80% overlap in the samples for each successive survey). To cover a long enough pre-period before the referendum, LFS data was compiled for four full pre-referendum survey years, beginning in 2012 Q3, and two full post-referendum years, ending in 2018 Q2. The analysis therefore covers sixteen quarters pre-referendum (where the last quarter, 2016 Q2, includes the June 2016 referendum) and eight quarters post-referendum.

The two worker outcomes studied are hourly wages and job-related education and training. The hourly wage is defined for full-time private sector workers aged 22 to 65, based upon the wage and hours questions asked in quarters 1 and 5 of the LFS. The survey also contains a series of questions on training, asked to individuals in all five quarters. The main one studied in this paper is whether individuals report that they received job related education and training in the four weeks preceding the survey.[20] There is also a longer window measure, which asks LFS respondents whether they have participated in training in the three months before the survey. Finally, LFS variables on gender, age, whether individuals have a degree, are natives, region and size of workplace are used as control variables in the empirical analysis.

Trade data was matched to the individual-level LFS data at the two-digit level, across the whole economy. This covers 85 industries, comprising 23 in manufacturing and 62 in services. This is the finest level of disaggregation at which supply-use tables are available for the UK, and for which there are reasonable sample sizes when matched to the Labour Force Survey. The trade measures come from the Office of National Statistics (ONS), including publicly available information on trade prices for manufacturing industries and from a freedom of information request we undertook to

[20]The four week aspect of the question does cause an issue in the weeks immediately following the referendum of June 23. The LFS survey is carried out in various weeks within the relevant quarter and so for the main analysis observations when individuals were surveyed on June 26, July 3, July 10 and July 17 of 2016 are omitted. This turns not to matter for the overall results, as is discussed later.

obtain trade prices for services. Two price indexes are produced by ONS, for exports and for intermediate import prices, and these are used in the analysis of the impact of the sterling depreciation on trade outcomes. The trade weights used to construct the exchange rate measures are based on pre-referendum data in 2015 combining goods trade from UN COMTRADE and services trade from ONS International Trade in Services (ITIS). As discussed above, and because it offers an exogenous currency shock, the exchange rate changes ΔE are measured for most of the analysis for the 24 hour window around the referendum date between June 23 and 24, 2016.

The share S_{odx} and S_{sio} for industry o are taken from the industry-country values of exports and imports reported in the ITIS by firms in each output industry. For goods, the UK does not conduct a corresponding input use survey across firms. It is therefore necessary to use supply-use tables to construct $S_{sio} = S_{io}S_{si}$ for goods, where S_{io} is the share of imports of intermediate i used in output industry o from the UK Supply-Use tables and S_{si} is the share of source country s in UK imports of intermediate i in the pre-referendum period from UN COMTRADE data. For the bulk of the analysis, industries are classified according to SIC 2007 2-digit codes. This is the finest level of disaggregation at which supply-use tables are available for the UK, and for which there are reasonable sample sizes in the Labour Force Survey.

Research Design

Reduced form difference-in-differences specifications relate the outcomes of interest – trade prices and worker outcomes – before and after the EU referendum to the pre-referendum trade weighted industry-specific depreciation shock. The reduced form approach for labour outcomes has similarities to recent papers on trade and labour market outcomes, which typically examine employment as the dependent variable with initial trade or trade policy exposure as the independent variable across manufacturing industries (for example, Pierce and Schott 2016; Acemoglu et al. 2016). Estimating both trade price and worker outcome reduced forms means they can be combined in an instrumental variable setting to study the causal impact of trade prices on worker outcomes.

The reduced form impact of the exchange rate appreciation/depreciation on trade and worker outcome measures is modelled in a difference-in-differences framework where the relevant pre-referendum trade weighted sterling appreciation/depreciation is entered as an independent variable interacted with a post-referendum dummy variable. For the trade reduced form – the first stage - this can be estimated with industry-level quarterly

panel data using the following specification for industry o in quarter q of year t:

$$log(P^T_{oqt}) = \alpha_o + \alpha_{qt} + \beta_{TT}\Delta E_{To} * Post_{qt} + \gamma_1 X_{oqt} + \varepsilon_{oqt} \tag{4.1}$$

where P^T_{oqt} is the relevant trade price ($T = X, M$) for output industry o, α_{qt} are quarter-year fixed effects, X is a set of controls (comprising demographics of workers in the industry) and ε_{oqt} is an error term.

The difference-in-differences estimate of interest in equation 4.1 is β_T, the coefficient on the interaction between the relevant trade weighted appreciation or depreciation measure, denoted by ΔE, and the post-referendum dummy variable $Post$. The coefficients include $\beta_{MM}, \beta_{XM}, \beta_{XX}$ across specifications. The inclusion of output industry fixed effects α_o absorbs the time-invariant level of the trade-weighted exchange rate appreciation/depreciation, and so this is controlled for throughout in the empirical work.

The reduced form for worker outcomes is analogous to Equation 4.1 for worker i in output industry o in quarter q of year t becomes:

$$log(Y_{ioqt}) = \alpha_o + \alpha_{qt} + \beta^{YY}_T \Delta E_{To} * Post_{qt} + \gamma_2 X_{ioqt} + \upsilon_{ioqt} \tag{4.2}$$

where Y is the worker outcome of interest – in this case training and wages – and υ is an error term. In Equation 4.2, the difference-in-differences estimand of interest is β^{YY}_T. Of course, the key variation is at industry-level as all statistical inference from appropriately computed standard errors is conducted at this level.

The industry aggregated (or equivalently the individual-level industry weighted) reduced forms 4.1 and 4.2 can be combined with the trade price regressions to estimate a structural form which, under the assumption that ΔE_T is a legitimate instrument that can be excluded, enables identification of a causal effect of trade on worker outcomes Y. The precise specification is:

$$log(Y_{ioqt}) = \alpha_o + \alpha_{qt} + \beta^{Y}_T log(T_{oqt}) * Post_{qt} + \gamma_2 X_{ioqt} + \upsilon_{ioqt} \tag{4.3}$$

with υ being the error term of the equation. The difference-in-differences instrumental variable estimate is β^Y_T, which is equal to β^{YY}_T/β_{TT}, the ratio of the two reduced form coefficients on $\Delta E_T * Post$ in equations (4.1) and (4.2).

5 Results and Discussion

This section reports the paper's main findings. Following a discussion of the basic pre-post referendum features of the data, statistical results based on the trade and labour reduced forms are first discussed, after which the discussion moves to highlight how the reduced form findings can be combined to form the structural form estimates showing the causal impact of trade prices on worker outcomes. The causal estimates are then interpreted in a calibration exercise that connects back to the model presented in Section 3.

Raw Difference-in-Differences

Table 2 shows what happened to the trade and worker outcome measures before and after the referendum by reporting average changes between 2012 Q3 and 2016 Q2 (the before period) and 2016 Q3 and 2018 Q2 (the after period). The Table shows before/after referendum changes by quintiles of the exchange rate change measures, with panel A showing before /after changes by intermediate import weighted depreciation quintiles and panel B by exports weighted appreciation quintiles.

Considering first the before/after changes in trade prices with respect to the intermediate import weighted depreciation, columns (1) and (2) of panel A show clearly that higher depreciation industries experienced faster growth in intermediate import prices but not in export prices. On the former, the price of intermediate imports were 8.1 log points higher in the highest quintile depreciation industries in the post-referendum period, a higher growth rate than in the other quintiles, with the lowest increase of only 3.7 log points occurring in the lowest quintile. Growth in intermediate import prices in the middle three quintiles lies in between the two. The implied differences-in-differences between the top and bottom quintile is therefore 4.4 log points, reflecting a much bigger cost shock resulting from higher prices in the industries facing a higher exchange rate depreciation because of the differential magnitude of exchange rate depreciations arising from the referendum dependent upon which countries they import intermediates from. The same is not true of export prices, which also rise in the post-referendum period albeit in a very neutral pattern with a highly similar rate of growth across quintiles.

There are also between-quintile depreciation differences in pre-post referendum changes in log(wages) and training receipt. These are shown in columns (3) and (4) of panel A of Table 2. Wage growth is seen to be lower in the relatively higher depreciation industries. In the highest fifth of industries ranked by depreciation, wages are around 6 percent higher, whereas in the bottom two quintiles they rise by nearly 9 percent.

This corresponds to a highest-lowest quintile difference-in-differences of 2.7 log points. In qualitative terms, the same is true of training receipt. It falls by 0.8 of a percentage point in the upper quintile, and stays almost the same in the lowest quintile, again reflecting a statistically significant difference-in-differences of a -0.7 percentage point drop in training.

There is much less responsiveness – for all four outcomes variables – in the lower panel of Table 2 which considers pre-post referendum changes by quintiles of the exports weighted exchange rate appreciation. All of the highest-lowest quintile difference-in-differences are small in magnitude and statistically insignificant. In fact, the pre-post referendum changes are in all cases highly similar across all five quintiles for both trade price measures and both worker outcome variables.

The main action on changing trade price patterns and worker outcomes across industries facing differential exchange rate shocks therefore very much comes about on the cost side of things, due to differences in intermediate imports weighted depreciations. This can be seen clearly in the scatterplots shown in Figures 2 and 3 charting the pre-post referendum changes for all 85 industries against the depreciation/appreciation measures for trade prices and worker outcomes.

Trade Prices

Table 3 shows results from estimating difference-in-differences reduced form specifications for prices of intermediate imports and exports. Results from log-log specifications are reported so that the coefficients on the depreciation/appreciation measures are elasticities and, because of this, so that the size of the estimates can be benchmarked against other estimates from the exchange rate pass through literature. As the theoretical framework suggests, only the intermediates import weighted depreciation is entered on the right hand side of the log(intermediate import prices) regression, whilst both this and the exports weighted appreciation are included regressors in the log(export prices) equation. Three specifications were estimated for each trade price, with the time period of estimation being different in each after a careful empirical examination of pre-referendum events and trade price trends was considered.

The first specification, in column (1), reports estimates for the full sample of all 24 quarters between 2012 Q3 and 2018 Q2. In the case of intermediate prices, shown in panel A, there is strong evidence that the exchange rate depreciation had a significant price raising impact, with an estimated elasticity of 0.38. This shows that industries with a higher sterling depreciation faced a bigger cost shock. 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 3.8 percent. This is sizable, and in line with magnitudes seen in other work looking at price pass-through for imports. For example, in their study of large devaluations, Burstein and Gopinath (2014) estimate an exchange rate pass through of 0.37 for the UK.[21]

The full sample specification for export prices, shown in column (1) of panel B, however does not show responsiveness of export prices to either exchange rate measure. Both estimated coefficients are positive, but statistically insignificant.[22] In fact, the estimated price pass through from the exports weighted exchange rate appreciation is tiny at 0.006, and shows no pass through at all in pound terms. [23]Maybe surprisingly, one cannot reject the null hypothesis that the Brexit vote induced exchange rate appreciation had no differential effect on industry export prices. Nonetheless, the column (1) specifications are suggestive that it is the cost channel that dominates in terms of reflecting effects of the referendum induced exchange rate shifts. It implies the main impact was to raise the price of intermediate imports, thus generating a cost shock that disproportionately hit industries more exposed to higher currency depreciations.

While some studies find high pass through of exchange rate shocks on export prices, our findings are more in line with the literature on global value chains where importing and exporting go hand in hand and access to intermediate inputs from abroad enables firms to export.[24] They are consistent with the existing literature on intermediate imports, which finds that exports from OECD countries contain a large fraction of imported content.

It is, however, premature to reach this conclusion without first considering possible pre-referendum trend differences in the trade price outcomes of interest. We explored this carefully in various ways, looking at pre-trend differences in trade prices by depreciation/appreciation quantiles, and from including pre-trend quarter interactions. It turns out that two pre-trend events may have resulted in there being some pre-referendum differences in the evolution of trade prices for higher and lower de-

[21]The 0.37 is their concurrent estimate (cumulative estimates over a two year window are even larger).

[22]If the exports weighted appreciation variable was also entered into the intermediate imports price regressions, it always attracted a statistically insignificant coefficient and barely moved the estimated coefficient on the depreciation measure. For the column (1) panel A specification, the estimated coefficient (and associated standard error) was -0.007 (0.022) for the log(exports weighted appreciation) and 0.383 (0.100) for the log(intermediate imports weighted depreciation).

[23]The same is true if only the log(exports weighted appreciation) variable was entered.

[24]See, inter alia, Amiti and Konings (2007); Kugler and Verhoogen (2009); Kasahara and Lapham (2013); Halpern et al. (2015); Kugler and Verhoogen (2012). See Berman et al. (2012) for export pass through.

preciation/appreciation industries. The first of these is the announcement that the referendum would take place, which was made on 22 February 2016. Exchange rates did react to the news of this announcement, albeit in a more muted aggregate manner when compared to the referendum result, as there was a drop in sterling on the day and the days that followed. One might be concerned about the potential of this pre-referendum drop in exchange rates to influence pre-trends, especially since the structure of the exchange rate drop was very similar in terms of relative depreciations of sterling against different currencies, and because of possible hedging behaviour by firms.[25]

Column (2) of Table 3 shows what happens to the results if the time period between the referendum announcement and the actual referendum is excluded. The results remain much the same and the pass through to intermediate import prices actually rises a little, going up to 0.41 from 0.37. The exports price results are also highly similar. A second possible identification threat owing to differential pre-trends is potentially a more serious one, as there was a reasonably sustained exchange rate depreciation that occurred in the pre-referendum period which relates to when the United States stopped its quantitative easing programme and when the European Central bank began theirs. From 1 September 2014 to the announcement date, there was a sharp drop in the pound-dollar exchange rate from 1.66 to 1.42, and a modest rise in the pound-euro exchange rate in the same period. These patterns are, of course, the same in relative terms as the referendum variation that we use in this paper.[26]

Figure 4 shows how this – and to a lesser extent the referendum announcement – do cause some issues with the parallel trends assumption we require for identification. The chart plots above/below median trends in log(intermediate import prices) for the 24 quarters of our empirical analysis. The trends are highly similar until the QE ceasing from the US occurs. There is then some divergence, after which the trends become similar again. Because of this, we have also excluded the QE depreciation quarters from the estimation. Results from doing so for trade prices are shown in column (3) of Table 2. The price pass through estimate actually rises again, going up to 0.53 from the column (1) estimate of 0.38. It thus seems that, if anything, the trade price responsiveness is underestimated owing to these pre-referendum trends, but that the evidence of a significant cost shock due to the referendum induced exchange rate

[25]For the 26 currencies in Table 1, there is a Spearman rank correlation of 0.67 (with an associated p-value of 0.00) for the referendum date depreciation and the announcement depreciation (the latter being defined for a 7 day window around 22 February 2016).

[26]A significant correlation between the 24 hour referendum window and QE depreciation is clear for the 26 currencies in Table 1, with a Spearman rank correlation of 0.62 (with an associated p-value of 0.00) for the referendum date.

depreciation remains strong.

Wages

Table 4 reports estimates of reduced form difference-in-differences log(wage) equations and combines them with some of the trade price first stages from Table 3 to report causal IV estimates of the impact of trade prices on wages. Estimates from four reduced forms are reported in the odd numbered columns of the Table and are converted to their respective paired IV estimates in the adjacent even numbered columns. The upper panel A shows two sets of reduced form and IV paired results for the full sample, whilst the lower panel B shows estimates for the restricted samples already considered for the trade price results.

The wages reduced form, shown in column (1), shows a significant wage lowering effect of the intermediate imports weighted depreciation. The estimated elasticity is -0.20, showing that a 10 percent higher exchange rate depreciation was connected to a 2 percent fall in wages. Combining this with the first stage trade price elasticity of 0.38, produces the causal IV elasticity of -0.52 reported in column (2). Thus, by using the referendum induced exchange rate depreciation as an instrumental variable for intermediate import prices uncovers a causal wage reducing impact of the trade induced cost shock that occurred.

The reduced form and IV estimates pair in columns (3) and (4) instrument both intermediate import and export prices using their respective trade weighted exchange rate changes. Not surprisingly given there is not a significant first stage for the export based measure, the results lose some precision but importantly the reduced form impact of the intermediate imports weighted depreciation and the associated causal estimate remain highly robust (the former going to -0.204 as compared to -0.201, and the latter to -0.545 from -0.515).

Even more reassuringly, the lower panel estimates that restrict the samples owing to the identification concerns raised by the referendum announcement and the earlier QE induced depreciation produce reduced forms that are incredibly similar. When the announcement to referendum time periods are left out, the reduced form estimate shown in column (5) is -0.206 and when the QE period is omitted the estimate in column (7) is very close at -0.190. Thus the reduced form estimates are highly consistent and stable with the cost shock resulting from the referendum having a significant wage growth slowing impact.

The strongly consistent reduced form impacts observed in the different comparison

periods reflect that there are no significant issues on diverging pre-trends in wages before the referendum. However, because there was some degree of change in the first stage coefficients, the paired causal IV estimates shown in columns (6) and (8) do move somewhat. For the sample excluding the announcement to referendum time, the IV estimate gets a little smaller (in absolute terms) to -0.483; for the sample further excluding the QE depreciation period it becomes -0.343. Both estimates, however, show there to be a causal wage reducing impact of higher intermediate import prices. The range is useful to demonstrate robustness of the key finding of a negative wage-intermediate import price elasticity, and for use as checks of sensitivity in the model calibration, to which the paper next turns.

Calibration

The estimated wage elasticity with respect to intermediate import prices is negative in all reported specifications, in a range from -0.35 to -0.55 which amounts to evidence for a gross complementarity between workers and intermediate imports. To understand what the elasticities imply about the Allen Uzawa elasticity of substitution, we specify the parameters from data. For our baseline, the indirect effects are set to zero, which corresponds to sticky prices ($\kappa = 0$) or unit cost pricing ($\sigma = 1$). The elasticity of labour demand is taken as -0.5 which is standard in the literature for short term labour market responses. The range of Allen Uzawa elasticities is then -2.15 to -3.95 in Table 5 which implies net complementarity. The indirect effects from domestic costs are also absorbed in the estimated structural wage coefficient. To calibrate to the demand side, the probability of non-adjustment is set to $\kappa = 0.75$ and the elasticity of substitution is varied between 3 and 5, based on the literature. Then the range of Allen Uzawa elasticities increases in magnitude to -2.50 to -6.47.

Training

An analogous set of results to the wage equations shown in Table 4 are given for worker training in Table 6. They very much act to confirm the negative effect of the cost shock induced by the exchange rate depreciation following the referendum vote. The results very clearly show that workers employed in higher depreciation industries experienced a significant fall in training. The reduced form impact is, as it was for wages, relatively stable across the four specifications reported in the odd number columns (always being negative and statistically significant, and in the range from -0.048 to -0.073 showing that for a 10 percent higher intermediate imports weighted sterling

depreciation the probability of training receipt was around 0.5 to 0.7 of a percentage point lower). The causal estimates of the impact of intermediate import prices, shown in the even numbered columns, is also negative. Thus, overall the cost shock from the referendum induced fall in sterling had a wage lowering, deskilling impact on UK workers.

Extensions

Various other extensions and probes of robustness were undertaken:

Initial trade structure

One further question of interest is whether the initial trade structure also impacted upon trade changes, or whether it is the exchange rate impact upon intermediate prices that was the key outcome associated with the referendum induced exchange rate depreciation. Table 7 considers this by additionally entering the share of imported inputs in total inputs interacted with the post-Brexit vote dummy into the estimating equations.[27] In undertaking this exercise, it is important to bear in mind that any levels effect of these variables are absorbed into the industry fixed effects that have been included in all the statistical specifications already reported. The estimated coefficients on the interacted initial trade structure measures themselves turn out to be statistically insignificant and do not affect the general tenor of the results. This suggests the country variations in depreciations are what matters for the overall findings.

Indirect imports channel

The revenue and cost channels of the trade changes resulting from the sterling depreciation have been considered so far in terms of exports and intermediate imports, with economic effects resulting more from the latter than former channel. This does not consider any possible additional effects that may result from easing of import competition in final goods and services that may have the followed the referendum vote. This could, in principle, act to further change the structure of sales in the domestic market and, if present, this could benefit domestic producers. It also does not capture indirect imports that the industries might be buying from other industries.

[27] We also experimented with including an interaction with the share of exports in final demand. Its inclusion had no impact and since there is no first stage on the exports side of things, we did not purse this further.

Because of data limitations, in particular not having available data on prices of final imports, we can only investigate this possibility through consideration of an imports weighted exchange rate depreciation measure that also accounts for the imports of the industry coming into other industries. To do so, a total imports based exchange rate depreciation variable was constructed by adding up all the purchases of imports of o coming across all other industries $o' \neq o$. Table 8 shows what happens to the trade price, wage and training reduced form results when this measure of total import weighted exchange rate depreciation is included. The pattern that emerges is fairly clear to see, namely that the measure which includes both indirect imports to weight the country specific exchange rate depreciations attracts an estimated coefficient of the same sign as the intermediate imports weighted measure, but it is always smaller in magnitude, and often statistically insignificant. This is what would be expected if the other industries do not pass on all the costs arising from the sterling depreciation to the indirect buyers. Moreover, it does not change the pattern of results on the impact of the intermediate inputs weighted depreciation at all.

Alternative exchange rate timings

For reasons already discussed in detail, the exchange rate variation exploited in the empirical work so far is the plausibly exogenous change that took place in between June 23 and 24 of 2016. Of course, exchange rate fluctuations that take place around a time window any longer than the information period reflecting the unexpected nature of the Brexit referendum shock may occur for reasons not to do with the shock itself then this plausibility is reduced. Looking at correlations with the 24 hour change and windows of 7 and 15 days reflects exactly this – the correlation is very strong for 7 days, but weakens as the window is widened. Tables A2 and A3 of the Appendix shows comparable results to those using the 24 hour window measure, but by replacing the intermediate imports depreciation measure with one calculated in the same way for time windows of 7 and 15 days. The 7 day window results, shown in Table A2, prove very similar, albeit a little less precise in statistical terms. For the 15 day window, this imprecision becomes more marked, in line with the argument that exchange rate movements are likely reflecting other information flows not related to the foreign exchange markets reaction to the unexpected referendum vote.

Hours estimates

Appendix Tables A3 and A4 show total hours and overtime hours results. Table A4 shows a weakly negative hours coefficient associated with the exchange rate depreciation, and one cannot reject the null of a zero effect in the IV models. Table A5 focusses only on hours of paid overtime, and does uncover evidence of significant reductions, suggesting this is a margin by which employers were able to adjust to the depreciation shock. This complements the training cutback evidence shown earlier, which suggests that it was not just wages that fell as a result of the depreciation induced cost shock that occurred. This is consistent with Campa and Goldberg (2001) who also find much higher magnitudes of overtime elasticities using two decades of annual data from US manufacturing, and suggests that flow variables (like training and overtime) can be used to detect early signs of economic adjustments to shocks. They are likely to respond faster than stock variables like employment that are also subject to contractual obligations and search frictions.

Finally, as the wage analysis reported to date was for full-time workers, Table A5 also shows a robustness check looking at the wage for all workers. The estimates are statistically a little bit stronger and the magnitudes of the causal IV estimates a little larger (in absolute terms) with the main result of wage falls being connected to the rise in the costs of intermediate inputs remaining strong.

Further robustness checks

Further robustness checks, relating to the training and wages measures used, are reported in Appendix Table A6, first studying what happens when the observations that were previously excluded on the grounds of being within a four week window of the referendum are put back into the analysis, second looking at an alternative training measure from the Labour Force Survey. The first two columns of the Table also show that reinstating the previously excluded observations also does nothing to the basic IV results. The negative wage and training effects remain intact, and highly similar to the estimates reported in the earlier Tables 4 and 6. The final column (3) of the Table shows results for training receipt over a longer time period, the three months preceding the survey. This offers a useful counterpoint to the more commonly studied four week measure, in that it is likely to have a lower proportion of induction training for newly hired workers. The estimates prove robust and, if anything stronger in statistical terms, when using this measure.

6 Conclusions

This paper presents new evidence on the empirical connections between trade and the labour market, by considering what happened to both trade and worker outcomes in the face of a big world event that produced an unprecedentedly large negative shock to the UK exchange rate. In the 24 hours around the previously unexpected vote by the UK electorate to leave the European Union, the value of sterling fell massively against other nations' currencies. The empirical analysis exploits this exogenous variation and its variation by the different currency structure of industries to look at the causal impact of trade on wages and future earnings potential measured by job related education and training.

The results that emerge are striking and show that intermediate import prices rose by more in sectors where the exchange rate depreciated by more and that this had a negative effect on worker outcomes. Both training and hourly wages fell for workers employed in sectors where the intermediate import price rose by more because of the sterling depreciation. The finding of a reduction in wages and training after the Brexit vote offers poignant evidence on how the recent surge in economic nationalism is affecting workers. Many have argued that the economic disparities of the last few decades have polarised people and contributed to the current rise in nationalist politics. The common rationale behind nationalist policies is that putting up protectionist barriers will protect domestic production and undo the economic damage suffered by those who lost out earlier. But this reasoning does not account for the fact that trade is no longer dominated by final demand, and the fragmentation of production into global value chains has changed the classic reasoning on protectionism. Calibrating the estimated wage elasticity with respect to intermediate import prices to theory shows complementarity between workers and intermediate imports. At the very least these results show that trade is no longer dominated by final demand, and that in the modern world of global value chains, the way in which trade impacts on worker welfare needs to be reappraised.

To reiterate the point, in a classic setting with just trade in final goods, the sterling depreciation from the Brexit vote would be expected to benefit UK exporters and increase demand for domestic workers. We find instead that it had a relatively deskilling workers in industries that rely on specific foreign sources for their intermediate inputs. Although export prices fall in terms of foreign currencies, the rise in the costs of imported inputs create relatively worse worker-level outcomes in industries experiencing higher depreciation of imported input prices. This could translate into a long-term neg-

ative impact on human capital and worker earnings — quite the opposite of what the leave vote was expected to deliver by many. The cut back in training is accompanied by a rise in the prices of imported goods and services since the Brexit vote. Breinlich et al. (2017) find that inflation after the Brexit vote was higher in product categories that had higher shares of imported products. Therefore, the evidence shows there has been a relative decline in real earnings for workers since the Brexit vote, which has likely acted to reinforce pre-existing trends of real wage stagnation that have already been particularly marked for UK workers in the past decade (see Blanchflower et al. 2017).

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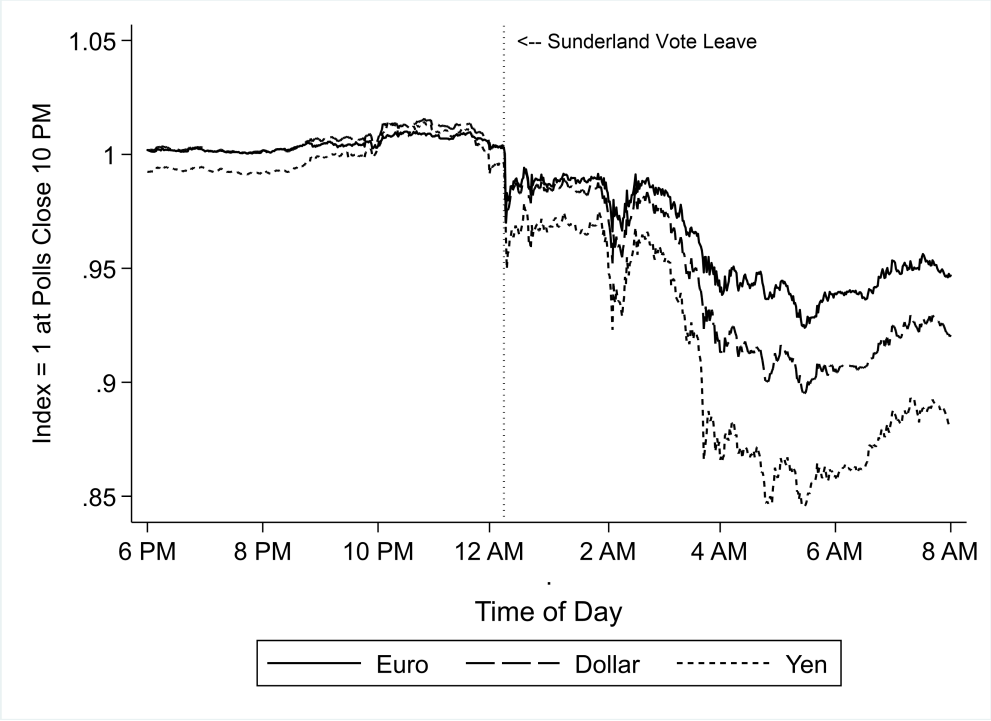
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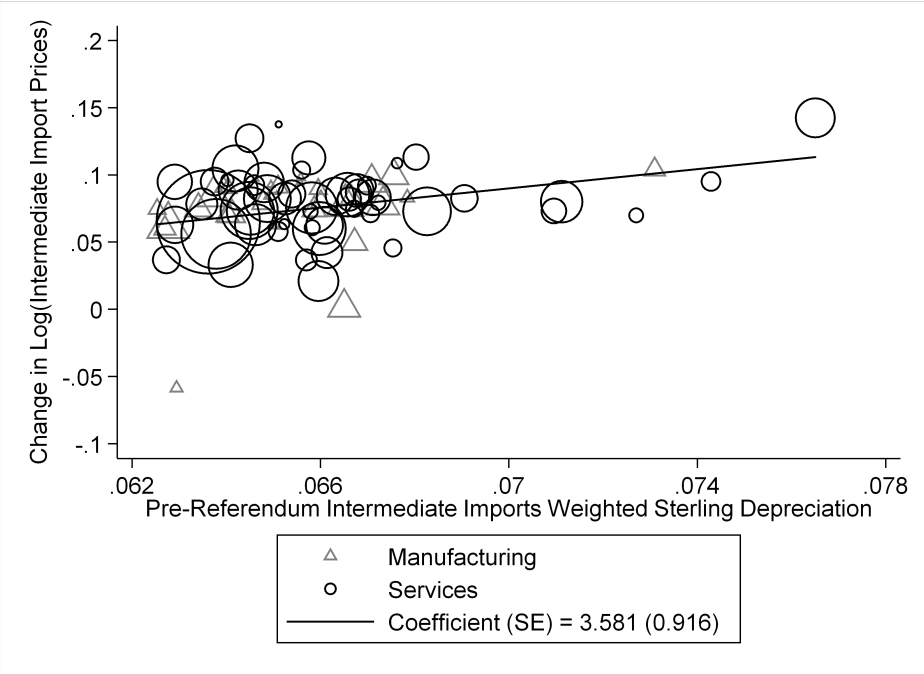
Figure 1: Exchange Rate Movements in the 6 PM to 8AM Window Around The Referendum



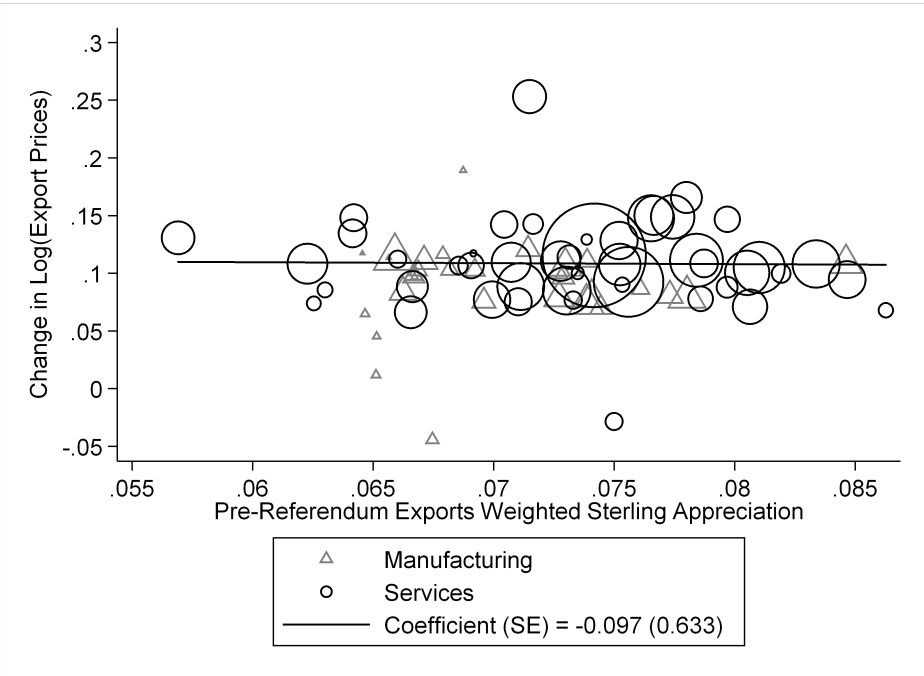
Notes: Exchange rates are taken from HistData (FOREX).

Figure 2: Pre/Post Referendum Changes in Trade Prices and Exchange Rates

(a) Intermediate Import Prices



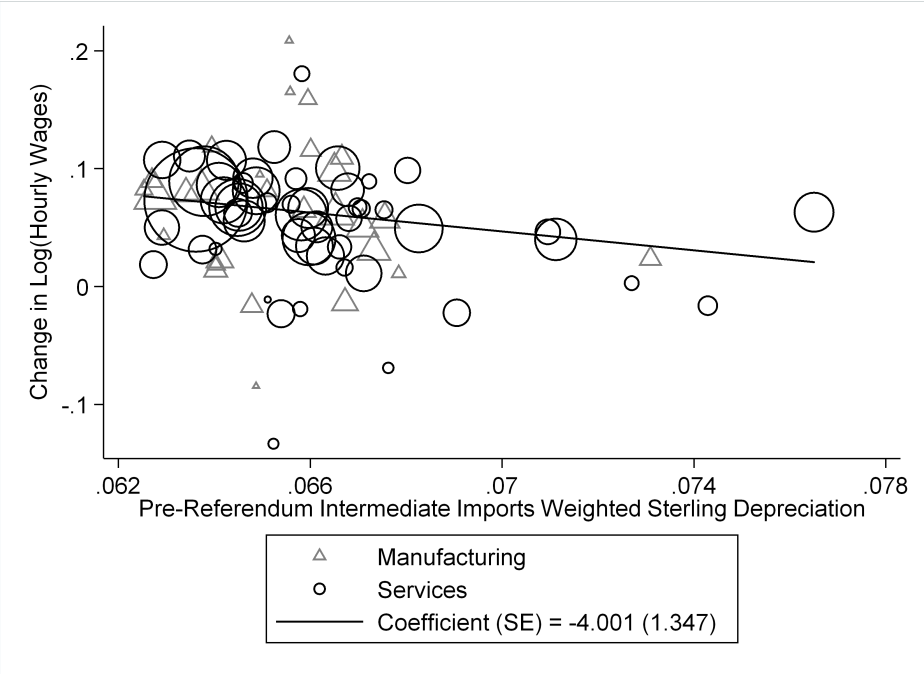
(b) Export Prices



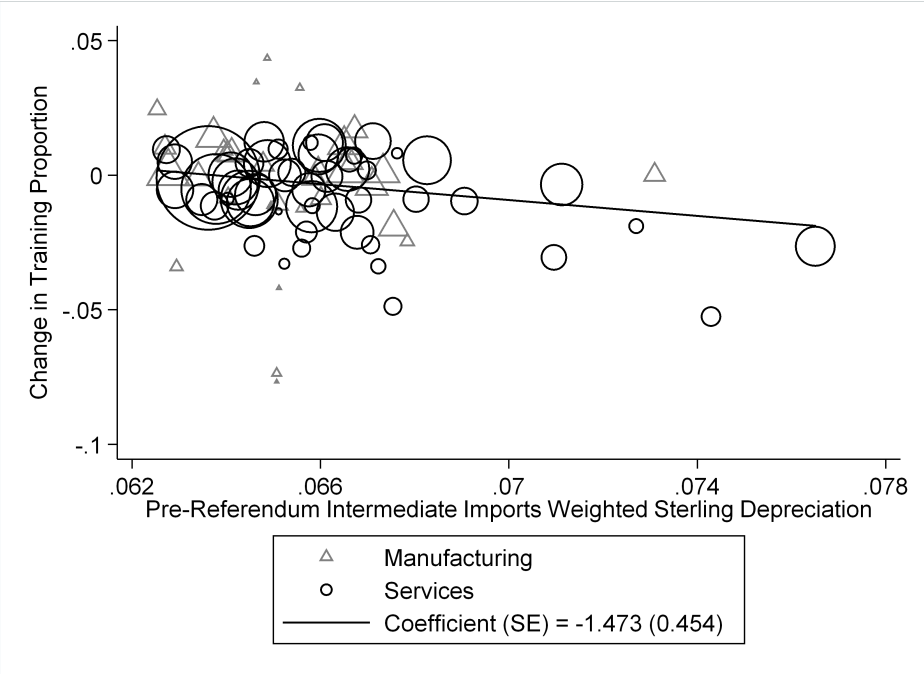
Notes: Size of the markers correspond to LFS industry weights.

Figure 3: Pre/Post Referendum Changes in Worker Outcomes and Exchange Rates

(a) Wages



(b) Training



Notes: Size of the markers correspond to LFS industry weights.

Figure 4: Trends in Intermediate Import Prices

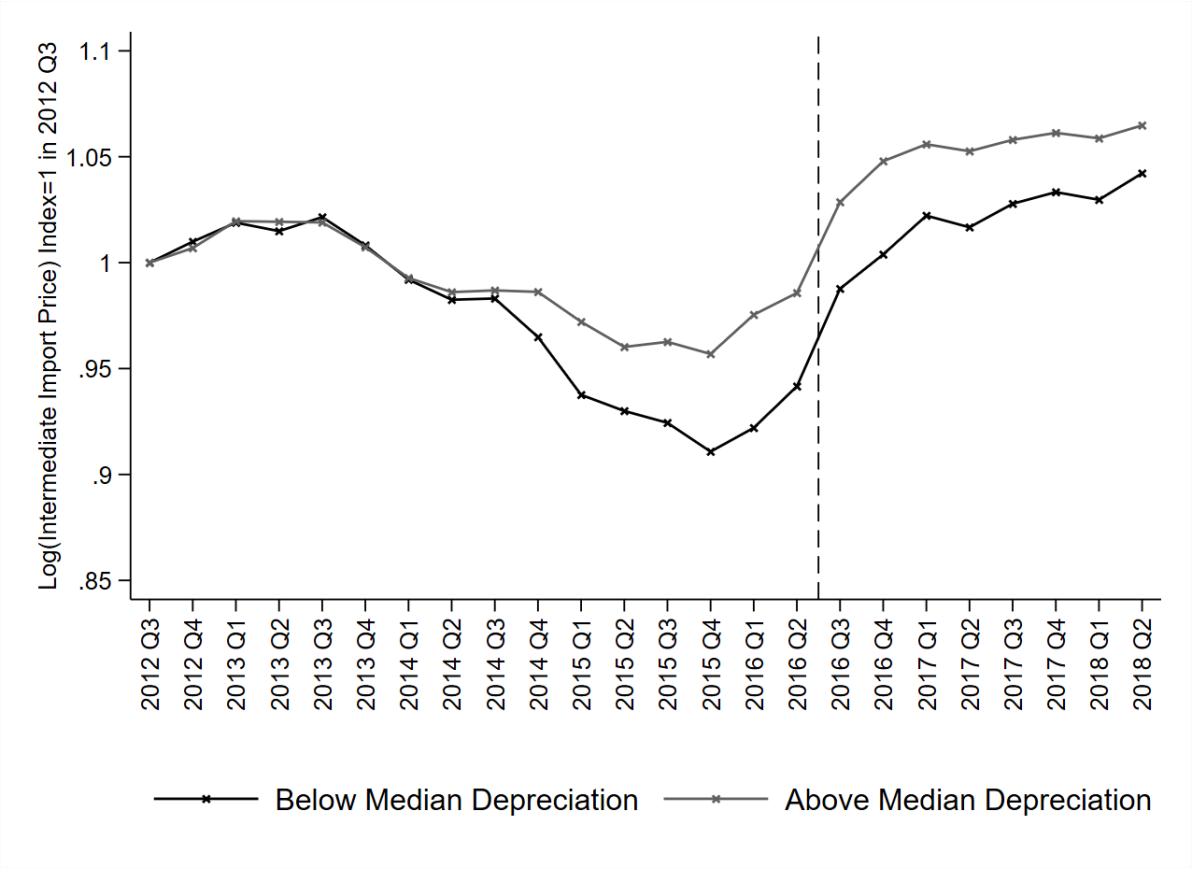


Table 1: Country Specific Sterling Depreciations, 23 to 24 June 2016

	Currency	Percent Depreciation
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

Notes: Exchange rate depreciations defined over 24-hour window for official set of currencies listed by the Bank of England.

Table 2: Pre-Post Referendum Changes in Trade Prices and Worker Outcomes

	Post - Pre Referendum Changes			
	Intermediate Import Prices	Export Prices	Wages	Training
	(1)	(2)	(3)	(4)
A. Intermediate Imports Weighted Depreciation				
Highest Quintile	0.081	0.105	0.060	-0.008
	(0.008)	(0.010)	(0.007)	(0.003)
2nd Highest Quintile	0.043	0.118	0.075	0.003
	(0.009)	(0.009)	(0.010)	(0.002)
Middle Quintile	0.074	0.108	0.077	-0.002
	(0.004)	(0.012)	(0.008)	(0.003)
2nd Lowest Quintile	0.052	0.101	0.087	-0.003
	(0.015)	(0.013)	(0.007)	(0.003)
Lowest Quintile	0.037	0.102	0.087	-0.001
	(0.007)	(0.009)	(0.008)	(0.001)
Difference-in-Differences	0.044	-0.006	-0.027	-0.007
(Highest - Lowest Quintile)	(0.010)	(0.015)	(0.010)	(0.003)
B. Exports Weighted Appreciation				
Highest Quintile	0.052	0.097	0.077	-0.004
	(0.017)	(0.004)	(0.009)	(0.003)
2nd Highest Quintile	0.062	0.125	0.081	-0.001
	(0.013)	(0.015)	(0.009)	(0.002)
Middle Quintile	0.047	0.108	0.064	-0.004
	(0.009)	(0.006)	(0.011)	(0.002)
2nd Lowest Quintile	0.070	0.107	0.073	0.002
	(0.007)	(0.013)	(0.008)	(0.002)
Lowest Quintile	0.051	0.096	0.089	-0.002
	(0.010)	(0.007)	(0.009)	(0.002)
Difference-in-Differences	0.001	0.001	-0.011	-0.003
(Highest - Lowest Quintile)	(0.020)	(0.008)	(0.013)	(0.003)

Notes: Standard errors in parentheses. Weighted by LFS industry weighted cell sizes.

Table 3: Trade Prices and Exchange Rates

	Full Sample	Restricted Samples	
		Excluding Announcement	Excluding QE
	(1)	(2)	(3)
A. Intermediate Imports			
Log(Intermediate Imports Weighted	0.375	0.411	0.526
Depreciation) X Post-Referendum	(0.100)	(0.107)	(0.137)
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	1870	1360
B. Exports			
Log(Intermediate Imports Weighted	0.164	0.171	0.233
Depreciation) X Post-Referendum	(0.111)	(0.114)	(0.136)
Log(Exports Weighted	0.006	0.007	0.009
Appreciation) X Post-Referendum	(0.016)	(0.016)	(0.019)
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	1870	1360

Notes: The dependent variable is log of price of intermediate imports in Panel A and log of price of exports in Panel B. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Regressions are weighted by LFS industry weighted cell sizes. Panel B specifications include a dummy for non-exporting industry interacted with post-referendum period. Full sample is from 2012 Q3 to 2018 Q2. Restricted sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restricted sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

Table 4: Wages, Trade Prices and Exchange Rates

	A. Full Sample			
	Reduced Form	IV	Reduced Form	IV
	(1)	(2)	(3)	(4)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.201 (0.075)		-0.204 (0.074)	
Log(Exports Weighted Appreciation) X Post-Referendum			-0.013 (0.014)	
Log(Price of Intermediate Imports)		-0.515 (0.251)		-0.545 (0.226)
Log (Price of Exports)				0.075 (0.101)
First-Stage F Statistic		14.1		4.6
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	123,489	123,489	123,489	123,489
	B. Restricted Samples			
	Exclude Announcement		Exclude QE	
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.206 (0.074)		-0.190 (0.087)	
Log(Price of Intermediate Imports)		-0.483 (0.221)		-0.343 (0.175)
First-Stage F Statistic		14.1		14.0
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	117,380	117,380	92,492	92,492

Notes: The dependent variable is log of full time hourly wages. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Panel A Columns (3) and (4) specifications include a dummy for non-exporting industry interacted with post-referendum period. Full sample is from 2012 Q3 to 2018 Q2. Restricted sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restriced sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

Table 5: Calibration of Elasticity of Substitution between Workers and Intermediate Imports

(a) Parameter Values for Calibration

	Notation	Value	Source
Ratio of imported intermediate share to labour share	$\frac{S_{P_M C}}{S_{WC}}$	0.1/0.4	ONS
Labour demand elasticity	ϵ^C_{WW}	-0.5	
Share of domestic sales in total sales	S_{uk}	0.70	ONS
Probability of non-adjustment of prices	κ	0.75	Itskhoki and Mukhin (2017)
Output elasticity of substitution	σ	1, 3, 5	Broda and Weinstein (2006)

(b) Estimates for Allen Uzawa Elasticities of Substitution (AUES)

Estimated Wage Elasticity $\hat{\beta}^W_M$	Implied AUES between Workers and Intermediate Imports $\sigma^C_{WP_M}$		
	Baseline	$\sigma = 3$	$\sigma = 5$
(1)	(3)	(5)	(6)
-0.35	-2.15	-2.57	-2.99
-0.40	-2.60	-3.23	-3.86
-0.45	-3.05	-3.89	-4.73
-0.50	-3.50	-4.55	-5.60
-0.55	-3.95	-5.21	-6.47

Notes: Estimated Wage Elasticities in Column (1) are values within the range of the estimated IV coefficient $\hat{\beta}^W_M$. To recover the Allen-Uzawa elasticity of substitution (AUES) between workers and intermediate imports, the parameter values are taken from (a). Baseline corresponds to $\kappa(\sigma - 1) = 0$ which incorporates sticky prices (no adjustment) and perfect competition ($\sigma = 1$).

Table 6: Training, Trade Prices and Exchange Rates

	A. Full Sample			
	Reduced Form	IV	Reduced Form	IV
	(1)	(2)	(3)	(4)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.069 (0.021)		-0.071 (0.022)	
Log(Exports Weighted Appreciation) X Post-Referendum			-0.001 (0.007)	
Log(Price of Intermediate Imports)		-0.184 (0.073)		-0.196 (0.076)
Log (Price of Exports)				0.024 (0.044)
First-Stage F Statistic		14.1		4.9
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	578,282	578,282	578,282	578,282
	B. Restricted Samples			
	Exclude Announcement		Exclude QE	
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.073 (0.022)		-0.048 (0.022)	
Log(Price of Intermediate Imports)		-0.177 (0.073)		-0.090 (0.053)
First-Stage F Statistic		14.8		14.7
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	548,079	548,079	434,431	434,431

Notes: The dependent variable is a dummy for whether the individual received job-related education or training in the past 4 weeks. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Panel A Columns (3) and (4) specifications include a dummy for non-exporting industry interacted with post-referendum period. Full sample is from 2012 Q3 to 2018 Q2. Restricted sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restricted sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

Table 7: Inclusion of Pre-Referendum Intermediate Import Shares

	Intermediate Import Prices	Worker Outcomes	
	First Stage	Reduced Form	IV
	(1)	(2)	(3)
A. Wages			
Log(Intermediate Imports Weighted	0.383	-0.205	
Depreciation) X Post-Referendum	(0.107)	(0.072)	
Share of Imports in	-0.035	-0.026	
Intermediates X Post-Referendum	(0.037)	(0.025)	
Log(Price of Intermediate Imports)			-0.430
			(0.210)
First-Stage F Statistic			8.3
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	123,489	123,489
B. Training			
Log(Intermediate Imports Weighted	0.371	-0.068	
Depreciation) X Post-Referendum	(0.101)	(0.021)	
Share of Imports in	-0.035	0.003	
Intermediates X Post-Referendum	(0.035)	(0.009)	
Log(Price of Intermediate Imports)			-0.177
			(0.068)
First-Stage F Statistic			8.5
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	578,282	578,282

Notes: The dependent variable is log of price of intermediate imports in Column (1), log of full time hourly wages in Columns (2) and (3) in Panel A and a dummy for whether the individual received job-related education or training in the past 4 weeks in Columns (2) and (3) of Panel B. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region).

Table 8: Reduced Forms Including Total Import Weighted Depreciation

	Full Sample			Restricted Samples Excluding Announcement	Restricted Samples Excluding QE
	(1)	(2)	(3)	(4)	(5)
A. Intermediate Import Price					
Log(Intermediate Imports Weighted	0.375		0.357	0.391	0.500
Depreciation) X Post-Referendum	(0.100)		(0.096)	(0.103)	(0.133)
Log(Total Imports Weighted		0.156	0.141	0.159	0.203
Depreciation) X Post-Referendum		(0.052)	(0.053)	(0.057)	(0.067)
Sample Size	2,040	2,040	2040	1870	1360
B. Wages					
Log(Intermediate Imports Weighted	-0.201		-0.192	-0.197	-0.181
Depreciation) X Post-Referendum	(0.075)		(0.077)	(0.077)	(0.090)
Log(Total Imports Weighted		-0.069	-0.059	-0.065	-0.060
Depreciation) X Post-Referendum		(0.045)	(0.045)	(0.044)	(0.048)
Sample Size	123,489	123,489	123,489	117,380	92,492
C. Training					
Log(Intermediate Imports Weighted	-0.069		-0.063	-0.067	-0.043
Depreciation) X Post-Referendum	(0.021)		(0.022)	(0.023)	(0.021)
Log(Total Imports Weighted		-0.051	-0.048	-0.045	-0.037
Depreciation) X Post-Referendum		(0.014)	(0.014)	(0.015)	(0.015)
Sample Size	578,282	578,282	578,282	548,079	434,431

Notes: The dependent variable is log of price of intermediate imports in Panel A, log of full time hourly wages in Panel B and a dummy for whether the individual received job-related education or training in the past 4 weeks in Panel C. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Full sample is from 2012 Q3 to 2018 Q2. Restricted sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restricted sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

A Appendix: Full Timeline of Sterling Depreciation

Thursday June 23, 2016:

- 10pm - 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.
- 10pm - A YouGov opinion poll released at the same time suggests Remain are on course for victory with 52% and Leave on 48%.
- 10.15pm - Ukip's Nigel Farage concedes the Brexit campaign may be beaten and Remain "will edge it" - but promises "Ukip and I are going nowhere".
- 10.30pm - 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.
- 11.25pm - Gibraltar is the first area to declare, with a predictable landslide for Remain at 96% of the vote.

Friday, June 24, 2016:

- 12.04am - The first big result is declared, with a narrow win in Newcastle for Remain with 50.7% against Leave on 49.3%. Newcastle-upon-Tyne was second to announce with a slight win for the Remain campaign by 1,806 votes from a total of 129,072. It was an expected win in Newcastle, but not by the margin many suspected, and shortly afterwards the odds of Leave winning the vote was slashed by bookmakers.
- 12.20am - 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.
- 12.30am - Sterling 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.
- 1.30am – People started to sense that Leave would win, and it showed in their Google searches.
- 1.55am - The City of London count is announced as vote to Remain in the EU.

- 2am - Bookmakers change their odds in favour of Leave winning the referendum, with Ladbrokes putting odds of 1/2 on a Brexit result. Having had an 86% chance of Remain winning at the close of polls, the odds have shrunk to 6/4, or 38%.
- 2.01am - Swansea votes to Leave, with 61,936 backing a Brexit against 58,307 voting to remain.
- 2.17am - Nigel Farage, who earlier said he sensed Remain would take victory, tweeted that he is "so happy with the results in North East England".
- 2.30am – Remain went back ahead for the first time since the Sunderland announcement after big wins in Lambeth and Glasgow.
- 3.44am – 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.
- 3.51am - Leave's lead stretches to 500,000 votes as results pass 200 out of 382.
- 3.57am - Sterling's 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.
- 6.02am - The Leave campaign officially passes the estimated winning post 16,763,272 in the EU referendum.
- 7.01am - The Bank of England says it will take "all necessary steps" to ensure monetary and financial stability in the wake of the Brexit vote.
- 7.04am - The final count of the EU referendum shows Leave won 51.9% of the total vote to Remain's 48.1%.
- 8.08am - The FTSE 100 falls more than 7% within minutes of the markets opening following Britain's decision to leave the EU.
- 8.50am - 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.

B Theory and Data Appendix

B.0.1 Change in worker outcomes

From the model, the changes in intermediate input costs and prices are $\hat{C}_s = -\frac{c_I/E_s}{C_s}\hat{E}_s \equiv -(1-\delta)\hat{E}_s$ and $\hat{P}_{si} = \kappa^M\left(\hat{\tau}_{si} + \hat{E}_s + \hat{C}_s\right) = \kappa^M\left(\hat{\tau}_{si} + \delta\hat{E}_s\right)$. The output costs are $C_o = C\left(R\left(W_o, W_H, W_T\right), P_M\left(P_i\left(P_{si}\right)\right)\right)$ for labour, human capital H and overtime T.

The costs change by $\hat{C} = S_{RC}\sum_v S_{W_vR}\hat{W}_v + S_{P_MC}\sum_i S_{P_iP_M}\sum_s S_{P_{si}P_i}\hat{P}_{si}$ for $v \in \{o, H, T\}$. Therefore the change in output prices is $\hat{P} = \hat{\tau} + \hat{C} - \hat{E}_d = \hat{\tau} - \hat{E}_d + S_{RC}\sum_v S_{W_vR}\hat{W}_v + S_{P_MC}\sum_i S_{P_iP_M}\sum_s S_{P_{si}P_i}\hat{P}_{si}$ and the resulting change in sales to each destination is $S_d(\hat{PQ})_d = \frac{1}{1-\mu}S_d\hat{P} + \boldsymbol{A}_d$ is $\hat{Q} = -\frac{\mu}{\mu-1}\hat{P} + \boldsymbol{A}_d$ where $\boldsymbol{A}_d \equiv \sum_{o'}\epsilon_{o'}S_{o'd}\hat{P}_d + \epsilon_I\hat{I}$, $\epsilon_{o'}$ is the cross-price elasticity of demand and ϵ_I is the income elasticity of demand. For the UK, $\boldsymbol{A}_{uk} = \sum_{o'}\epsilon_{o'}S_{o'd}\hat{P}_d$ because endowments do not change and for export destinations of the UK, $\boldsymbol{A}_d = 0$ when the UK is small in its destination market $d \neq UK$.

The change in wages is determined by differentiating the labour market clearing condition which gives:

$$
\begin{aligned}
0 =& \left(\frac{RC_{RR}}{C_R} - \frac{RC_R}{C}\right)\left(\sum_v \frac{R_{W_v}W_v}{R}\hat{W}_v\right) + \left(\frac{P_MC_{RP_M}}{C_R} - \frac{P_MC_{P_M}}{C}\right)\left(\sum_i\sum_s \frac{P_iP_{M_{P_i}}}{P_M}\frac{P_{i_{P_{si}}}P_{si}}{P_i}\hat{P}_{si}\right) \\
&+ \sum_v \frac{R_{WW_v}W_v}{R_W}\hat{W}_v + \sum_d S_d(\hat{PQ})_d \\
=& \left(\sigma^C_{RR} - 1\right)S_{RC}\left(\sum_v S_{W_vR}\hat{W}_v\right) + \left(\sigma^C_{RP_M} - 1\right)S_{P_MC}\left(\sum_i S_{P_iP_M}\sum_s S_{P_{si}P_i}\hat{P}_{si}\right) \\
&+ \sum_v \sigma_{WW_v}S_{W_vR}\hat{W}_v + \sum_d S_d(\hat{PQ})_d \\
=& \sum_v\left(\left(\sigma^C_{RR} - 1\right)S_{RC} + \sigma_{WW_v} - \kappa\left(\sigma - 1\right)S_{uk}S_{RC}\right)S_{W_vR}\hat{W}_v \\
&+ \left(\sigma^C_{RP_M} - 1 + \frac{\kappa^X}{1-\mu}S^C_{uk}\right)S_{P_MC}\hat{P}_M - \left(1 - S_{uk}\right)\left(\sigma - 1\right)\hat{P}_X + \boldsymbol{A}_{uk}
\end{aligned}
$$

The import prices change by

$$
\hat{P}_M \equiv \sum_i S_{P_iP_M}\sum_s S_{P_{si}P_i}\hat{P}_{si} = \delta\kappa^M\left(\sum_i S_{P_iP_M}\sum_s S_{P_{si}P_i}\hat{E}_s\right) + \kappa^M\sum_i S_{P_iP_M}\sum_s S_{P_{si}P_i}\hat{\tau}_{si}
$$

Export prices and sales change by

$$\hat{P}_X = \kappa \sum_{d \neq uk} S_{dx} \left(\hat{\tau}_d - \hat{E}_d + S_{RC} \sum_v S_{W_v R} \hat{W}_v + S_{P_M C} \hat{P}_M \right)$$

Substituting for the change in wages, the change in export prices and sales is

$$\begin{aligned} \hat{P}_X = & \kappa S_{P_M C} \left(\frac{\sigma^C_{RP_M} - \sigma^C_{RR} - \sigma_{WW}/S_{RC}}{1 - \sigma^C_{RR} - \sigma_{WW}/S_{RC} + \kappa(\sigma - 1)} \right) \hat{P}_M \\ & - \kappa \left(\frac{1 - \sigma^C_{RR} - \sigma_{WW}/S_{RC} + S_{uk}\kappa(\sigma - 1)}{1 - \sigma^C_{RR} - \sigma_{WW}/S_{RC} + \kappa(\sigma - 1)} \right) \sum_{d \neq uk} S_{dx} \left(\hat{E}_d - \hat{\tau} \right) + \boldsymbol{A}''_{uk} \end{aligned}$$

where the aggregate shifter is $\boldsymbol{A}'_{uk} \equiv \boldsymbol{A}_{uk} / \left(1 - \sigma^C_{RR} - \sigma_{WW}/S_{RC} + \kappa(\sigma - 1) S_{uk}\right) S_{RC} S_{WR}$ and $\boldsymbol{A}''_{uk} \equiv \kappa \frac{1 - \sigma^C_{RR} - \sigma_{WW}/S_{RC} + S_{uk}\kappa(\sigma-1)}{1 - \sigma^C_{RR} - \sigma_{WW}/S_{RC} + \kappa(\sigma-1)} S_{RC} S_{WR} \boldsymbol{A}'_{uk}$.

From the human capital choice, $H = C_R R_H \sum_d \tau_d Q_d / E_d$ and the change in human capital accumulation is therefore

$$\begin{aligned} \hat{H} = & S_{RC} \sigma_{RR} \left(\sum_v S_{W_v R} \hat{W}_v \right) + S_{P_M C} \sigma_{RP_M} \left(\sum_i \sum_s S_{P_i P_M} S_{P_{si} P_i} \hat{P}_{si} \right) \\ & + \sum_v \sigma_{W_H W_v} S_{W_v R} \hat{W}_v - \sum_v S_{RC} S_{W_v R} \hat{W}_v - \sum_i \sum_s S_{P_M C} S_{P_i P_M} S_{P_{si} P_i} \hat{P}_{si} + \sum_d S^C_d (\hat{PQ})_d \\ = & - \sum_v \left(1 - \sigma_{RR} - \sigma_{W_H W_v}/S_{RC} + S_{uk}\kappa(\sigma - 1)\right) S_{RC} S_{W_v R} \hat{W}_v \\ & - \left(1 - \sigma_{RP_M} + S_{uk}\kappa(\sigma - 1)\right) S_{P_M C} \hat{P}_M - S_X (\sigma - 1) \hat{P}_X + \boldsymbol{A}_{uk} \end{aligned}$$

Substituting for the wage change, the change in human capital is

$$\begin{aligned} \hat{H} = & - \left(\frac{\left(1 - \sigma^C_{RP_M} + \kappa(\sigma - 1)(1 - S_X)\right) S_{P_M C} \left(\sigma^R_{W_H W} - \sigma^R_{WW}\right)}{\left(1 - \sigma^C_{RR} - \sigma^R_{WW}/S_{RC} + S_{uk}\kappa(\sigma - 1)\right) S_{RC}} \right) \hat{P}_M \\ & - \left(\frac{(1 - S_{uk})(\sigma - 1)\left(\sigma^R_{W_H W} - \sigma^R_{WW}\right)}{\left(1 - \sigma^C_{RR} - \sigma^R_{WW}/S_{RC} + S_{uk}\kappa(\sigma - 1)\right) S_{RC}} \right) \hat{P}_X + A^H \end{aligned}$$

where $A^H_{uk} \equiv \left(\frac{\left(\sigma^R_{W_H W} - \sigma^R_{WW}\right)/S_{RC}}{1 - \sigma^C_{RR} - \sigma^R_{WW}/S_{RC} + S_{uk}\kappa(\sigma-1)} \right) \boldsymbol{A}_{uk}$. As earlier, we can re-write this as a

system of equations

$$\begin{aligned}
\hat{H} =& \beta_M^H \hat{P}_M + \beta_X^H \hat{P}_X + \boldsymbol{A}_{uk}^H \\
\hat{P}_M =& \beta_{MM} \left(\sum_i \sum_s S_{sio} \hat{E}_s \right) + \kappa^M \left(\sum_i \sum_s S_{sio} \hat{\tau}_{si} \right) \\
\hat{P}_X =& \beta_{MX} \hat{P}_M + \beta_{XX} \left(\sum_{d \neq uk} S_{dx} \hat{E}_d \right) + \beta_{XX} \sum_{d \neq uk} S_{dx}^c \hat{\tau}_d + \boldsymbol{A}_{uk}''
\end{aligned}$$

where $A_{uk}^H \equiv \left(\frac{\left(\sigma_{W_H W}^R - \sigma_{WW}^R\right)/S_{RC}}{1 - \sigma_{RR}^C - \sigma_{WW}^R/S_{RC} + S_{uk}\kappa(\sigma-1)} \right) \boldsymbol{A}_{uk}$, $\beta_M^H \equiv \beta_M^W S_{WR} \left(\sigma_{W_H W}^R - \sigma_{WW}^R\right)$ and $\beta_X^H \equiv \beta_X^W S_{WR} \left(\sigma_{W_H W}^R - \sigma_{WW}^R\right)$.

Similarly, firms' optimal choice of overtime workers is $T = C_R R_T \sum_d \tau_d Q_d / E_d$ and the change in overtime is therefore

$$\begin{aligned}
\hat{T} =& \beta_M^T \hat{P}_M + \beta_X^T \hat{X} + \boldsymbol{A}_{uk}^T \\
\hat{P}_M =& \beta_{MM} \left(\sum_i \sum_s S_{sio} \hat{E}_s \right) + \kappa^M \left(\sum_i \sum_s S_{sio} \hat{\tau}_{si} \right) \\
\hat{P}_X =& \beta_{MX} \hat{P}_M + \beta_{XX} \left(\sum_{d \neq uk} S_{dx} \hat{E}_d \right) - \beta_{XX} \sum_{d \neq uk} S_{dx} \hat{\tau}_d + \boldsymbol{A}_{uk}''
\end{aligned}$$

where $A_{uk}^T \equiv \left(\frac{\left(\sigma_{W_T W}^R - \sigma_{WW}^R\right)/S_{RC}}{1 - \sigma_{RR}^C - \sigma_{WW}^R/S_{RC} + S_{uk}\kappa(\sigma-1)} \right) \boldsymbol{A}_{uk}$, $\beta_M^T \equiv \beta_M^W S_{WR} \left(\sigma_{W_T W}^R - \sigma_{WW}^R\right)$ and $\beta_X^T \equiv \beta_X^W S_{WR} \left(\sigma_{W_T W}^R - \sigma_{WW}^R\right)$.

B.1 Data Description

B.1.1 Exchange Rates

Reuters Datastream collects the daily exchange rates for the most relevant traded currencies, including the sterling pound rates against most currencies in the world. In the few cases for which no exchange rate against the pound was available, suitable conversion is based on its reported dollar exchange rate. The daily measures of exchange rate are defined as the value at the official time of closure of the New York Stock Exchange 4pm EST (8pm GMT).

Mapping of currencies to country of use is based on the official UN Operational

Currency correspondence.[28]The final dataset is composed of 245 countries and 145 currencies.

The minute-by-minute exchange rates for a selected bundle of currencies against the sterling pound are taken from HistData.[29]

B.1.2 Trade Values, Volumes and Prices Time-Series

Quarterly time-series of import and export trade values (current price measure) and volumes (chained volume measure) are made available by ONS for 2 digit UK SIC (Standard Industry Classification) industries in sectors A, B and C: Agriculture, Forestry and Fishing; Mining and Quarrying; and Manufacturing. Those are supplemented by trade values and volumes for 13 aggregate of services product-industry: 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 ratio of trade values and trade volumes after the necessary input-output import use allocations for the case of intermediate imports.

B.1.3 Trade Weights Data

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.

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.[30] Secondly we map NAICS 2012 to NACE 2 using the Eurostat official correspondence table.[31]

ITIS is provided by ONS matched directly to the UK firm register hence identifying the industry of activity of the firm exporting or importing the services.

[28]https://treasury.un.org/operationalrates/OperationalRates.php
[29]http://www.histdata.com/download-free-forex-data/
[30]http://faculty.som.yale.edu/peterschott/sub_international.htm
[31]http://ec.europa.eu/eurostat/ramon/relations/index.cfm?
TargetUrl=LST_REL&StrLanguageCode=EN&IntCurrentPage=10

B.1.4 Supply Use Tables

Data on import use is from the import use tables (product by industry) of the ONS for 2014.[32] Following Autor, Dorn and Hanson (2013), we use the intermediate demand values, which do not include demand from households, non-profit institutions, serving households, central government, local authorities, gross fixed capital formation, valuables, changes in inventories and exports of goods and services.

B.1.5 Labour Force Survey Data

Labour force data refer to all employed individuals aged 22 to 65, and are taken from the UK Quarterly Labour Force Survey 2012 Q3 to 2018 Q2.

The 4-week training indicator is coded as one if the individual has "taken part in any education or any training connected with his/her job or a job that the individual might be able to do in the future in the past 4 weeks". The value of this variable is conditional on a positive answer to the question: "taken part in any education or any training connected with his/her job or a job that the individual might be able to do in the future in the past 3 months?". The same indicator is constructed for the 3-month training and used as robustness.

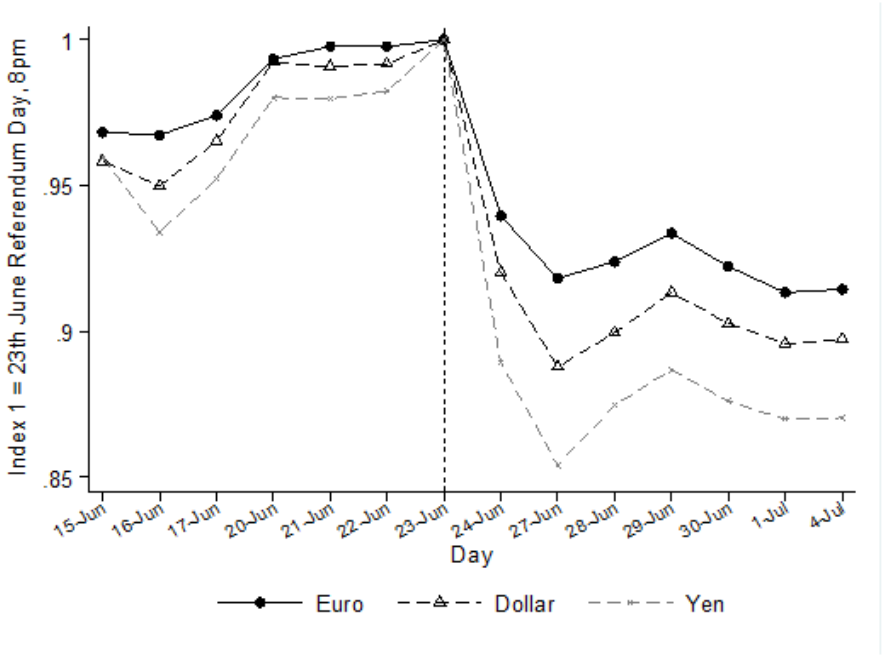
Hourly wages are calculated for individuals answering positively to the questions on weekly wages and hours are reported. The hourly wages are censored at the lowest UK minimum wage, the under 18 years of age minimum wage, in the relevant quarter. The small number of individuals working in industries labelled as household production (i.e.: UK SIC divisions 97, 98 and 99) are excluded from the samples of analysis.

[32] https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

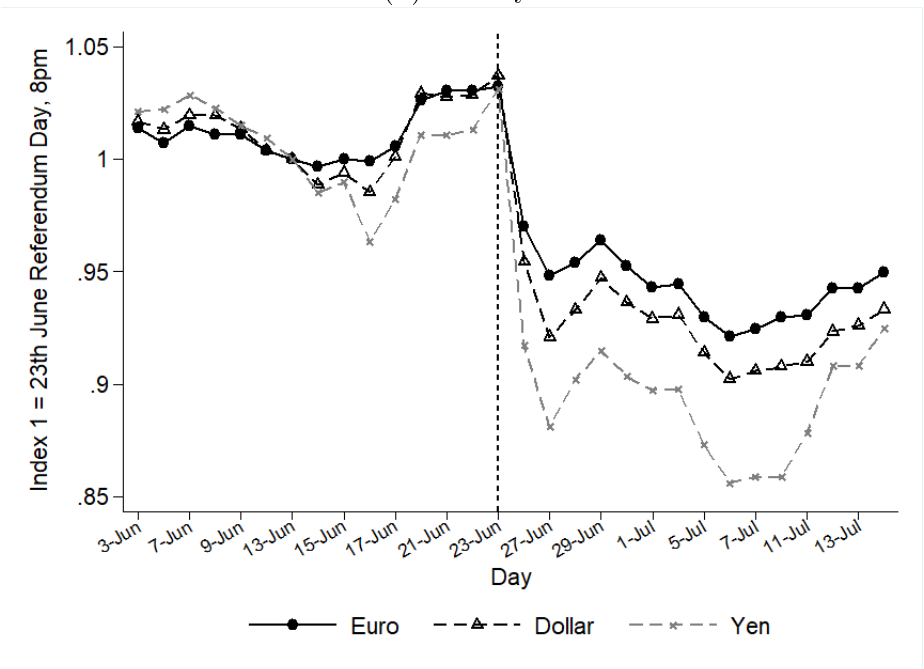
C Additional Tables and Figures

Figure A1: The EU Referendum – 7 days and 15 days windows

(a) 7 Days



(b) 15 Days



Notes: Daily exchange rates from Reuters Datastream.

Table A1: Pre-Post Referendum Changes in Trade Values

	Full Sample	Restricted Samples	
		Excluding Announcement	Excluding QE
	(1)	(2)	(3)
A. Intermediate Imports			
Log(Intermediate Imports Weighted	0.447	0.500	0.641
Depreciation) X Post-Referendum	(0.103)	(0.119)	(0.174)
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	1870	1360
B. Exports			
Log(Intermediate Imports Weighted	-0.297	-0.322	-0.405
Depreciation) X Post-Referendum	(0.217)	(0.232)	(0.278)
Log(Exports Weighted	0.017	0.016	0.014
Appreciation) X Post-Referendum	(0.042)	(0.045)	(0.053)
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	1870	1360

Notes: The dependent variable is log of value of intermediate imports in Panel A and log of value of exports in Panel B. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Panel B specifications include a dummy for non-exporting industry interacted with post-referendum period. Full sample is from 2012 Q3 to 2018 Q2. Restricted sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restricted sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

Table A2: Estimates with 7-Day Exchange Rate Windows

	Intermediate Import Prices	Worker Outcomes	
	First Stage	Reduced Form	IV
	(1)	(2)	(3)
A. Wages			
Log(Intermediate Imports Weighted	0.383	-0.189	
Depreciation) X Post-Referendum	(0.116)	(0.074)	
Log(Price of Intermediate Imports)			-0.495
			(0.270)
First-Stage F Statistic			10.9
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	123,489	123,489
B. Training			
Log(Intermediate Imports Weighted	0.370	-0.073	
Depreciation) X Post-Referendum	(0.113)	(0.024)	
Log(Price of Intermediate Imports)			-0.197
			(0.084)
First-Stage F Statistic			10.8
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	578,282	578,282

Notes: The dependent variable is log of full time hourly wages in Column (1) and a dummy for whether the individual received job-related education or training in the past 4 weeks in Column (2). Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region).

Table A3: Estimates with 15-Day Exchange Rate Windows

	Intermediate Import Prices	Worker Outcomes	
	First Stage	Reduced Form	IV
	(1)	(2)	(3)
A. Wages			
Log(Intermediate Imports Weighted	0.402	-0.102	
Depreciation) X Post-Referendum	(0.129)	(0.054)	
Log(Price of Intermediate Imports)			-0.252
			(0.169)
First-Stage F Statistic			9.2
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	123,489	123,489
B. Training			
Log(Intermediate Imports Weighted	0.386	-0.052	
Depreciation) X Post-Referendum	(0.127)	(0.024)	
Log(Price of Intermediate Imports)			-0.136
			(0.076)
First-Stage F Statistic			9.2
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	2040	578,282	578,282

Notes: The dependent variable is log of full time hourly wages in Column (1) and a dummy for whether the individual received job-related education or training in the past 4 weeks in Column (2). Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region).

Table A4: Hours, Trade Prices and Exchange Rates

	A. Full Sample			
	Reduced Form	IV	Reduced Form	IV
	(1)	(2)	(3)	(4)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.052 (0.032)		-0.051 (0.032)	
Log(Exports Weighted Appreciation) X Post-Referendum			0.009 (0.007)	
Log(Price of Intermediate Imports)		-0.137 (0.105)		-0.103 (0.104)
Log (Price of Exports)				-0.069 (0.039)
First-Stage F Statistic		14.3		5.0
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	571,335	571,335	571,335	571,335
	B. Restricted Samples			
	Exclude Announcement		Exclude QE	
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.050 (0.033)		-0.061 (0.039)	
Log(Price of Intermediate Imports)		-0.122 (0.097)		-0.116 (0.088)
First-Stage F Statistic		15.0		14.9
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	541,567	541,567	429,214	429,214

Notes: The dependent variable is log of total weekly hours worked. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Panel A Columns (3) and (4) specifications include a dummy for non-exporting industry interacted with post-referendum period. Full sample is from 2012 Q3 to 2018 Q2. Restriced sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restriced sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

Table A5: Overtime Hours, Trade Prices and Exchange Rates

	A. Full Sample			
	Reduced Form	IV	Reduced Form	IV
	(1)	(2)	(3)	(4)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.147 (0.049)		-0.140 (0.051)	
Log(Exports Weighted Appreciation) X Post-Referendum			-0.017 (0.001)	
Log(Price of Intermediate Imports)		-0.392 (0.176)		-0.314 (0.168)
Log (Price of Exports)				-0.122 (0.049)
First-Stage F Statistic		14.1		4.9
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	578,282	578,282	578,282	578,282
	B. Restricted Samples			
	Exclude Announcement		Exclude QE	
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.141 (0.052)		-0.150 (0.051)	
Log(Price of Intermediate Imports)		-0.342 (0.163)		-0.285 (0.120)
First-Stage F Statistic		14.8		14.7
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	548,079	548,079	434,431	434,431

Notes: The dependent variable is log of paid overtime weekly hours worked. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Panel A Columns (3) and (4) specifications include a dummy for non-exporting industry interacted with post-referendum period. Full sample is from 2012 Q3 to 2018 Q2. Restriced sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restriced sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

Table A6: Wages (All Workers), Trade Prices and Exchange Rates

	A. Full Sample			
	Reduced Form	IV	Reduced Form	IV
	(1)	(2)	(3)	(4)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.247 (0.082)		-0.251 (0.082)	
Log(Exports Weighted Appreciation) X Post-Referendum			-0.009 (0.012)	
Log(Price of Intermediate Imports)		-0.652 (0.312)		-0.661 (0.287)
Log (Price of Exports)				0.029 (0.142)
First-Stage F Statistic		14.4		4.9
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	159,957	159,957	159,957	159,957
	B. Restricted Samples			
	Exclude Announcement		Exclude QE	
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.251 (0.080)		-0.253 (0.103)	
Log(Price of Intermediate Imports)		-0.607 (0.271)		-0.478 (0.233)
First-Stage F Statistic		14.9		14.8
Controls	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Sample Size	152,065	152,065	119,953	119,953

Notes: The dependent variable is log of hourly wages (all workers). Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region). Panel A Columns (3) and (4) specifications include a dummy for non-exporting industry interacted with post-referendum period. Full sample is from 2012 Q3 to 2018 Q2. Restriced sample excluding announcement is from 2012 Q3 to 2015 Q4 and from 2016 Q3 to 2018 Q2. Restriced sample excluding quantitative easing (QE) is from 2012 Q3 to 2014 Q2 and from 2016 Q3 to 2018 Q2.

Table A7: Robustness of Wages and Training Equations

	Excluding Observations Close to Referendum		Received training in Last Three Months
	Wages	Training	Training - 3 months
	IV	IV	IV
	(1)	(2)	(3)
Log(Price of Intermediate	-0.489	-0.176	-0.319
Imports) X Post-Referendum	(0.252)	(0.071)	(0.139)
First-Stage F Statistic	13.5	13.9	14.1
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
Sample Size	121,954	571,049	578,282

Notes: The dependent variable is log of full time hourly wages in Column (1), a dummy for whether the individual received job-related education or training on the last 4 weeks in Column (2) and a dummy for whether the individual received job-related education or training in the last 3 months. Standard errors clustered by industry in parentheses. Controls are LFS demographics of workers in the industry (age, gender, education, full-time, native, workplace size and region).