Trade and Worker Deskilling

Rui Costa[a], Swati Dhingra[b] and Stephen Machin[b]

March 2019

Abstract

This paper presents new evidence on international trade and worker outcomes. It examines 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 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 worker training. Wages and training fell for workers employed in sectors where the intermediate import price rose by more as a result of the 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, changes in the cost of intermediate imports increasingly act as a driver of the impact of globalization on worker welfare. The episode studied also adds to widely expressed, growing concerns about patterns of real wage stagnation in contemporary labour markets.

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. Data from the Quarterly Labour Force Survey (QLFS) and the International Trade in Services (ITIS) is collected by the Office for National Statistics and supplied by the Secure Data Service at the UK Data Service. This work contains statistical data from ONS which is Crown Copyright. The use of the data in this work does not imply the endorsement of ONS or the Secure Data Service in relation to the interpretation or analysis of the data. This work uses research datasets which may not exactly reproduce National Statistics aggregates. We would also like to thank participants in a number of seminars for helpful comments and suggestions.

[a]Centre for Economic Performance, LSE.

[b]Department of Economics and Centre for Economic Performance, LSE.

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 this worsening of economic performance (see, for example, Mishel 2015 and De Long 2017). At times, empirical studies in international trade and labour economics have attempted to connect the two, via a number of research areas studying 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 and how trade can causally impact upon worker outcomes - remain far from resolved.[2]

This paper offers complementary new evidence on connections between international 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, the empirical approach adopted looks at what happened to trade and worker outcomes in the UK before and after the Brexit referendum vote of June 23, 2016. The focus is on responses to the sizable depreciation of sterling that arose because of the unanticipated vote outcome.

The UK electorate's vote to leave the EU came as a big surprise to almost all observers, and had very big and quickly realised effects on foreign exchange, equity and commodity markets. Immediately following it, sterling suffered its biggest one day loss since the introduction of free-floating exchange rates in the 1970s. In 24 hours, the pound-dollar exchange rate had fallen 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).[3] In fact, the Brexit vote sterling drop is the biggest one day fall that has ever occurred in any of the world's four major currencies that make up the bulk of global hard cash reserves since the collapse of Bretton Woods (Reuters 2016).[4]

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

[3] https://www.theguardian.com/business/2016/jun/23/british-pound-given-boost-by-projected-remain-win-in-eu-referendum

[4] https://uk.reuters.com/article/us-britain-markets-sterling/sterlings-post-brexit-fall-is-biggest-loss-in-a-

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 rate fell by 6 percent. Because imports and exports differ in their source and destination countries, industries trading in different world markets faced a different sterling depreciation. Individuals working in industries therefore faced different cost and revenue shocks because of these country specific variations in the unexpected sterling depreciation.

According to international trade theory, a rise in exports is expected to benefit workers. The impact of a rise in imports on workers is less clearcut. This is reflected in how evidence on import effects has altered over time. Early studies tended to report a negative impact of imports on workers (Grossman 1987, Revenga 1992). This is consistent with the theoretical literature that highlights the import-competing effects on domestic firms. But a key development in trade patterns in the last few decades has been the huge rise of trade in intermediate goods and services, commonly 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 effects of trade and trade policy – for example, import tariffs need not protect domestic producers when they rely on imports as intermediate inputs into their production (Antras and Staiger 2012).

As a consequence, traditional conclusions for the impacts of trade on worker outcomes are no longer as straightforward as they were when the earlier literature studied final goods trade arising from factor price differences across countries. As in that work, imports may have negative impacts on domestic workers when they have to compete with offshored sources of supply of tasks they perform.[5] But domestic workers can also benefit from cheaper foreign inputs when cost savings abroad raise the productivity or scale of domestic production. These two 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. Both the empirical research pioneered by Feenstra and Hanson (1999)

hard-currency-idUKKCN0ZN1R0

[5]Work by Campa and Goldberg (2001) expands the analysis of Revenga 1992) to intermediate imports, continuing to find similarly signed wage elasticities. Similarly, Goldberg and Tracy (2001) estimate a negative, but statistically insignificant, wage elasticity with respect to import-weighted exchange rate depreciation for 2-digit SIC industries in US manufacturing from 1971-1995 (Appendix Table 2). 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.

and the now quite sizable body of research on offshoring very much confirms this, with results emerging that show the impact of imports on worker outcomes may prove positive in some settings and negative in others.[6] A critical feature of this sign variation is whether workers and intermediate imports are complements or substitutes in production.

This paper offers new evidence on trade and the labour market that is in line with these recent developments. It presents findings that depreciation induced increases in intermediate import prices hurt workers. The sizable depreciation of sterling following the EU referendum vote made intermediate imports more expensive and the mode of adjustment to this cost shock was lower wages and reduced worker training. At the same time there was no benefit to offset this for exports, so the depreciation imposed extra costs on firms. Workers bore the brunt of this cost shock. Empirical estimates show that 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 resonate with some of the more recent offshoring work that finds evidence of complementarities between labour and intermediate imports.[7]

These negative effects on wages were further compounded by a cutback in job-related education and training. This loss of future earnings potential via lower training has important implications for future wage and productivity growth.[8] Beyond its contribution to economic

[6]Feenstra and Hanson (1999) report that real wages of production workers were largely unaffected by offshoring activities of US firms while the real wages of non-production workers increased with 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. 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). The recent literature on offshoring and the labour market is reviewed in the comprehensive survey by Hummels et al. (2018).

[7]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 related work to ours using exchange rate movements, 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 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 at the US parent firm with respect to a BTT-induced increase in affiliate employment.

[8]A substantial fraction of investment in skills takes place through job-related education and training of workers, which is an important contrinbutor to wage and productivity growth (for example, Lynch 1992, or Dearden et al. 2006). 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 1998). In many developed countries, training makes up the single-largest component of investments in intangibles, higher than software and databases, R&D or brand

growth, job-related education and training is an important lever to cushion workers during changes in their economic environment. Whilst rarely offering direct evidence, the offshoring literature frequently has recognised the importance of training in redistributing the gains from globalization to workers who are hurt by it. Displaced individuals need skills to transition into better jobs, and this is particularly important for workers who are hurt by offshoring (Hummels et al. 2012). Yet empirical research connecting 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.[9]

The focus on a large, unexpected exchange rate depreciation facilitates study of an exogenous variation that impacts worker outcomes through trade price movements.[10] Other economic shocks that move exchange rates are less plausibly exogenous than the referendum induced exchange rate depreciation of the pound studied here. 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 were driven by monetary policy actions, which are often adopted to bolster employment outcomes.

This paper advances trade and labour market research in several other noteworthy directions. First of all, the available data and setting enable study of the impact of trade on all workers in the economy (i.e. not just in manufacturing), as the UK provides high quality (and relatively scarce in international terms) services trade data.[11] Second, as trade policy in

equity (example, van Ark et al. 2009).

[9]What little empirical work exists on training and trade comprises a few recent papers that 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.

[10]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 (2005), Auer et al. (2018).

[11]A few papers have moved beyond manufacturing and find workers benefit from trade in intermediate inputs, but the effects are small even over long periods of time (example, Amiti and Konings 2007, Liu and Trefler 2008, Liu and Trefler 2011). Harrison et al. (2011) in their survey discuss the notion that, complementarity between workers and intermediate imports could be masked by a stronger negative labour supply effect of offshoring,

most developed countries has remained relatively stable this means that variations in tariffs and exchange rate movements are usually too small to study causal trade effects (Hummels et al. 2018), making instruments for imports hard to come by, especially in services (Liu and Trefler 2011, Ebenstein et al. 2014). The UK experience around the referendum therefore provides a unique setting in the developed country context to utilise the large currency depreciation to lever plausible exogenous variation.

Finally of relevance to this paper is the growing body of research on the potential and actual impacts of the recent surge in nationalist politics. 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, or the surveys by Van Reenen 2016, or Sampson 2017 for Brexit). In related work on counterfactual outcomes, Auer et al. (2018) model the distributional effects of revoking NAFTA on US workers and also note that the impact on industry-specific workers through the intermediate imports channel is quantitatively important. Looking at the Trump trade war of 2018, Fajgelbaum et al. (2019) estimate the impact of US tariff policy on trade outcomes, and use that to model the implied impact on workers, who are immobile across sectors and regions. Amiti et al. (2019) estimate the losses in conumer welfare arising from the Trump trade war. To the best of our knowledge, we provide the first evidence on actual worker-level outcomes being adversely affected by the current surge in nationalist politics.[12]

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 presents the statistical results. Section 6 discusses and interprets the key findings by means of a calibration exrcise that links back to the theory. Section 7 concludes.

2 The EU Referendum Vote

The United Kingdom is one of the most open economies in the world. Its trade to GDP share is over 60 per cent. The European Union (EU) is the UK's largest trade partner. Prior to the UK joining the European Economic Community (EEC) in 1973, around one third of

especially as many studies focus on offshoring to low-wage-countries like China and India.

[12]More recently, a few studies have started to look at post-referendum data on stock market valuations of firms, prices, entry and exit of exporters of merchandise goods, economic uncertainty and trade policy uncertainty (Davies and Studnicka 2018, Breinlich et al. 2017, Crowley et al. 2018, Bloom et al. 2018, and Graziano et al. 2018 respectively).

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).

Whilst a member of the EU, the UK has been in a customs union and a single market. 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 to trade such as border controls, rules of origin checks, cross-country differences in regulations over rules like product standards and safety, and threats of anti-dumping duties.

Membership lowers the costs of doing business between member states, who are required to coordinate on trade policy, including tariffs and non-tariff barriers and other trade-related policies like migration, foreign investment and related regulations. Over time, many political groups in the UK have seen 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 or to leave. This campaign was heavily stepped up by Nigel Farage, leader of the UK Independence Party (UKIP), then a single issue party campaigning for Britain's exit from the EU. UKIP started to see electoral gains from its campaign and this put political pressure on the main parties. Consequently, 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). When the referendum took place, 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 2016). The forex market exhibited similar uncertainty over the result of the Brexit vote. A full timeline of the events of June 23/24 is given in Appendix A, and here we summarize the main episodes.

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, UK Independence Party's Nigel Farage conceded the Brexit campaign may be beaten and said Remain "will edge it." Sterling surged against the US dollar on the back of the favourable opinion poll for Remain and Farage's comments, rising to 1.5 dollars, its strongest performance in 2016. Figure 1 shows this rise (which is actually dwarfed by the scale of what was to follow) by plotting the value of the pound

compared to the dollar, euro and yen between 6 PM on the day of the vote and 8 AM the next day. The three exchange rates are indexed to 1 at 10 PM when the polls closed so as to clearly show the before/after shifts.

Shortly after midnight the first big result was declared. It was 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 were cut by bookmakers. But the big upset came at 12.20am. 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 had tumbled against the US dollar, as Figure 1 shows with an instantaneous near 4.7 percent drop - greater than the Black Wednesday crash in 1992.

People started to feel that Leave could be winning, 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 more and more 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 its high of the previous night of just over 1.5 dollars. Investors reacted by moving from the sterling to other currencies and investment avenues, as reflected in the sterling value against major foreign currencies shown in Figure 1. Table 1 gives more detail on the quite wide discrepancies in the percentage fall that sterling experienced against a bigger range of currencies in the 24 hour period surrounding the referendum.

After 7am on June 24, the Leave campaign had officially won. In our empirical work, we use this overnight exchange rate drop to capture the unanticipated depreciation shock to the pound against other currencies. Sterling depreciated most against the Japanese Yen and the US dollar which were considered safe haven assets in this event window by forex traders and analysts (CNBC 2016).[13] In contrast, sterling depreciated relatively less against EU currencies like the Euro and the Polish Zloty, which were 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 other more minor currencies as forex traders looked for new avenues and trades (Euromoney 2016).[14]

[13]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

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

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. 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).[15] Within a day, prices of safe assets like silver, precious metal ETFs and 10-year US Treasury bonds rose sharply (Forbes 2016).[16] The sterling depreciation can therefore be viewed as an unexpected news shock, which is 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 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 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 begins toraise endogeneity concerns not present for 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.

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

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

3 Theoretical Framework

This section presents a theoretical framework that can be used to generate an empirical strategy to study and interpret the connections between worker outcomes, trade and exchange rates. The starting point is a description of the economy and the market equilibrium, after which the exposition proceeds to the empirical set up and discussion of the possible impacts of the sterling depreciation.

Model Structure

Intermediate Input Prices

Intermediate goods and services are produced by combining the numeraire good from the producer's location and from the location of the using output industry. Suppliers need C_{s0} and C_0 units of the numeraire good from the source country and the UK (the location of the output industry) to provide a unit of their intermediate. Then the unit cost of providing the intermediate is $C_{si} = P_{0s}C_{0s} + E_sC_0$ where P_{0s} is the price of the numeraire good in the foreign source country. It is assumed that $C_0 > 0$ as this is a standard way of adding distribution costs in the exchange rate literature. E_s is the cost of the numeraire good in the UK in terms of source country currency. Intermediate inputs from abroad entail iceberg transport costs $\tau_{si} \geq 1$.

As is standard, we assume intermediate suppliers can price discriminate across locations but not across buyers within a location. Markets are segmented and firms are monopolistically competitive. Suppliers choose prices to maximize profits, taking their derived demand M_{si} from all industries in the UK as given. Their optimal sterling price is $P_{si} = \mu^M \tau_{si} C_{si}/E_s$ where $\mu^M \equiv 1/\left(1 + 1/\left(\partial \ln M_{si}/\partial \ln P_{si}\right)\right)$ is the inverse derived demand elasticity of intermediates which we assume is constant.[17]

Output Prices

Firms in output industry o have a homothetic production function with unit cost C_o. 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. The unit cost function can be written

[17] We assume constant markups as we will not be able to decompose prices into markups and costs. More generally, under variables markups, our estimated coefficients would incorporate the elasticity of markups to expenditures. Under oligopolistic competition, they would include the sensitivity of the aggregate price index to own prices. For a detailed exposition of such price effects in a general framework, see Amiti et al. (forthcoming).

as $C_o = C\left(W_o, P_o^M\left(P_i\left(P_{si}\right)\right)\right)$ where P_i summarizes the import price index from intermediate industry i and P^M summarizes the import price index across all intermediates.[18]

As earlier, firms can price discriminate across locations but not within locations, and they are monopolistically competitive. Following Burgess and Knetter (1998) and Campa and Goldberg (2001), firms face destination-specific inverse demand $P\left(Q_{od}, A_d\right) = A_d Q_{od}^{-1/\sigma}$ where Q_{od} denotes the units of output o consumed in destination d, A_d is an aggregate demand shifter for destination d, and $\sigma > 1$ is the elasticity of demand.[19]

When firms sell their output abroad, they incur iceberg transport costs $\tau_{od} \geq 1$ in destination d. They must also pay for distribution costs in the foreign destination, which require C_{0d} units of the numeraire good from the foreign destination. Therefore, the unit cost of selling in foreign markets is $\tau_{od}\left(C_o + P_{0d}C_{0d}/E_d\right)$ where P_{0d} is the price of the numeraire in the destination market and E_d is the exchange rate that converts destination d prices into sterling. Firms therefore choose $P_{od} = \frac{\sigma}{\sigma-1}\tau_{od}\left(C_o + P_{0d}C_{0d}/E_d\right)$ and foreign consumers are charged $E_d P_{od}$ in their own currency.

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, $\bar{L}_o = C_W\left(W_o, P_o^M\right)\sum_d \tau_{od} Q_{od}$ where $C_W > 0$ is the partial derivative of unit costs C with respect to the wage rate. Having specified the market equilibrium, how equilibrium outcomes change with a depreciation of the exchange rate can next be considered.

Impacts of the Referendum Sterling Depreciation

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

Sterling Depreciation

The international finance literature (for example, as summarized in Engel 2015), examines exchange rate changes over very short time intervals following news announcements.

[18] Specifically, the cost function is $C_o = C\left(W_o, P_o^M\left(P_i\left(P_{si}\right)\right), P_o^D\left(P_i\left(1\right)\right)\right)$ where P^D denotes domestic inputs and 1 denotes the price of the numeraire good which for brevity, we write without the third argument as it stays the same.

[19] In the baseline, A_d summarizes other prices, tastes or incomes in the destination country, which do not vary with the exchange rate. The Appendix extends the theory to allow for explicit dependence of A_d on the destination exchange rate.

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. The approach here also takes this line, by looking at the narrow window of the Brexit referendum night to determine the news shock from the EU referendum results.

The key news that is announced during the 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. As in Faust et al. (2007), let $\mathscr{S}$ be the vector describing all variables in the economy that can be viewed as fixed in the time period of the results announcement.[20] Let $\tilde{\mathscr{S}}$ be the public's best estimate of $\mathscr{S}$. Then the equilibrium exchange rate of the pound with respect to country c can be written as $E_c = \phi_c\left(\mathscr{S}, \tilde{\mathscr{S}}\right)$ where the c subscript allows the exchange rate to depend on country-specific factors such as trade costs or prices, in addition to state variables that need not have a country dimension like the state of the aggregate world economy.

Linearizing and time differencing the result during the 24 hour window, $\Delta E_c = \phi_{1c}\Delta\mathscr{S} + \phi_{2c}\Delta\tilde{\mathscr{S}}$ 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), $\Delta\mathscr{S} = 0$ and $\Delta\tilde{\mathscr{S}}$ gives the marginal effect on the currency of a change in the public's perception of the state variable. Conditional on information at the beginning of the window $\tilde{\mathscr{S}}$ and the Brexit referendum news B, the estimate of the state variable changes by $\Delta\tilde{\mathscr{S}} = gB$. Therefore, the depreciation from the Brexit referendum news can be summarized by $\Delta E_c = \phi_{2c} gB$.

Trade Impacts

The trade price impact can be analysed by solving for how the equilibrium outcomes change as a result of the vote-induced sterling depreciation. Following the exchange rate literature, let κ denote the probability that a firm can adjust its price following an exchange rate shock. Incorporating this sticky price mechanism, changes in equilibrium outcomes are discussed here and details are in the Appendix. For ease of notation, let $\hat{Z}$ denote the log change in Z with respect to the 24-hour exchange rate depreciation ΔE.

From the supplier's optimal price equation, the change in the price of intermediates from industry i in source country s is $\hat{P}_{si} = \kappa^M\left(\hat{C}_{si} - \hat{E}_s\right)$ where κ^M is the probability of adjustment for suppliers of intermediate imports. Let $\delta^M \equiv P_{0s}C_{0s}/\left(P_{0s}C_{0s} + E_sC_0\right)$ denote the share of source country costs in the total costs of the intermediate supplier. Assuming the UK is a small open economy, the price of the numeraire good in foreign countries is unchanged by the Brexit news. Then the price of imported intermediates in the UK increases by $\hat{P}_{si} =$

[20] 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.

$-\delta^M \kappa^M \hat{E}_s$. A sterling depreciation ($\hat{E}_s < 0$) works like an increase in trade costs and so raises the prices of imported intermediates.

The change in the intermediate import price index is a weighted average of all intermediate prices from various foreign source countries, $\hat{P}_o^M \equiv \sum_i \sum_{s \neq uk} S_{sio} \hat{P}_{si}$. The shares $S_{sio} \equiv S_{P_i P_o^M} S_{P_{si} P_i}$ are the shares of intermediates of industry i from source county s in the factor expenditures of output industry o. $S_{P_{si} P_i}$ and $S_{P_i P^M}$ are the shares of source s and intermediate i in the relevant intermediate costs of the industry, P_i and P^M respectively.

From the output unit cost function, $\hat{C}_o = S_{WC} \hat{W}_o + S_{P^M C} \hat{P}_o^M$ where S_{WC} and $S_{P^M C}$ are the shares of labour and imported intermediates in the industry's factor costs C_o. Incorporating into the optimal price equation, output prices change by $\hat{P}_{od} = \kappa \left(\delta \hat{C}_o - (1-\delta) \hat{E}_d \right)$ where $\delta \equiv C_o / \left(C_o + P_{0d} C_{0d} / E_d \right)$ is the share of UK-based costs in total unit costs of the output industry.

Defining S_{dxo} as the share of destination d in exports of UK firms in output industry o. The export price index for UK firms can be written as $\hat{P}_o^X \equiv \sum_{d \neq uk} S_{dxo} \hat{P}_{od}$. Substituting for the change in output prices, $\hat{P}_o^X = \kappa \delta S_{P^M C} \hat{P}_o^M + \kappa \delta S_{WC} \hat{W}_o - \kappa (1-\delta) \sum_{d \neq uk} S_{dxo} \hat{E}_d$. Holding all else fixed, a sterling depreciation ($\hat{E}_d < 0$) raises the export price that UK firms charge on account of the destination-specific costs, but lowers the export price in terms of the foreign consumer's currency.

Wage Impacts

To determine the before/after change in wages, let σ_{XY} denote the Allen-Uzawa elasticities of substitution (AES) between factors with prices X and Y. Specifically, σ_{WW} is the own elasticity of labour demand which is less than zero for downward sloping demand, and equals $\sigma_{WW} \equiv \varepsilon_{WW} / S_{WC}$ where $\varepsilon_{WW} \equiv C_{WW} W / C_W$ and $C_{WW} < 0$ is the second order partial derivative of the unit cost function with respect to wage. Similarly, $\sigma_{W P^M} \equiv \varepsilon_{W P^M} / S_{P^M C}$ is the Allen-Uzawa elasticity of substitution between workers and imported intermediates. From Shephard's lemma, the elasticity of labour demand with respect to the price of imported intermediates is $\varepsilon_{W P^M} \equiv C_{W P^M} P^M / C_W$ which is less than zero (greater than zero) for Allen-Uzawa complements (substitutes).

From labour market clearing, the change in wages is given by

$$\sigma_{WW} S_{WC} \hat{W}_o = -\sigma_{W P^M} S_{P^M C} \hat{P}_o^M + \sum_d S_d \hat{Q}_{od} \tag{3.1}$$

where $\sum_d S_d \hat{Q}_{od}$ is the change in scale of UK firms across all destinations and S_d is the share of sales to destination d in total sales of UK firms. The sum of the two terms on the RHS of equation 3.1 determines whether workers and intermediate imports are gross sub-

stitutes or complements. The first term on the RHS determines the net complementarity or substitutability of workers with imported intermediates. When $\sigma_{WP^M} < 0$, an increase in the price of imported intermediates drives down the wage rate of workers in the industry and also has the direct effect of reducing the absolute cost share of workers (because $\partial \ln S_{WC} / \partial \ln P_o^M = -S_{P^MC}(1 - \sigma_{WP^M}) < 0$ iff $\sigma_{WP^M} < 1$). 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 change in scale in terms of price changes in equation 3.1, enables us to arrive at the estimating equations in the next sub-section.[21]

Structural and Reduced Form Relationships

The structural and reduced form equations for the empirical application to the Brexit news shock can now be derived. Technical details are relegated to the Appendix. Here the emphasis is placed on highlighting the structural relationship in terms of changes in wages, intermediate import prices and export prices that can be taken to the data with an appropriate empirical model.

The trade measures used in the empirical work are an intermediate import price index and an export price index. The focus on prices is based on the reasoning by Grossman (1987) that, if available, they 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, but we are fortunate in our setting to have access to good price data, parallel results using the quantities of imports are also shown in Table A1 of the Appendix.

[21] 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 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 and Pierce and Schott 2016). In fact, Bloom et al. (2018) find that UK businesses report lack of clarity over the transition and future arangements as a key source of economic uncertainty. However, 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.

From the inverse demand function, the change in scale is $\hat{Q}_{od} = -\sigma\hat{P}_{od} + \sigma\hat{A}_d$. When A_d summarizes destination-specific real incomes and the UK is a small open economy, $\sigma\sum_d S_d\hat{A}_d$ would just be the change in the aggregate price index in the UK. Substituting for $\hat{Q}_{od}$ and explicitly writing out the change in domestic sales $\hat{Q}_{uk}$, the change in wage rate from equation 3.1 can be written in terms of imported intermediate and export prices as

$$\begin{aligned}(\sigma_{WW} - \delta S_{uk}\kappa\sigma)\, S_{WC}\hat{W}_o = & -(\sigma_{WP^M} - \delta S_{uk}\kappa\sigma)\, S_{P^MC}\hat{P}_o^M \\ & -(1 - S_{uk})\,\sigma\hat{P}_o^X + \sigma S_{uk}\hat{A}_{uk}\end{aligned}$$

where S_{uk} is the share of sales at home in total sales of UK firms.

The structural equation that relates the pre-post referendum change in wages to changes in trade prices is therefore:

$$\hat{W}_o = \alpha + \theta_{MW}\hat{P}_o^M + \theta_{XW}\hat{P}_o^X \tag{3.2}$$

and the underlying reduced forms for changes in wages and trade prices with respect to the sterling depreciation are:

$$\hat{W}_o = \alpha_W + \beta_{MW}\hat{E}_o^M + \beta_{XW}\hat{E}_o^X \tag{3.3}$$

$$\hat{P}_o^M = \alpha_M + \beta_{MM}\hat{E}_o^M \tag{3.4}$$

$$\hat{P}_o^X = \alpha_X + \beta_{XX}\hat{E}_o^X + \beta_{MX}\hat{E}_o^M \tag{3.5}$$

where α denote economy-wide shifters. The exchange rate changes are $\hat{E}_o^M \equiv \sum_i \sum_{s\neq uk} S_{sio}\hat{E}_s$ and $\hat{E}_o^X \equiv -\sum_{d\neq uk} S_{dxo}\hat{E}_d$, which are respectively the intermediate import weighted exchange rate depreciation and the export weighted exchange rate appreciation for the industry. When used as instruments, the construction of exchange rate changes is similar to the input tariff changes that Goldberg et al. (2009) construct for their study of product adoption from reduction in intermediate input tariffs in India. The β and θ coefficients are respectively the relevant reduced form and structural form estimands of interest. How these relate to the model primitives is discussed next with empirical implementation and interpretation in mind, first for trade prices, then for wages.

As sterling depreciates, $\hat{E}_o^M < 0$ and prices of intermediate imports rise for $\beta_{MM} < 0$. The estimated exchange rate pass through to import prices is $\beta_{MM} \equiv -\delta^M\kappa^M$ which incorporates the share of source country resources used in the provision of the intermediate δ^M and the probability of price adjustment in importing κ^M. Note that only the intermediate import weighted sterling depreciation enters the RHS of equation 3.4, and not the export-weighted sterling depreciation. This is because theoretically UK firms and their suppliers do

not negotiate on intermediate prices based on how much they sell in foreign markets. The intermediate import prices therefore do not depend on the export weighted sterling appreciation. Empirically, this provides a reasonable setting where firms incur a cost shock through a rise in intermediate import prices and this does not depend on the revenue shock that they receive from UK exports becoming cheaper for foreign consumers.

As sterling appreciates, $\hat{E}_o^X > 0$, the estimated pass-through of the exports-weighted appreciation to export prices that UK firms receive is $\beta_{XX} \equiv \kappa(1-\delta)\frac{\sigma_{WW}-\delta S_{uk}\kappa\sigma}{\sigma_{WW}-\delta\kappa\sigma} > 0$ (for downward sloping labour demand). The extent of the pass-through depends on the probability of price adjustment in the output market κ and the indirect effects through wage changes incorporated in σ_{WW} and S_{uk}. Combining this with the direct effect of the sterling depreciation, export prices in foreign currency are lower.

But there may also be an offsetting effect as export costs rise in the UK due to the rise in the price of intermediate imports when $\beta_{MX} < 0$. The estimated coefficient $\beta_{MX} \equiv \delta\kappa S_{P^MC}\beta_{MM}\frac{\sigma_{WW}-\sigma_{WP^M}}{\sigma_{WW}-\delta\kappa\sigma}$ is the exchange rate pass through of intermediate import costs to exports, and it incorporates the export price pass through $\delta\kappa$, the intermediate import price pass through $S_{P^MC}\beta_{MM}$ and the indirect effects through wages which is captured in the elasticities of substitution and demand. The sign of this coefficient depends on the difference in the elasticity of substitution of workers with respect to costs of intermediate imports relative to wages ($\sigma_{WP^M} - \sigma_{WW}$). When workers and intermediate imports are Allen-Uzawa substitutes, $\sigma_{WP^M} > 0 > \sigma_{WW}$, 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. Then export prices rise with the sterling depreciation on account of the cost channel when workers and intermediates are not complementary enough to reduce the total factor costs of exporters.

The sterling depreciation changes wages 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 $\theta_{MW} \equiv -\frac{(\sigma_{WP^M}-\delta S_{uk}\kappa\sigma)S_{P^MC}}{(\sigma_{WW}-\delta S_{uk}\kappa\sigma)S_{WC}}$ measures the elasticity of wages with respect to intermediate import prices. It incorporates Allen-Uzawa complementarity through σ_{WP^M}, the relative importance of workers and intermediates through their factor cost shares

$(S_{P^M C}, S_{WC})$, and the pass-through to UK prices through $\delta S_{uk}\kappa\sigma$.

In the absence of pass-through of factor costs to UK domestic prices ($\delta S_{uk}\kappa\sigma = 0$), the coefficient is just the relative Allen-Uzawa elasticities of substitution and factor shares. In the presence of pass-through to UK domestic prices, the coefficient θ_{MW} 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 θ_{MW} is similar to Alfaro et al. (forthcoming). 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. When workers and intermediate imports are Allen-Uzawa complements, $\sigma_{WP^M} < 0 < \delta S_{uk}\kappa\sigma$ and workers' wages fall through the intermediate import cost channel of the exchange rate depreciation ($\theta_{WM} < 0$).

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 $\theta_{XW} \equiv \frac{(1-S_{uk})\sigma}{(\sigma_{WW}-\delta S_{uk}\kappa\sigma)S_{WC}}$ measures the pass through of higher export earnings into wages, which is positive for downward sloping labour demand.

To sum up, the sterling depreciation raises intermediate import and export prices. When workers and intermediate imports are Allen-Uzawa complements, the sterling depreciation induced rise in intermediate import prices lowers wages in industries that experience a greater intermediate imports weighted depreciation. In contrast, the rise in (sterling) export prices induced by a sterling depreciation raises wages in industries that experience a greater exports weighted appreciation, but these may be mediated by a rise in import costs. Which effect dominates depends on the relativities between the revenue and cost shocks.

Empirical Model

In practical terms, these relationships from the reduced forms in equations 3.3 to 3.5 are empirically operationalised by means of difference-in-differences specifications that relate the outcomes of interest – wages and trade prices – before and after the EU referendum to the pre-referendum trade weighted industry-specific sterling shock. The reduced form approach for wages has some similarities to recent papers on trade and labour market outcomes, which typically examine employment changes from the event of interest across industries that differ in their initial trade structure or trade policy exposure (for example, Pierce and Schott 2016, Acemoglu et al. 2016). Specifically, Pierce and Schott (2016) examine US manufacturing employment before and after China received permanent most favored nation status across manufacturing industries based on differences in their pre-determined tariff cuts from

permanent MFN status. The trade price reduced forms display similarities to the exchange rate pass through work already mentioned but rely on the exogenous exchange rate shock induced by the unexpected vote outcome, rather than general exchange rate movements that arise for a variety of reasons. As the referendum shock is measured in terms of the 24 hour window industry-specific exchange rate change, the research design in practice is set up in a difference-in-differences setting, which we turn to next.

To interpret the regression estimands of interest as elasticities, and where relevant for ease of comparison to draw with existing estimates, a double-log difference-in-differences specification is adopted. In terms of key independent variables, let $Log\left(\text{Depreciation}_o^M\right)$ denote the log of the import share weighted sum of the exchange rate E_s in the post-referendum period divided by its pre-referendum value. Similarly, $Log\left(\text{Appreciation}_o^X\right)$ is the log of the export share weighted exchange rate E_d in the post-referendum period divided by its pre-referendum value. The weights are the pre-referendum trade shares and the log depreciation/appreciation variables enter as independent variables interacted with a post-referendum dummy to pick up changes in the dependent variables before and after the referendum.

For the dependent variable, the values (in logs) of the post-referendum outcomes correspond to the sum of their pre-referendum values in logs and log changes in the outcomes induced by the sterling depreciation. For the reduced forms of import and export prices – the first stage - the reduced form changes of equations 3.4 and 3.5 can be estimated with industry-level quarterly panel data using the following differences-in-differences specification for industry o in quarter q of year t:

$$Log(P_{oqt}^M) = \alpha_o + \alpha_{qt} + \beta_{MM} Log\left(\text{Depreciation}_o^M\right) * Post_{qt} + \beta_{ZM} Z_{oqt} + \varepsilon_{oqt}^M \tag{3.6}$$

$$\begin{aligned} Log(P_{oqt}^X) = {} & \alpha_o + \alpha_{qt} + \beta_{XX} Log\left(\text{Appreciation}_o^X\right) * Post_{qt} \\ & + \beta_{MX} Log\left(\text{Depreciation}_o^M\right) * Post_{qt} + \beta_{ZX} Z_{oqt} + \varepsilon_{oqt}^X \end{aligned} \tag{3.7}$$

where P_{oqt}^M is the intermediate import price index of output industry o and P_{oqt}^X is its export price index. The pre-referendum values for the industry are subsumed in industry fixed effects α_o. 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. α_{qt} are quarter-year fixed effects, Z is a set of controls (comprising demographics and other characteristics of workers in the industry) and ε_{oqt} are error terms. The difference-in-differences estimands of interest in equations 3.6 and 3.7 are β_{MM}, β_{XX} and β_{MX}, the coefficients on the interaction between the relevant trade weighted appreciation or depreciation measures and the post-referendum dummy variable $Post$.

The reduced form for wages can also be operationalised in an analogous way to equations 3.6 and 3.7, other than we now have worker level data to work with. For worker j in output industry o in quarter q of year t,

$$Log(W_{joqt}) = \alpha_o + \alpha_{qt} + \beta_{MW} Log\left(\text{Depreciation}_o^M\right) * Post_{qt} + \beta_{XW} Log\left(\text{Appreciation}_o^X\right) * Post_{qt} + \beta_{ZW} Z_{joqt} + \varepsilon_{joqt}^W \quad (3.8)$$

where W_{joqt} is the wage rate and ε_{oqt} is an error term. In equation 3.8, the difference-in-differences estimands of interest are β_{MW} and β_{XW}. Of course, the key variation remains at the industry-level so 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 3.6, 3.7 and 3.8 can be combined to estimate a structural form which, under the assumption that the vote-induced sterling depreciation/appreciation is a legitimate instrument that can be excluded, enables identification of a causal effect of trade on wages. The precise specification is:

$$Log(W_{joqt}) = \alpha_o + \alpha_{qt} + \theta_{MW} Log(P_{oqt}^M) + \theta_{XW} Log(P_{oqt}^X) + \theta_{ZW} Z_{joqt} + \upsilon_{joqt} \quad (3.9)$$

with υ being the error term of the equation. The difference-in-differences instrumental variable estimates are θ_{MW} and θ_{XW}. In terms of model parameters, $\theta_{MW} = \beta_{MW}/\beta_{MM} - \beta_{XW}\beta_{MX}/\beta_{MM}\beta_{XX}$ and $\theta_{XW} = \beta_{XW}/\beta_{XX}$, and these relations will be used in the model calibration presented after the statistical estimates.

Generalizing to Human Capital

The focus so far was on inelastic labour supply to industries, thereby allowing for one single margin of adjustment in workers' outcomes - wage rates. When wages are downward sticky, the 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. But when there is limited ability to change wages, adjustment could occur along other margins of labour costs. There are several possible adjustment margins. The one we mostly choose to focus upon is job-related education and training of workers.[22] This is, of course, a significant contributor to human capital investment of workers across their work

[22]Other possibilities are overtime hours and hours worked, and we present some estimates briefly on this later in the paper.

lives.

To incorporate this channel of adjustment, the unit cost function nests training costs as $C = C\left(R\left(W_o, W_T\right), P_o^M\left(P_i\left(P_{si}\right)\right)\right)$ where W_T is the per unit cost of providing job-related education and training to workers (in terms of the numeraire). Firms choose $T_o = C_R R_{W_T} \sum_d \tau_{od} Q_{od}$ where C_R is the partial derivative of the unit cost function with respect to labour costs R, and R_{W_T} is the partial derivative of the labour costs with respect to training costs W_T.

Firms cannot immediately hire and fire workers, but they can change their outlays on investments in worker skills. Training costs are assumed to not change with the Brexit news, though the model can be easily extended to accommodate them. Then proceeding as earlier for wages, the structural relationship for training responses is $\hat{T}_o = \alpha_T + \theta_{MT}\hat{P}_o^M + \theta_{XT}\hat{P}_o^X$, which is empirically operationalised as

$$T_{joqt} = \alpha_o + \alpha_{qt} + \theta_{MT} Log(P_{oqt}^M) + \theta_{XT} Log(P_{oqt}^X) + \theta_{ZT} Z_{joqt} + \eta_{joqt} \tag{3.10}$$

where T is a dummy variable indicating worker training receipt and η is an error term. The difference-in-differences instrumental variable estimates are θ_{MT} and θ_{XT}. These would also take the signs of the corresponding coefficients in the structural wage equation if both wage and training are channels of adjustment observed in response to the exchange rate depreciation and under the earlier assumption that own elasticities are larger in magnitude than cross elasticities of substitution. More detail is given in the Appendix.

4 Data Description

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.[23] 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 of SIC 2007 classification, 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 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_{dxo} 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. Figures 2a) and 2b) show the intermediate imports and exports trade weight composition by main trading partner for 11 broad industry categories ranked by depreciation (or appreciation) magnitude.[24] Figure 2a shows clearly how the country composition of industry trade with countries whose currency gained more ground against the pound

[23]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.

[24]For disclosure reasons we are not able to provide trade weights and calculated depreciations at a more disaggregate level of industry or country of origin/destination.

(United States, Japan) maps into higher intermediate import weighted depreciation. The same is broadly true for the export counterpart, shown in Figure 2b, although in this case it proves a litte harder to spot in the visual representation.

5 Results

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 discussed first, after which the discussion moves to highlight how the reduced form findings can be combined to get 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. After that, various extensions are presented and issues of robustness are probed.

Raw Difference-in-Differences

Table 2 shows what happened to the trade and worker outcome measures before and after the referendum by reporting 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 based on 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 3 and 4 that respectively chart 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, with the coefficients on the depreciation/appreciation being elasticities that can be benchmarked against 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.

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 (concurrent) to 0.87 (after two years) for the UK.

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.[25] 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.[26] 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.[27] On first reflection, it might seem surprising that export prices do not move much despite the large exchange rate shock. But this is in fact consistent with a growing body of work that finds low exchange rate pass through on the exporting side (Amiti et al. 2014, Ahmed et al. 2015, de Soyres et al. 2018, Fauceglia et al. 2015). This literature on exchange rate disconnect identifies intermediate imports and global value chain participation as channels for low export reponses due to rising import costs. Exports from OECD countries contain a large fraction of imported content, and this is true for the UK as well.

It is, however, premature to reach the conclusion that the key result is a depreciation induced cost shock to intermediate import without first considering possible pre-referendum trend differences. We explored this carefully in various ways, looking at pre-trend differences in trade prices by depreciation (or appreciation) quantiles, and from including pre-trend quarter interactions. It turns out that two pre-trend events may have resulted in there being

[25] 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).

[26] The same is true if only the exports weighted appreciation variable was entered.

[27] See Berman et al. (2012) and Leigh et al. (2016) for export pass through.

some pre-referendum differences in the evolution of trade prices for higher and lower depreciation/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.[28]

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. Figure A2 of the Appendix shows the dollar and euro exchange rate movements against the pound and identifies the moments of quantitative easing from both the United States and the European Central Bank. 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.[29]

Figure 5 shows how this – and to a lesser extent the referendum announcement – could 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.[30] There is then some divergence, after which the trends become similar again. Because of this, we report results with the the QE depreciation quarters excluded from the estimation.[31]

[28]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).

[29]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.

[30]Indeed, looking at Figure A2 one can see that exchange rate movements with respect to dollar and euro are considerably parallel until the QE announcements.

[31]Contrary to the significant correlation found between the 24 hour referendum window and QE depreciation, the Spearman rank correlation between the referendum drop in sterling and the change in the pre-QE period for

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 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 slowing impact on wage growth.

the 26 currencies of Table 1 is of -0.006 (with an associated p-value of 0.98). This supports the idea that excluding the QE period helps to ensure the validity of parallel trends in the analysis.

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, which is presented later in Section 6.

Training

An analogous set of results to the wage equations shown in Table 4 are given for worker training in Table 5. 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 both a wage lowering and a deskilling impact on UK workers.

Extensions

Various other extensions and probes of robustness were undertaken:

(i) 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 6 considers this by additionally entering the share of imported inputs in total inputs interacted with the post-Brexit vote dummy into the estimating equations.[32] In undertaking this

[32]We also looked at other trade variables. For example, we experimented with including an interaction of the post-referendum dummy variable with the share of exports in final demand. Its inclusion had no impact and

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.[33]

(ii) 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. 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 show 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.

(iii) 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. The theory appendix adds overtime choice to the model to show that overtime hours have the same sign as the wage effects. This complements the training cutback evidence shown earlier, which

since there is no first stage on the exports side of things, we did not pursue this any further.

[33]The main results remained very robust to inclusion of a measure of the exchange rate depreciation weighted by import competition (to capture all final, direct and indirect imports this is defined as total imports of industry o imported by all industries). For example, the reduced form coefficients (and associated standard errors) on the Log(Intermediate Imports Weighted Depreciation) X Post-Referendum variable were 0.350 (0.091) for Log(Intermediate Import Prices), -0.187 (0.076) for Log(Wages) and -0.060 (0.020) for Training in specifications comparable to those of 0.375 (0.100), -0.201 (0.075) and -0.069 (0.021) reported in column (1) of Tables 3, 4 and 5 respectively.

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 uptil now 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.

(iv) Heterogeneity by Skill

Previous empirical work has found evidence of differential degrees of complementarity/substitutability between imports and workers of different skill levels. Table 7 shows estimates for full-time wages and training of high-skilled and low-skilled workers. The estimates are broadly robust across the different sample restrictions. There is evidence that high-skilled workers (defined as college graduates in the context of the analysis) have a higher degree of complementarity with intermediate imports than low-skilled workers. This is similar to Hummels et al. (2014) offhsoring results, which also suggests greater complementarity between intermediate imports and high-skilled workers, relative to intermediate imports and low-skilled workers.[34]

(vi) Further 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

[34]In terms of other aspects of heterogeneity, work by Ottaviano et al (2013) suggests migrant workers and offshoring have a higher degree of substitutability than do native workers in the context of manufacturing industries in the United States. Estimating the wage and training reponses across both dimensions of heterogeneity - nativity and skill, wage estimates for migrant workers are lower in magnitude than for native workers across skill groups. Wages and training of high-skilled migrants responds negatively to the rise in intermediate import prices, while low-skilled migrants show a positively signed (albeit statistically insignificant) wage effect, suggesting substitutability with respect to imported intermediate prices. The results are also robust to including the initial share of migrants interacted with the post-referendum dummy.

4 and 5. 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 Calibration

The theoretical discussion of Section 3 highlighted a number of key aspects of connections between trade and worker outcomes. We now link the empirical estimates of the previous section to those predictions through a model calibration exercise. The first issue of interest considers what the reported results on wages have to say regarding the extent of substitutability/complementarity between labour and intermediates, including variations across different types of workers. We then move on to compare these to estimates from other related research. And lastly we consider how the findings on other margins of adjustment connect back to the theory.

The estimated wage elasticity with respect to intermediate import prices, $\hat{\theta}_{MW}$, is negative in all reported specifications and, dependent on sample, lies in a range from -0.35 to -0.55. Returning to the theory, this corresponds to there being a gross complementarity between workers and intermediate imports. To understand what the elasticities imply about the Allen Uzawa elasticity of substitution, we can specify the parameters from data and the existing literature. The elasticity of labour demand is taken as -0.5 which is standard in the literature for short term labour market responses. Moving on to incorporate the indirect effects from domestic price, we calibrate the estimated structural wage coefficient to demand elasticities. To calibrate to the demand side, the probability of price adjustment with respect to factor costs is set to $\delta\kappa = 0.25$. The share of home sales in the UK is $S_{uk} = 0.7$ and the relative share of wages to imported intermediate input costs is $S_{WC}/S_{P^MC} = 0.4/0.1$ in the UK data. The elasticity of substitution is varied between 1, 3 and 5, based on the literature. Then the range of Allen Uzawa elasticities is -1.82 to -3.80 in Table 8 which implies net complementarity.

As stated earlier in the paper, in both the theoretical setup and in the empirical implementation, we use trade prices to compute the appropriate elasticities. To our knowledge, ours is the only study based upon recent data that uses prices, and that looks at intermediates. The much earlier work on the effect of import competition on wages and employment by Grossman (1987) and Revenga (1992) does study import prices and reports evidence of positive wage-import price elasticities in US manufacturing in the 1960s, 1970s and 1980s. For intermediate import prices, with UK data from 2012-18, our study finds the opposite

sign for the wage-price elasticity. One way in which this apparent contradiction could be resolved is if the rising importance of intermediate imports over time has changed the nature of the relationship between imports and wages and they have shifted from being substitutes for labour in the past towards being complements more recently. This is in fact what Grossman and Rossi-Hansberg (2008) model as a labour-augmenting productivity effect that raises domestic wages through cost savings from offshoring, and is also raised in the more recent empirical work on offshoring. It is also in line with two empirical observations: first, that far more imports are now intermediates; and second, the well established finding of productivity enhancing effects of intermediate imports.[35]

Rather than looking at trade prices, the newer research on offshoring and the labour market utilises trade value data (surveyed by Hummels et al. 2016). Because values contain both price and quantity components, this does not map well to the theoretical concept of an elasticity of substitution among factors. Moreover, it is often the case that value measures are expressed as the share of imports in total purchases and therefore also contain changes arising from domestic intermediate supply conditions (Feenstra et al. 2010). Nonetheless, and despite these reservations regarding value measures, the magnitudes of the wage-price elasticities that we have estimated and their implications for complementarity/substitutability can, with some appropriate assumptions about import demand elasticities, be compared with related work using values. Specifically, if one is willing to assume an intermediate import demand elasticity in line with the literature of -8.6 (the mean in Alfaro et al. forthcoming), an empirical wage elasticity with respect to import values can be calculated in the range 0.05 to 0.07. This modestly sized, but positive elasticity reflects, on average, the complementarity between labour and intermediates.[36]

Most of the wage elasticities with respect to intermediate import values reported in the offhsoring literature are small and of varying sign across different papers (see the Hummels et al. 2016 survey). They also display heterogeneity across different worker types, in particular by skill. For example, the offshoring estimates for Danish manufacturing reported in Hummels et al. (2014) are in the range of 0.03 to 0.07 for high-skilled workers and -0.06 to -0.11 for low-skilled workers (in their Table A5). As Table 7 showed earlier our estimates also display heterogeneity by skill. Under the same assumption as made before regarding the import demand elasticity, the empirical wage-intermediate import value elasticities for graduates are around 0.08, which turns out to be very close to the Hummels et al. range. One cannot reject the null hypothesis of a zero elasticity for the non-graduate group (numerically

[35] See, inter alia, Amiti and Konings (2007), Kugler and Verhoogen (2009), Kasahara and Lapham (2013), Halpern et al. (2015), Kugler and Verhoogen (2012).

[36] Specifically, it is computed as $\hat{\theta}_{MW} \cdot (1/(1-8.6))$.

the range runs from 0 to -0.03). This suggests complementarity with intermediates in our analysis is confined to the graduate group.

Thus our estimates, like those of Hummels et al (2014), show that, in relative terms, graduates are more complementary to intermediates than non-graduates. Therefore the finding that the graduate/non-graduate wage premium is increased by intermediate imports is also common to our study. Moreover, the impact on these relative wage differentials the implied magnitudes are similar to the Hummels et al. ones, as 0.08 to 0.11 compared to their 0.09 to 0.18.[37]

The earlier analysis also reported significant training cutbacks connected to higher intermediate import prices. The IV specifications reported earlier were linear probability models with a binary dependent variable and so are semi-log estimates. The IV semi-elasticities range from -0.09 to -0.20. Converting to an elasticity produces elasticity estimates of the order of -0.88 to -1.81. These are evidently larger in absolute terms than the wage elasticities, intuitively suggesting a greater sensitivity of training to trade prices. As discussed in the introduction, there is little work on training responses to trade, despite the very obvious salience of training as a labour adjustment mechanism to globalization. Of the small body of research that does study training and trade, its focus is mostly on public training programs (for example, Hummels et al. 2012, Hyman 2018). Recently, a few papers have started to examine on-the-job training and its relationship with import penetration, typically from low-wage countries, and they find mixed results. In recent work using US SIPP data, Guner et al. (2018) find that the share of workers receiving job training dropped signicantly more in occupations with growing import penetration. They model globalization as raising the returns to on-the-job training for high-skill workers, relative to low-skill workers, which is consistent with our finding of a negative training response for graduates after a rise in intermediate import prices.

7 Conclusions

This paper presents new evidence on empirical connections between trade and the labour market. It does so 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 currency depreciation and its variation by the

[37] In their pioneering work studying intermediates, Feenstra and Hanson (1999) also find higher shares of offshoring increase wages for non-production workers and to some degree for production workers (when offshoring occurs outside the main industry of activity).

different structure of trade partners across industries to look at the causal impact of trade on wages and future earnings potential measured by job related education and training. Intermediate import prices rose by more in sectors where the exchange rate depreciated by more and this exerted 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 due to the sterling depreciation.

The finding of falls in wages and training after the Brexit vote offers poignant evidence on how the recent surge in economic nationalism is taking its toll by adversely affecting workers.[38] Many have argued that the economic disparities of the last few decades have polarised people and contributed to the current rise in nationalist politics. A common rationale behind nationalist policies is that putting up protectionist barriers protects domestic production and undo the economic damage suffered by those who lost out earlier. This reasoning very clearly does not account for trade no longer being dominated by final demand, nor recognise that the fragmentation of production into global value chains has changed classic reasoning on protectionism. Calibrating the estimated wage elasticity with respect to intermediate import prices to theory reveals a complementarity between workers and intermediate imports. Thus the cost shock that made intermediate imports more expensive required an adjustment by employers and it is workers who bore the brunt in the form of lower wages and training.

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 does not fit traditional conclusions. 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. Instead, it seems to have had a relatively deskilling impact upon workers in industries that rely on specific foreign sources for their intermediate inputs, and it is this effect which dominates. This has scope to translate into a long-term negative impact on human capital and worker earnings — quite the opposite of what the leave vote was expected to deliver by some. Moreover, 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 combined evidence shows 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). The episode studied therefore adds further to widely expressed, growing concerns about patterns of real wage stagnation in contemporary labour markets.

[38]This resonates with recent findings of Amiti et al. (2019) and Fajgelbaum et al. (2019) which examine the price and welfare effects of tariffs imposed by the Trump administration in 2018.

8 References

Acemoglu, D., D. Autor, D. Dorn, G. Hanson and B. Price (2016), "Import Competition and the Great US Employment Sag of the 2000s", *Journal of Labor Economics*, 34 (S1), pp. S141-S198.

Ahmed, S., M. Appendino and M. Ruta (2005), "Depreciations Without Exports? Global Value Chains and the Exchange Rate Elasticity of Exports," *World Bank Policy Research Working Paper 7390*, World Bank, Washington.

Alfaro, L., P. Antras, D. Chor and P. Conconi (forthcoming), "Internalizing Global Value Chains: A Firm-Level Analysis", *Journal of Political Economy*.

Amiti, M. and J. Konings (2007), "Trade liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia", *American Economic Review*, 97 (5), pp. 1611-1638.

Amiti, M. and D. Davis (2011), "Trade, Firms, and Wages: Theory and Evidence", *Review of Economic Studies*, 79 (1), pp. 1-36.

Amiti, M., O. Itskhoki and J. Konings (2014), "Importers, Exporters and Exchange Rate Disconnect", *American Economic Review*, 104 (7), pp. 1942-78.

Amiti, M., O. Itskhoki and J. Konings (forthcoming), "International Shocks, Variable Markups and Domestic Prices", *Review of Economic Studies*.

Amiti, M., S. Redding and D. Weinstein (2019), "The Impact of the 2018 Trade War on U.S. Prices and Welfare", *CEP Discussion Paper*, No. 1603.

Antras, P. and R. Staiger (2012), "Offshoring and the Role of Trade Agreements", *American Economic Review*, 102 (7), pp. 3140-83.

Auer, R., A. Burstein and S. Lein (2018), "Exchange Rates and Prices: Evidence from the 2015 Swiss Franc Appreciation", *Working Paper*.

Auer, R., B. Bonadio and A. Levchenko (2018), "The Economics and Politics of Revoking NAFTA", *NBER Working Paper 25379*.

Autor, D., D. Dorn and G. Hanson (2013), "The China Syndrome: Local Labor Market Effects of Import Competition in the United States", *American Economic Review*, 103 (6), pp. 2121-68.

Baldwin, R. (2016): "A New eBook: Brexit Beckons", *VoxEU*. Available in: https://voxeu.org/article/newebook-brexit-beckons, 2016.

Bastos, P., J. Silva and R. Proencca (2016), "Exports and Job Training", *Review of International Economics*, 24 (4), pp. 737-756.

Berman, N., P. Martin and T. Mayer (2012), "How do Different Exporters React to Exchange Rate Changes?", *Quarterly Journal of Economics*, 127 (1), pp. 437-492.

Blanchflower, D., R. Costa and S. Machin (2017), "The Return of Falling Real Wages", *CEP Technical Report*.

Bloom, N., P. Bunn, S. Chen, P. Mizen, P. Smietanka, G. Thwaites and G. Young (2018), "Brexit and Uncertainty: Insights from the Decision Maker Panel", *Fiscal Studies*, 39 (4), pp. 555-580.

Boehm, C., A. Flaaen and N. Pandalai-Nayar (2017), "Multinationals, Offshoring, and the Decline of U.S. Manufacturing, *Working Paper*.

Breinlich, H., E. Leromain, D. Novy, T. Sampson and A. Usman (2018), "The Economic Effects of Brexit: Evidence from the Stock Market", *Fiscal Studies*, 39 (4), pp. 581-623.

Breinlich, H., E. Leromain, D. Novy and T. Sampson (2017), "The Consequences of the Brexit vote for UK Inflation and Living Standards: First Evidence", *CEP Technical Report*.

Broda, C. and D. Weinstein (2006), "Globalization and the Gains from Variety", *Quarterly Journal of Economics*, 121 (2), pp. 541-585.

Burgess, S., M. Knetter (1998), "An International Comparison of Employment Adjustment to Exchange Rate Fluctuations", *Review of International Economi*cs, 6 (1), pp. 151-163.

Burstein, A., M. Eichenbaum and S. Rebelo (2005), "Large Devaluations and the Real Exchange Rate", *Journal of Political Economy*, 113 (4), pp. 742-784.

Burstein, A. and G. Gopinath (2014), "International Prices and Exchange Rates", in *Handbook of International Economics*, 4, Elsevier.

Campa, J. and L. Goldberg (2001), "Employment Versus Wage Adjustment and the US dollar", *Review of Economics and Statistics*, 83 (3), pp. 477-489.

Cravino, J. and A. Levchenko (2017), "The Distributional Consequences of Large Devaluations", *American Economic Review*, 107 (11), pp. 3477-3509.

Criscuolo, C. and L. Garicano (2010), "Offshoring and Wage Inequality: Using Occupational Licensing as a Shifter of Offshoring Costs", *American Economic Review*, 100 (2), pp. 439-43.

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

Datt, M., B. Hoekman and M. Malouche (2011), "Taking Stock of Trade Protectionism Since 2008", *World Bank - Economic Premise*, pp. 1-9.

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

De Long, B. (2017), "Let's Think Harder About the Role of Globalization in Wage Stagnation", *Blog entry*.

De Soyres, F., E. Frohm, V. Gunnella and E. Pavlova (2018), "Bought, Sold, and Bought Again : The Impact of Complex Value Chains on Export Elasticities", *Policy Research Working Paper*, No. 8535. World Bank, Washington, DC.

Dearden, L., H. Reed and J. Van Reenen (2006), "The Impact of Training on Productivity and Wages: Evidence from British Panel Data", *Oxford Bulletin of Economics and Statistics*, 68 (4), pp. 397-421.

Desai, M., C. Foley and J. Hines (2009), "Domestic Effects of the Foreign Activities of U.S. Multinationals", *American Economic Journal: Economic Policy*, 1 (1), pp. 181-203.

Dhingra, S., H. Huang, G. Ottaviano, J. Pessoa, T. Sampson and J. Van Reenen (2017), "The Costs and Benefits of Leaving the EU: Trade Effects", *Economic Policy*, 32 (92), pp. 651-705.

Dix-Carneiro, R. and B. Kovak (2017), "Trade Liberalization and Regional Dynamics", *American Economic Review*, 107 (10), pp. 2908-46.

Ebenstein, A., A. Harrison, M. McMillan and S. Phillips (2014), "Estimating the Impact of Trade and Offshoring on American Workers using the Current Population Surveys", *Review of Economics and Statistics*, 96 (4), pp. 581-595.

Engel, C. (2015), "Exchange Rates and Interest Parity," *Handbook of International Economics*, 4, Elsevier.

Fauceglia, D., A. Lassmann, A. Shingal and M. Wermelinger (2015), "Backward Participation in Global Value Chains and Exchange Rate Driven Adjustments of Swiss Exports", Study commissioned by the Swiss State Secretariat of Economic Affairs (SECO).

Fajgelbaum, P., P. Goldberg, P. Kennedy and A. Khandelwal (2019), "The Return to Protectionism", *NBER Working Paper 25638*.

Faust, F., J. Rogers, S. Wang and J. Wright (2007), "The High-frequency Response of Exchange Rates and Interest Rates to Macroeconomic Announcements", *Journal of Monetary Economics*, 54 (4), pp. 1051-1068.

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

Feenstra, R. and G. Hanson (1999), "The Impact of Outsourcing and High-technology Capital on Wages: Estimates for the United States, 1979–1990", *Quarterly Journal of Economics*, 114 (3), pp. 907-940.

Goldberg, L. and J. Tracy (2001), "Exchange Rates and Wages", *NBER Working Paper 8137*.

Goldberg, P., A. Khandelwal, N. Pavcnik and P. Topalova (2009), "Multi-product Firms and Product Turnover in the Developing World: Evidence from India", *Review of Economics and Statistics*, 92 (4), pp. 1042-1049.

Goldberg, P. and N. Pavcnik (2016), "The Effects of Trade Policy" in *Handbook of Commercial Policy*, 1, Elsevier.

Graziano, A., K. Handley and N. Limao (2018), "Brexit Uncertainty and Trade Disintegration", *Working Paper*.

Grossman, G. and E. Rossi-Hansberg (2008), "Trading Tasks: A Simple Theory of Offshoring", *American Economic Review*, 98 (5), pp. 1978-1997.

Grossman, G. and E. Rossi-Hansberg (2012), "Task Trade Between Similar Countries", *Econometrica*, 80 (2), pp. 593-629, 2012.

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

Guner, N., A. Ruggieri and J. Tybout (2018), "Training, Offshoring, and the Job Ladder", *2018 Meeting Papers*, SED.

Hakobyan, S. and J. McLaren (2016), "Looking for Local Labor Market Effects of NAFTA", *Review of Economics and Statistics*, 98 (4), pp. 728-741.

Halpern, L., M. Koren and A. Szeidl (2015), "Imported Inputs and Productivity", *American Economic Review*, 105 (12), pp. 3660-3703.

Hamermesh, D (1996), *Labor Demand*, Princeton University Press.

Handley, K. and N. Limao (2017), "Policy Uncertainty, Trade, and Welfare: Theory and Evidence for China and the United States", *American Economic Review*, 107 (9), pp. 2731-83.

Handley, K. and N. Limao (2015), "Trade and Investment under Policy Uncertainty: Theory and Firm Evidence", *American Economic Journal: Economic Policy*, 7 (4), pp. 189-222.

Harrison, A., J. McLaren and M. McMillan (2011), "Recent Perspectives on Trade and Inequality", *Annual Review of Economics*, 3 (1), pp. 261-289.

Helpman, E. (2017), "Globalisation and Wage Inequality", *Journal of the British Academy*, 5, pp. 125-162.

Hogrefe, J. and J. Wrona (2015), "Trade, Tasks and Training: The Effect of Offshoring on Individual Skill Upgrading", *Canadian Journal of Economics*, 48 (4), pp. 1537-1560.

Hummels, D., R. Jorgensen, J. Munch and C. Xiang (2014), "The Wage Effects of Offshoring: Evidence from Danish Matched Worker-Firm Data", *American Economic Review*, 104 (6), pp. 1597-1629.

Hummels, D., J. Munch, L. Skipper and C. Xiang (2012), "Offshoring, Transition, and Training: Evidence from Danish Matched Worker-Firm Data", *American Economic Review*, 102 (3), pp. 424-28.

Hummels, D., J. Munch and C. Xiang (2018), "Offshoring and Labor Markets", *Journal of Economic Literature*, 56 (3), pp. 981-1028.

Hyman, B. (2018), "Can Displaced Labor Be Retrained? Evidence from Quasi-Random Assignment to Trade Adjustment Assistance", *Working Paper*.

Johnson, R. and G. Noguera (2012), "Accounting for Intermediates: Production Sharing and Trade in Value Added", *Journal of International Economics*, 86 (2), pp. 224-236.

Kasahara, H. and B. Lapham (2013), "Productivity and the Decision to Import and Export: Theory and Evidence", *Journal of International Economics*, 89 (2), pp. 297-316.

Kosteas, V. (2017), "Workers' Participation in Training and Import Competition: Evidence from the USA", *World Economy*, 40 (6), pp. 1089-1104.

Kovak, B. (2013), "Regional Effects of Trade Reform: What is the Correct Measure of Liberalization?", *American Economic Review*, 103 (5), pp. 1960-76.

Kovak, B., L. Oldenski and N. Sly (2017), "The Labor Market Effects of Offshoring by U.S. Multinational Firms: Evidence from Changes in Global Tax Policies", *Federal Reserve Bank of Kansas City Working Paper*.

Kugler, M. and E. Verhoogen (2009), "Plants and Imported Inputs: New Facts and an Interpretation", *American Economic Review*, 99 (2), pp. 501-07.

Kugler, M. and E. Verhoogen (2012), "Prices, Plant Size, and Product Quality", *The Review of Economic Studies*, 79 (1), pp. 307-339.

Leigh, D., W. Lian, M. Poplawski-Ribeiro and V. Tsyrennikov (2015), "Exchange Rates and Trade Flows: Disconnected?", Chapter 3 in *World Economic Outlook*, IMF.

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

Liu, R. and D. Trefler (2008), "Much Ado about Nothing: American Jobs and the Rise of Service Outsourcing to China and India", *Working Paper*.

Lynch, L. (1992), "Private-sector Training and the Earnings of Young Workers", *American Economic Review*, 82 (1), pp. 299-312.

Mishel, L. (2015), "Causes of Wage Stagnation", Washington, DC: Economic Policy Institute. Available at: http://www.epi.org/publication/causes-of-wage-stagnation.

OECD (1998), "Human Capital Investment: An International Comparison". *OECD Publishing*.

Ottaviano, G., G. Peri and G. Wright (2013), "Immigration, Offshoring and American Jobs", *American Economic Review*, 103 (5), pp.1925-59

Pierce, J. and P. Schott (2016), "The Surprisingly Swift Decline of U.S. Manufacturing Employment", *American Economic Review*, 106 (7), pp. 1632-62.

Revenga, A. (1992), "Exporting Jobs?: The Impact of Import Competition on Employment and Wages in U.S. Manufacturing", *Quarterly Journal of Economics*, 107 (1), pp. 255-284.

Sampson, T. (2017), "Brexit: The Economics of International Disintegration", *Journal of Economic Perspectives*, 31 (4), pp. 163-84.

Schone, P. (2007), "Does Increased International Competition Increase the Need for Training?", *Applied Economics Letters*, 14 (2), pp. 151-155.

Sethupathy, G. (2013), "Offshoring, Wages, and Employment: Theory and Evidence", *European Economic Review*, 62 (C), pp. 73-97.

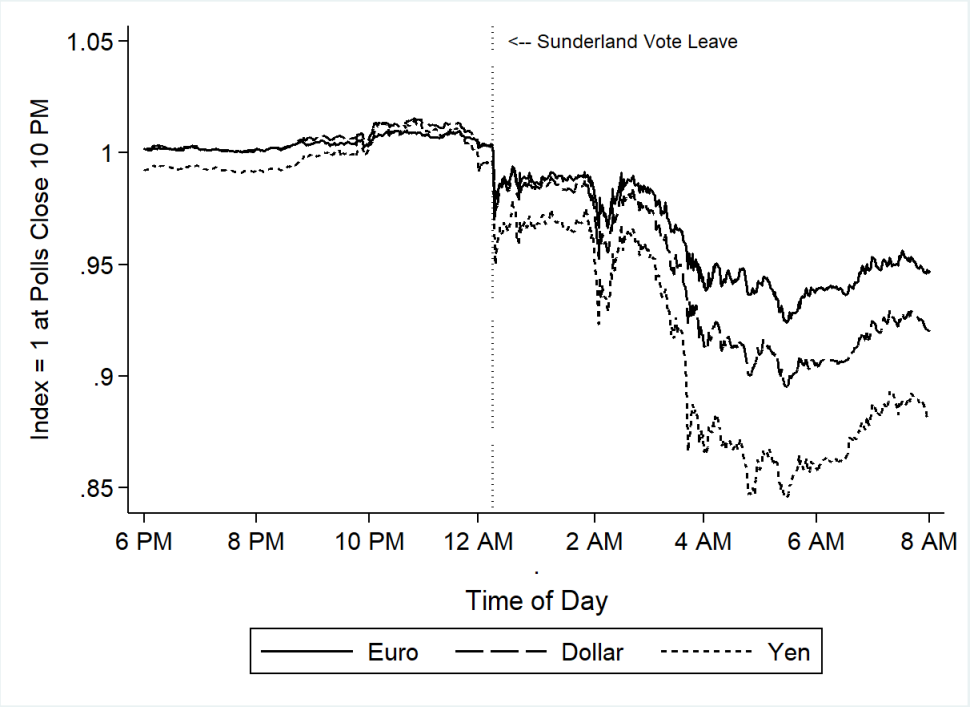
Sitchinava, M. (2008), "Trade, Technology, and Wage Inequality: Evidence from U.S. Manufacturing, 1989-2004", University of Oregon, Ph. D. dissertation.

Trefler, D. (2004), "The Long and Short of the Canada-U.S. Free Trade Agreement", *American Economic Review*, 94 (4), pp. 870-895.

Van Reenen, J. (2016), "Brexit's Long-run Effects on the UK economy", *Brookings Papers on Economic Activity*, 47 (2), pp. 367-383.

Van Ark, B., J. Hao, C. Corrado and C. Hulten (2009), "Measuring Intangible Capital and its Contribution to Economic Growth in Europe", *Working Paper*.

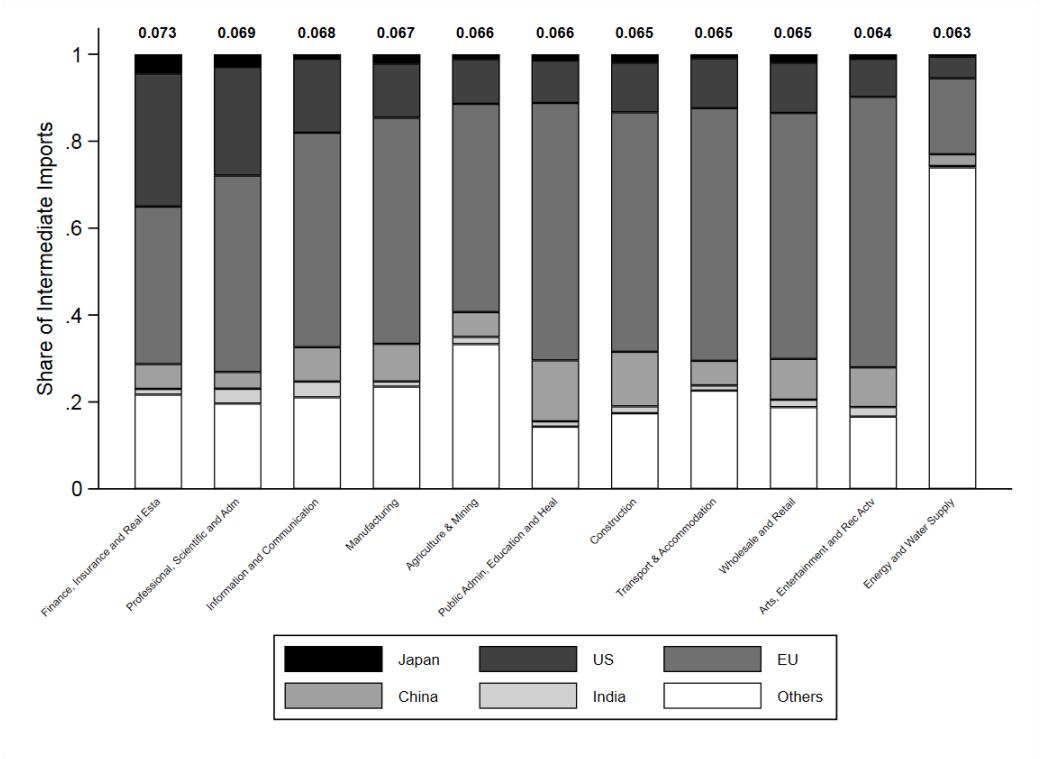
Figure 1: Exchange Rate Movements in the 6 PM to 8AM Window Around The Referendum



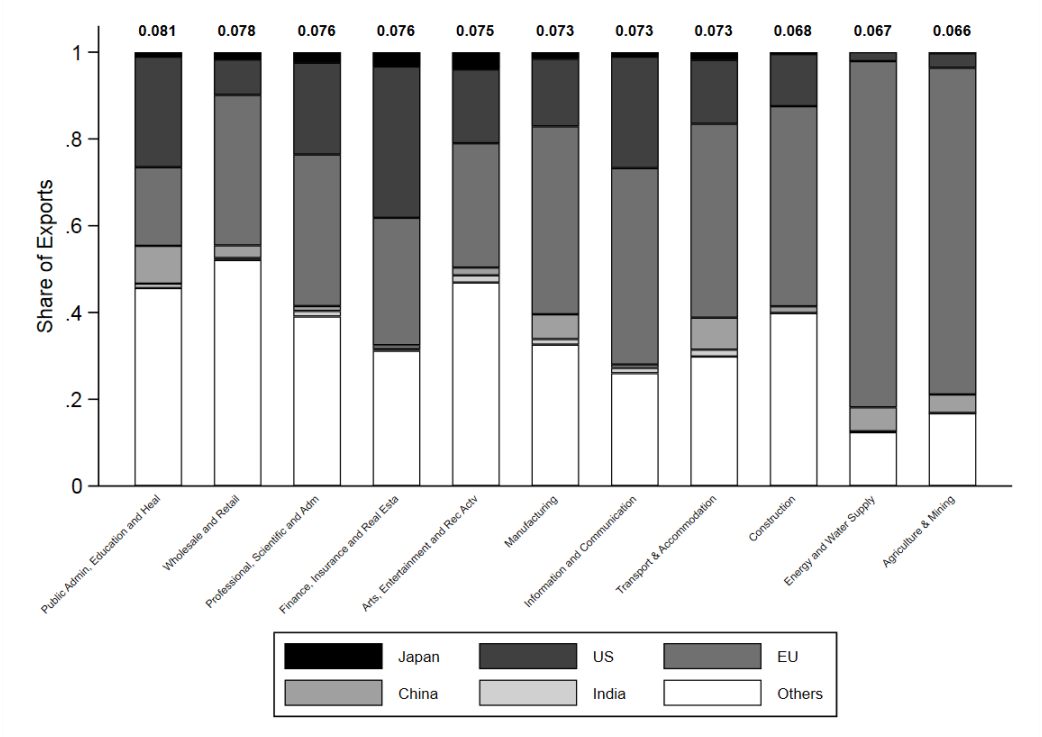
Notes: Exchange rates are taken from HistData (FOREX).

Figure 2: Trade Shares by Main Trading Partners in 2015

(a) Intermediate Imports



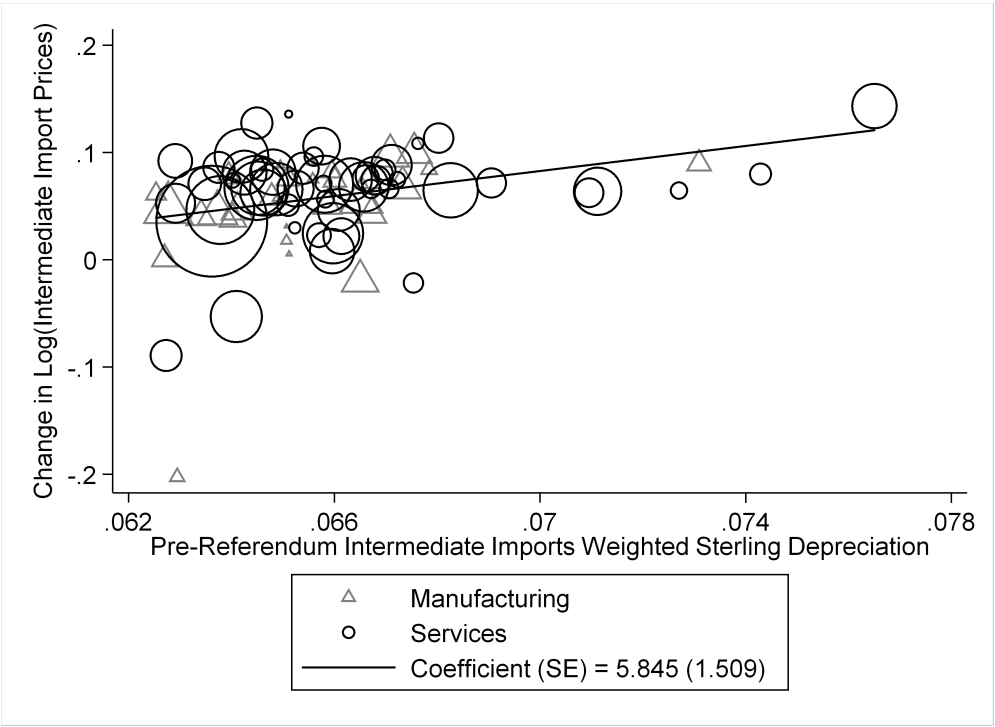
(b) Exports



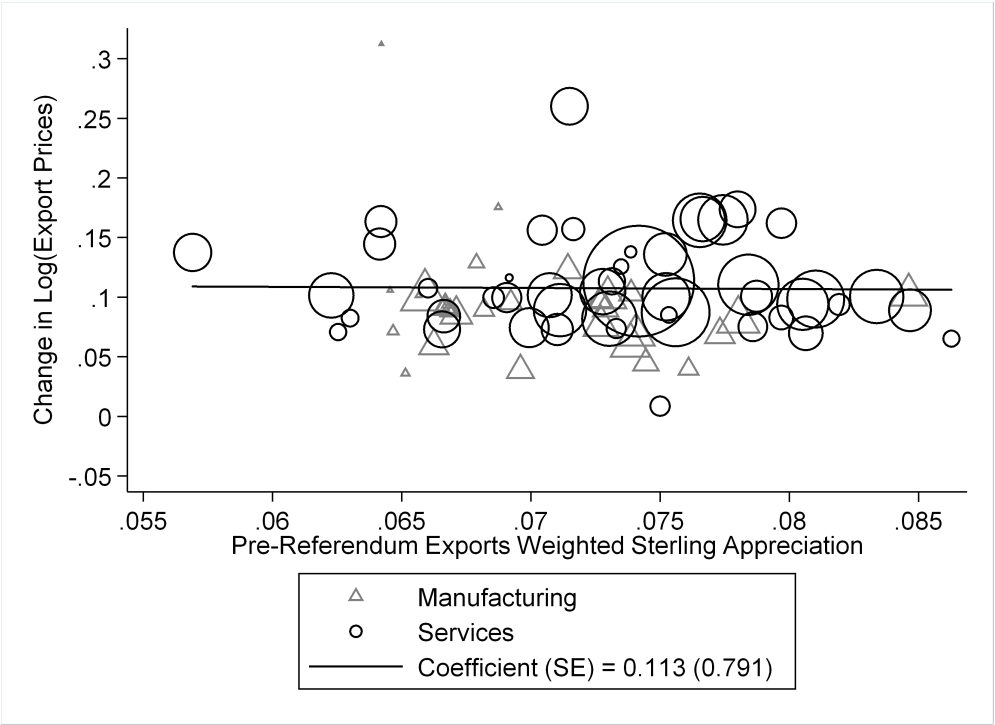
Notes: Shares of trade are calculated based on the sum of trade in goods and services for each industry aggregate. The numbers at the top of the bars represent the weighted depreciation/appreciation calculated for each industry aggregate.

Figure 3: Pre-Post Referendum Changes in Trade Prices and Exchange Rates

(a) Intermediate Import Prices



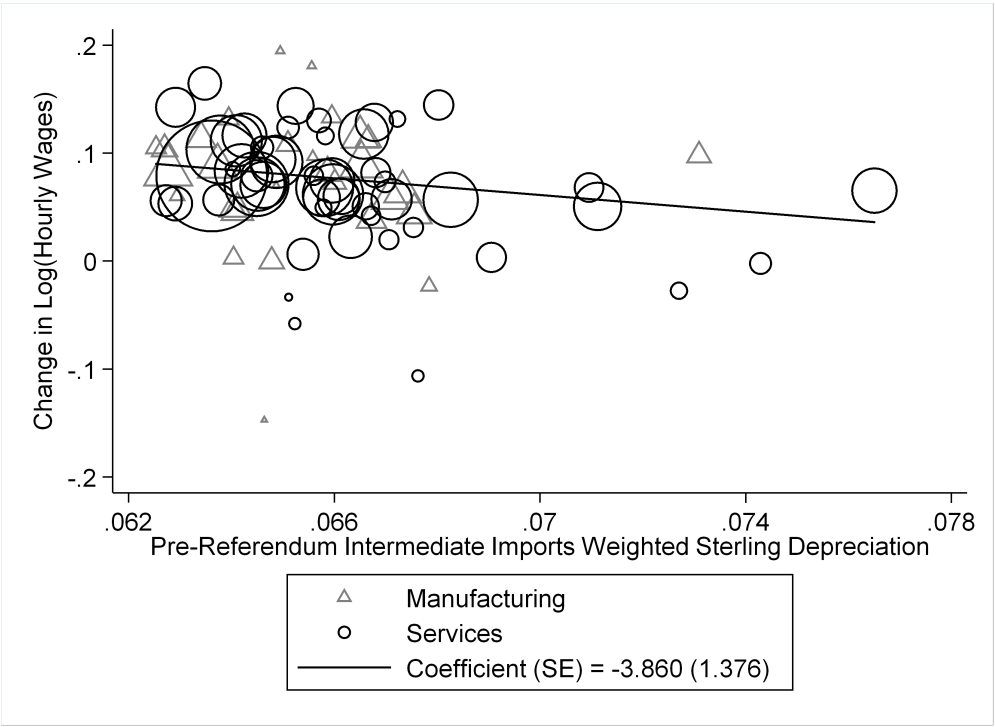
(b) Export Prices



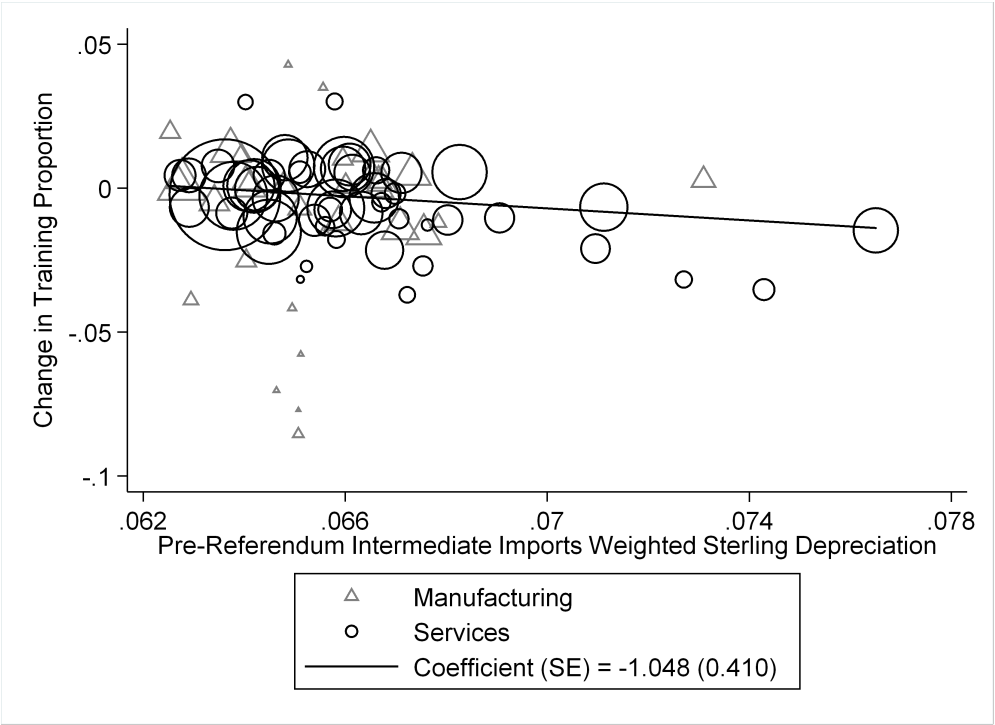
Notes: Size of the markers correspond to LFS industry weights.

Figure 4: Pre-Post Referendum Changes in Worker Outcomes and Exchange Rates

(a) Wages

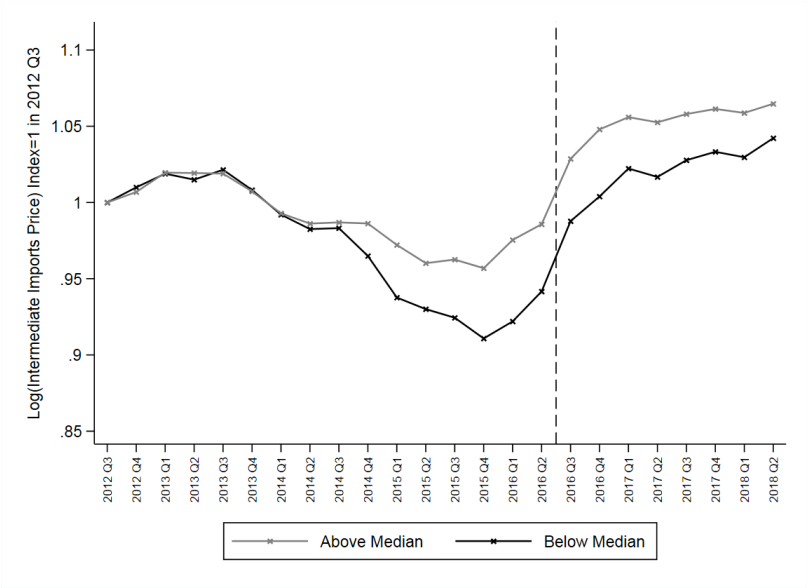


(b) Training



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

Figure 5: Trends in Intermediate Import Prices



Notes: Log of average intermediate import prices are calculated using LFS individual weights.

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 Depreciation) X Post-Referendum	0.375 (0.100)	0.411 (0.107)	0.526 (0.137)
B. Exports			
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	0.164 (0.111)	0.171 (0.114)	0.233 (0.136)
Log(Exports Weighted Appreciation) X Post-Referendum	0.006 (0.016)	0.007 (0.016)	0.009 (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(Intermediate Import Prices)		-0.515 (0.251)		-0.545 (0.226)
Log (Export Prices)				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	
	Reduced Form	IV	Reduced Form	IV
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.206 (0.074)		-0.190 (0.087)	
Log(Intermediate Import Prices)		-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. Sample definitions are as described in Table 3.

Table 5: Training, Trade Prices and Exchange Rates

	A. Full Sample			
	Reduced Form	IV	Reduced Form	IV
	(1)	(2)	(3)	(4)
Log(Intermediate Imports Weighted	-0.069		-0.071	
Depreciation) X Post-Referendum	(0.021)		(0.022)	
Log(Exports Weighted			-0.001	
Appreciation) X Post-Referendum			(0.007)	
Log(Intermediate Import Prices)		-0.184		-0.196
		(0.073)		(0.076)
Log (Export Prices)				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	
	Reduced Form	IV	Reduced Form	IV
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted	-0.073		-0.048	
Depreciation) X Post-Referendum	(0.022)		(0.022)	
Log(Intermediate Import Prices)		-0.177		-0.090
		(0.073)		(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. Sample definitions are as described in Table 3.

Table 6: 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(Intermediate Import Prices)			-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(Intermediate Import Prices)			-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 7: Heterogeneity By Skill

	Full Sample	Restricted Samples	
		Excluding Announcement	Excluding QE
	IV	IV	IV
	(1)	(2)	(3)
A. Wages			
Log(Price of Intermediate Imports)			
× Graduates	-0.616	-0.607	-0.601
	(0.216)	(0.191)	(0.176)
× Non-Graduates	-0.216	-0.184	-0.042
	(0.252)	(0.225)	(0.196)
First-Stage F-Statistic	6.8	7.3	12.8
Sample Size	123,489	117,380	92,492
B. Training			
Log(Price of Intermediate Imports)			
× Graduates	-0.205	-0.199	-0.148
	(0.067)	(0.067)	(0.061)
× Non-Graduates	-0.118	-0.124	-0.023
	(0.085)	(0.087)	(0.074)
First-Stage F-Statistic	6.9	7.4	11.3
Sample Size	578,282	548,079	434,431
Controls	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes

Notes: The dependent variable of Panel A is log of full time hourly wages and a dummy for whether the individual received job-related education or training in the past 4 weeks 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). Sample definitions are as described in Table 3.

Table 8: 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	$S_{P^M C}/S_{WC}$	0.1/0.4	ONS
Labour demand elasticity	ε_{WW}	-0.5	Hamermesh (1996)
Share of domestic sales in total sales	S_{uk}	0.70	ONS
Share of adjustment of prices	$\delta\kappa$	0.25	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 θ_{MW}	Implied AUES between Workers and Intermediate Imports σ_{WP^M}		
	$\sigma = 1$	$\sigma = 3$	$\sigma = 5$
	(1)	(2)	(3)
-0.35	-1.82	-1.96	-2.10
-0.40	-2.11	-2.32	-2.53
-0.45	-2.39	-2.67	-2.95
-0.50	-2.68	-3.03	-3.38
-0.55	-2.96	-3.38	-3.80

Notes: Estimated Wage Elasticities in Column (1) are values within the range of the estimated IV coefficient $\hat{\theta}_{MW}$. To recover the Allen-Uzawa elasticity of substitution (AUES) between workers and intermediate imports, the parameter values are taken from (a).

A Appendix: Full Timeline

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.1 Theory

Change in worker outcomes

The output costs are $C_o = C\left(R\left(W_o, W_T, W_V\right), P_o^M\left(P_i\left(P_{si}\right)\right), P_o^D\left(P_i\left(1\right)\right)\right)$ where T and V denote training and overtime. The costs change by $\hat{C}_o = S_{RC}\sum_v S_{W_vR}\hat{W}_v + S_{P^MC}\sum_i S_{P_iP^M}\sum_s S_{P_{si}P_i}\hat{P}_{si}$ for $v \in \{o, T, V\}$. Intermediate input prices change by $\hat{P}_{si} = \kappa^M\left(\hat{C}_{si} - \hat{E}_s\right) = -\kappa^M\delta^M\hat{E}_s$. Output prices change by $\hat{P}_{od} = \kappa\delta\hat{C}_o - \kappa\left(1-\delta\right)\hat{E}_d$ and the resulting change in sales to each destination is $S_d\hat{Q}_{od} = -\sigma S_d\hat{P}_{od} + \sigma S_d\hat{A}_d$. For the UK, $\hat{A}_{uk}$ summarizes the change in the domestic aggregate price index because endowments do not change. In export destinations of the UK, $\hat{A}_d = 0$ when the UK is small in its destination market $d \neq UK$.

Let $S_d \equiv \tau_{od}Q_{od}/\sum_d \tau_{od}Q_{od}$ denote the share ofsales in destination d. Then wage changes are determined by differentiating labour market clearing conditions ($\bar{L}_o = C_R R_W \sum_d \tau_{od}Q_{od}$) which gives:

$$
\begin{aligned}
0 =& \left(\frac{RC_{RR}}{C_R}\right)\left(\sum_v \frac{R_{W_v}W_v}{R}\hat{W}_v\right) + \left(\frac{P^MC_{RP^M}}{C_R}\right)\left(\sum_i\sum_s \frac{P_iP_{P_i}^M}{P^M}\frac{P_{i_{P_{si}}}P_{si}}{P_i}\hat{P}_{si}\right) \\
&+ \sum_v \frac{R_{WW_v}W_v}{R_W}\hat{W}_v + \sum_d S_d\hat{Q}_d \\
=& \sigma_{RR}S_{RC}\left(\sum_v S_{W_vR}\hat{W}_v\right) + \sigma_{RP^M}S_{P^MC}\hat{P}^M \\
&+ \sum_v \sigma_{WW_v}S_{W_vR}\hat{W}_v + S_{uk}\hat{Q}_{uk} + \sum_d S_d\hat{Q}_d \\
=& \sum_v \left(\sigma_{RR}S_{RC} + \sigma_{WW_v} - \delta S_{uk}\kappa\sigma S_{RC}\right)S_{W_vR}\hat{W}_v \\
&+ \left(\sigma_{RP^M} - \delta S_{uk}\kappa\sigma\right)S_{P^MC}\hat{P}^M - \left(1 - S_{uk}\right)\sigma\hat{P}^X + \sigma\sum_d S_d\hat{A}_d
\end{aligned}
$$

Import prices change by

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

Export prices change by

$$
\hat{P}^X = \kappa\sum_{d\neq uk} S_{dx}\left(\delta S_{RC}\sum_v S_{W_vR}\hat{W}_v + \delta S_{P^MC}\hat{P}^M - \left(1-\delta\right)\hat{E}_d\right)
$$

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

$$\begin{aligned}\hat{P}^X =& -\kappa\delta S_{P^MC}\left(\frac{\sigma_{RP^M}-\sigma_{RR}-\sigma_{WW}/S_{RC}}{\sigma_{RR}+\sigma_{WW}/S_{RC}-\delta\kappa\sigma}\right)\hat{P}^M \\ &+\kappa(1-\delta)\left(\frac{\sigma_{RR}+\sigma_{WW}/S_{RC}-\delta S_{uk}\kappa\sigma}{\sigma_{RR}+\sigma_{WW}/S_{RC}-\delta\kappa\sigma}\right)\left(-\sum_{d\neq uk}S_{dx}\hat{E}_d\right)+A\end{aligned}$$

where the aggregate shifter is $A \equiv \kappa\delta S_{RC}S_{WC}A_0/\left(\frac{\sigma_{RR}+\sigma_{WW}/S_{RC}-\delta\kappa\sigma}{\sigma_{RR}+\sigma_{WW}/S_{RC}-\delta S_{uk}\kappa\sigma}\right)$ and $A_0 \equiv -\sigma\sum\hat{A}_d/S_{RC}S_{WR}(\sigma_{RR}+\sigma_{WW}/S_{RC}-\delta S_{uk}\kappa\sigma)$.

When A_d is generalized to be an explicit function of the destination exchange rate (as in a local pricing example of $A_d = \bar{A}_d/E_d$ for $\bar{A}_d > 0$), the RHS of the wage equation can be written just in terms of quantities. The appropriate reduced form regression would then have the export quantity index changes instead of the sterling export price index change on the LHS and in the structural equation for wages. To account for this channel, Table A1 uses export quantities to show that assumptions on the aggregate demand shifter are not constraining the first stage.

From the training choice, $T = C_R R_{W_T}\sum_d \tau_d Q_d$ and the change in training is therefore

$$\begin{aligned}\hat{T} =& -\sum_v(\sigma_{RR}+\sigma_{W_TW_v}/S_{RC}-\delta S_{uk}\kappa\sigma)S_{RC}S_{W_vR}\hat{W}_v \\ &+(\sigma_{RP^M}-\delta S_{uk}\kappa\sigma)S_{P^MC}\hat{P}^M-(1-S_{uk})\sigma\hat{P}^X+\sigma\sum_d S_d\hat{A}_d\end{aligned}$$

Substituting for the wage change, the change in training is $\hat{T} = \alpha_T + \theta_{MT}\hat{P}^M + \theta_{XT}\hat{P}^X$ where $\alpha_T \equiv -\sigma\frac{(\sigma_{W_TW}-\sigma_{WW})/S_{RC}}{\sigma_{RR}+\sigma_{WW}/S_{RC}-\delta S_{uk}\kappa\sigma}\sum_d S_d\hat{A}_d$, $\theta_{MT} \equiv \theta_{MW}S_{WR}(\sigma_{W_TW}-\sigma_{WW})$ and $\theta_{XT} \equiv \theta_{XW}S_{WR}(\sigma_{W_TW}-\sigma_{WW})$.

Similarly, firms' optimal choice of overtime workers is $V = C_R R_{W_V}\sum_d \tau_d Q_d$, which changes by $\hat{V} = \alpha_V + \theta_{MV}\hat{P}^M + \theta_{XV}\hat{P}^X$ where $\alpha_V \equiv -\sigma\frac{(\sigma_{W_VW}-\sigma_{WW})/S_{RC}}{\sigma_{RR}+\sigma_{WW}/S_{RC}+-\delta S_{uk}\kappa\sigma}\sum_d S_d\hat{A}_d$, $\theta_{MV} \equiv \theta_{MW}S_{WR}(\sigma_{W_VW}-\sigma_{WW})$ and $\theta_{XV} \equiv \theta_{XW}S_{WR}(\sigma_{W_VW}-\sigma_{WW})$.

B.2 Data Description

Exchange Rates

Reuters Datastream collects daily exchange rates for the most relevant traded currencies, including sterling rates against most currencies in the world. In the few cases for which no exchange rate against sterling 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.[39] The final dataset contains 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.[40]

Trade Data

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 and export price indices are calculated as the ratio of trade values to trade volumes and, in the case of intermediates, this is caluclated after the necessary input-output import use allocations are made.

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 (ITIS) survey 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.[41] Secondly we map NAICS 2012 to NACE 2 using the Eurostat official correspondence table.[42]

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.

Data on import use is from the import use tables (product by industry) of the ONS for 2014.[43] 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

[39] https://treasury.un.org/operationalrates/OperationalRates.php

[40] http://www.histdata.com/download-free-forex-data/

[41] http://faculty.som.yale.edu/peterschott/sub_international.htm

[42] http://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL&StrLanguageCode=EN&IntCurrentPage=10

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

inventories and exports of goods and services.

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.

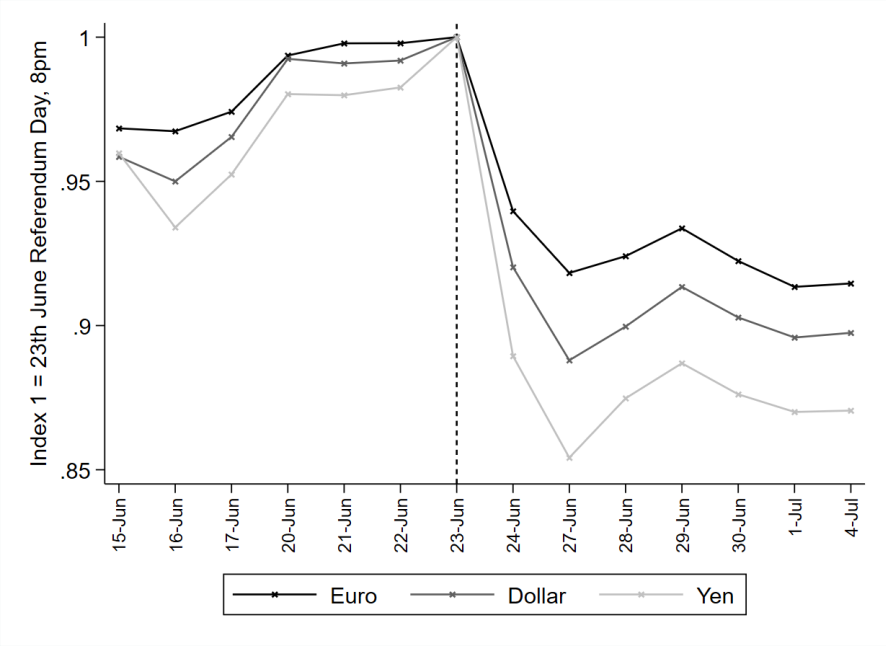
The 4-week training indicator is coded as one if the individual has "taken part in any education or any training connected with his/her job or a job that the individual might be able to do in the future in the past 4 weeks". The value of this variable is conditional on a positive answer to the question: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

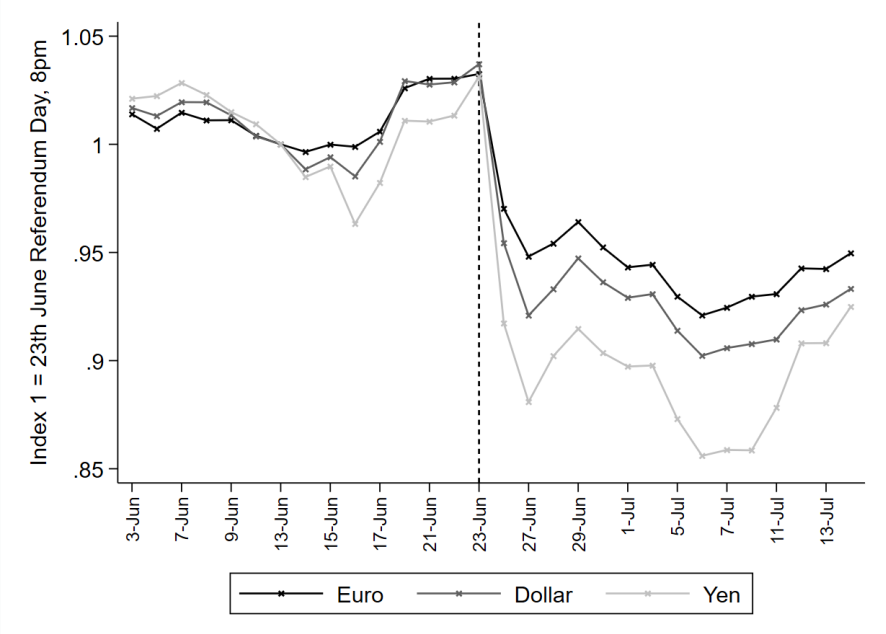
C Additional Tables and Figures

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

(a) 7 Day Window

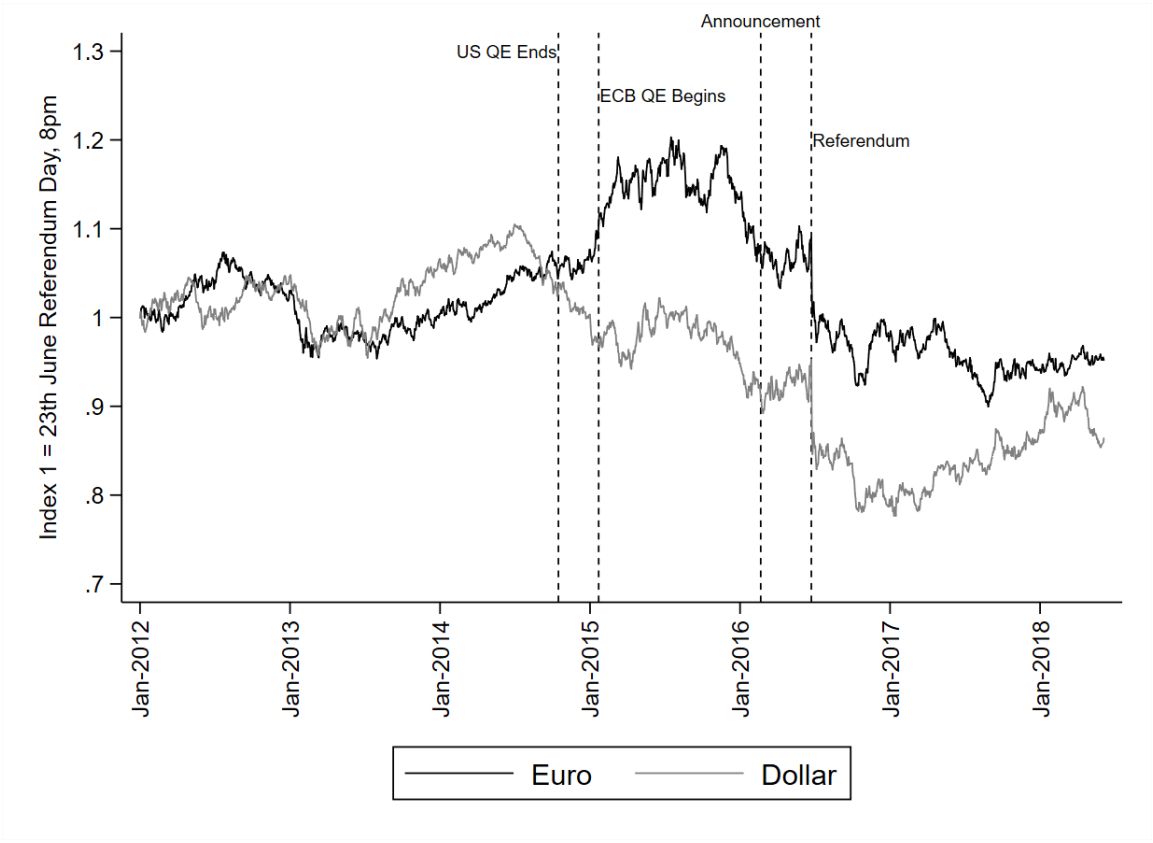


(b) 15 Day Window



Notes: Daily exchange rates from Reuters Datastream.

Figure A2: Dollar and Euro Exchange Rates and Event Timeline



Notes: Daily exchange rates from Reuters Datastream. Quantitative Easing (QE) are marked at time of announcement from Federal Reserve Board and European Central Bank.

Table A1: Pre-Post Referendum Changes in Trade Quantities

	Full Sample	Restricted Samples	
		Excluding Announcement	Excluding QE
	(1)	(2)	(3)
A. Intermediate Imports			
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	0.072 (0.079)	0.088 (0.085)	0.115 (0.102)
B. Exports			
Log(Intermediate Imports Weighted Depreciation) X Post-Referendum	-0.461 (0.289)	-0.493 (0.305)	-0.639 (0.366)
Log(Exports Weighted Appreciation) X Post-Referendum	0.010 (0.053)	0.009 (0.057)	0.004 (0.066)
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. Sample definitions are as described in Table 3.

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(Intermediate Import Prices)			-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(Intermediate Import Prices)			-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 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 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(Intermediate Import Prices)			-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(Intermediate Import Prices)			-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 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 A4: Hours, Trade Prices and Exchange Rates

	A. Full Sample			
	Reduced Form	IV	Reduced Form	IV
	(1)	(2)	(3)	(4)
Log(Intermediate Imports Weighted	-0.052		-0.051	
Depreciation) X Post-Referendum	(0.032)		(0.032)	
Log(Exports Weighted			0.009	
Appreciation) X Post-Referendum			(0.007)	
Log(Intermediate Import Prices)		-0.137		-0.103
		(0.105)		(0.104)
Log (Export Prices)				-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	
	Reduced Form	IV	Reduced Form	IV
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted	-0.050		-0.061	
Depreciation) X Post-Referendum	(0.033)		(0.039)	
Log(Intermediate Import Prices)		-0.122		-0.116
		(0.097)		(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. Sample definitions are as described in Table 3.

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	-0.147		-0.140	
Depreciation) X Post-Referendum	(0.049)		(0.051)	
Log(Exports Weighted			-0.017	
Appreciation) X Post-Referendum			(0.001)	
Log(Intermediate Import Prices)		-0.392		-0.314
		(0.176)		(0.168)
Log (Export Prices)				-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	
	Reduced Form	IV	Reduced Form	IV
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted	-0.141		-0.150	
Depreciation) X Post-Referendum	(0.052)		(0.051)	
Log(Intermediate Import Prices)		-0.342		-0.285
		(0.163)		(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 a dummy for individuals doing paid overtime weekly hours. 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. Sample definitions are as described in Table 3.

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	-0.247		-0.251	
Depreciation) X Post-Referendum	(0.082)		(0.082)	
Log(Exports Weighted			-0.009	
Appreciation) X Post-Referendum			(0.012)	
Log(Intermediate Import Prices)		-0.652		-0.661
		(0.312)		(0.287)
Log (Export Prices)				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	
	Reduced Form	IV	Reduced Form	IV
	(5)	(6)	(7)	(8)
Log(Intermediate Imports Weighted	-0.251		-0.253	
Depreciation) X Post-Referendum	(0.080)		(0.103)	
Log(Intermediate Import Prices)		-0.607		-0.478
		(0.271)		(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. Sample definitions are as described in Table 3.

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(Intermediate Import Prices) X Post-Referendum	-0.489	-0.176	-0.319
	(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 in Column (3). 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).