Essays in Macroeconomics and International Trade

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To my parents Anatolii and Liudmyla

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Preface

This dissertation contributes to the understanding of how the heterogeneity of workers and firms shapes the economic effects of economic policies. In Chapter 1, I study the reallocation of workers across firms induced by monetary policy shocks. Chapters 2 and 3 are dedicated to studying the gains from trade and reallocation of sales in the aftermath of trade liberalization, and the role of financial frictions and variable markups play in it.

Labor Market Effects of Monetary Policy Across Workers and Firms. In the first chapter, based on joint work with Andreas Gulyas (University of Mannheim) and Matthias Meier (University of Mannheim), we use Austrian social security records to analyze the effects of ECB monetary policy on the labor market. Our focus is on the role of worker and firm wage components, defined by an Abowd et al. (1999) wage regression. Our findings show that monetary tightening causes the largest employment losses for low-paid workers who are employed in high-paying firms before the tightening. Monetary tightening further causes a reallocation of workers to lower-paying firms. In particular low-paid workers who were originally employed in low-paying firms are prone to falling down the firm wage ladder.

The second and third chapters are based on the current work with Andrii Tarasenko (University of Mannheim) and Volodymyr Vakhitov (American University Kyiv). In Chapter 2, **Financial Frictions, Markups, and Trade Liberalization: Stylized Facts**, we study the episode of unilateral trade liberalization between the European Union and Ukraine, and document a number of empirical stylized facts. We find that the aggregate capital-labor ratio of Ukrainian exporters to the EU increased after trade liberalization, while non-exporters to the EU did not experience the same pattern. Looking at the contributing factors to the increase in capital intensity, we apply dynamic decomposition of the capital-labor ratio by Melitz and Polanec (2015) and find within-sector reallocation of sales toward more capital-intensive / less financially-constrained firms to be an important driver. Moreover, we also find that reallocation of sales happened towards firms with lower markups. Hence, stylized facts indicate that financial frictions and variable markups could explain reallocation patterns observed among Ukrainian exporters of manufacturing goods to the European Union.

Motivated by the findings in Chapter 2, Chapter 3, **Financial Frictions, Markups, and Trade Liberalization: Quantitative Exploration**, studies effects of trade liberalization in a small open economy with financial frictions and variable markups. We develop a small open-economy model and calibrate it to the Ukrainian manufacturing data. The model is generally based on Kohn et al. (2020) and borrows from Gopinath et al. (2020) and Edmond et al. (2023). The economy is populated by entrepreneurs that own intermediate producers, supply labor to a frictionless labor market, can borrow under a backward-looking collateral constraint, and export upon paying the fixed and iceberg-type cost of exporting. The final good is produced using Kimball (1995) aggregator that gives rise to variable markups in the domestic market, while abroad the markups are assumed to be constant. Unilateral trade liberalization increases welfare and productivity in the domestic economy. Moreover, the allocation of resources improves since the variation of both the effective cost of capital and markups decreases. The gains from trade are lower than in the model without financial frictions, but higher than in the model without variable markups.

Chapter 1

Labor Market Effects of Monetary Policy Across Workers and Firms

with Andreas Gulyas and Matthias Meier

1.1 Introduction

The distributional effects of monetary policy are both of direct concern for policymakers and important for the transmission of monetary policy.[1] In fact, a growing empirical literature studies the distributional effects of monetary policy across workers and firms.[2] However, understanding how the worker-level effects of monetary policy depend on both the worker type *and* the worker's firm type remains largely unexplored.

A key aspect of worker and firm heterogeneity is that they jointly determine the worker's wage. Wages depend on worker-specific components (e.g., worker productivity) and firm-specific components (e.g., firm profitability). Therefore, the distribution of workers across firms matters for earnings inequality (e.g., Bagger and Lentz, 2018; Song et al., 2018; Bonhomme et al., 2019, 2022), productive efficiency (e.g., Hagedorn et al., 2017), and earnings losses (e.g., Gulyas and Pytka, 2019; Lachowska et al., 2020; Bertheau et al., 2022). In addition, worker and firm type determine jointly whether a worker-firm match is sustained. Importantly, it is ex-ante unclear to what extent worker and firm-specific characteristics explain why some workers are more affected by monetary policy than others.

In this paper, we empirically characterize the distributional effects of ECB monetary policy shocks across workers and firms using Austrian social security records. Using an Abowd et al. (1999) wage regression, we estimate worker and firm (wage) fixed effects. From a worker's perspective, the firm fixed effect is arguably the most important aspect of firm heterogeneity, as it measures the firm wage premium relative to other firms. We refer to workers with a high worker fixed effect as high-paid workers, and to firms with a high firm fixed effect as high-paying firms, and analogously for low-paid workers and low-paying firms.

We document three novel results. First, we show that employment losses after monetary tightening are concentrated among low-paid workers in high-paying firms. Second, monetary tightening increases the rate at which workers reallocate across firms, in particular for low-paid workers. Third, the firms to which workers switch after monetary tightening tend to be lower-paying than their previous firms. Especially low-paid workers who were originally employed in low-paying firms reallocate to (even) lower-paying firms. All results apply symmetrically to expansionary monetary policy.

While our finding that low-paid workers are more affected by monetary policy is in line with the previous literature (quoted above), the novelty of our results is the role of the worker's original employer for the distributional effects of monetary policy. As low-paid

[1] See, e.g., McKay et al. (2016), Kaplan et al. (2018), Auclert (2019), Gornemann et al. (2021).

[2] See, e.g., Coibion et al. (2017), Holm et al. (2021), Broer et al. (2021), Andersen et al. (forthcoming), Amberg et al. (2022), Lenza and Slacalek (2022), Moser et al. (2022) on the heterogeneous effects of monetary policy across workers and Gertler and Gilchrist (1994), Bahaj et al. (2019), Ottonello and Winberry (2020), Meier and Reinelt (2022) on the heterogeneous effects across firms.

workers at high-paying firms tend to become non-employed, low-paid workers at low-paying firms tend to reallocate to lower-paying firms. Although a large literature studies heterogeneous effects of monetary policy across workers *or* firms, jointly studying worker and firm heterogeneity has been largely ignored. An exception is Moser et al. (2022) which estimates the distributional effects of lower credit supply due to negative interest rates on employment and pay both within and between firms. Another closely related paper is Crane et al. (2022) which studies the effects of recession across both worker and firm ranks.

Our analysis uses the universe of Austrian social security records, which includes a worker identifier, an establishment identifier, the start and end dates of employment and registered unemployment spells, the wage, and a few other worker characteristics. We use these records to construct a quarterly worker-level panel with 200 million observations between 1999 and 2018. We combine the worker panel with high-frequency identified ECB monetary policy shocks (Altavilla et al., 2019; Jarociński and Karadi, 2020). To characterize the distributional effects of monetary policy, we estimate worker-level panel local projections.

Our main findings show statistically and economically significant heterogeneity in the employment effects of monetary policy across workers and firms. Across all workers, the average employment probability is 0.27 percentage points (p.p.) lower one year after a one-standard deviation contractionary monetary policy shock, and the opposite for an expansionary shock. The average, however, masks large differences across workers. For workers with an above-median worker fixed effect, the employment probability falls by 0.23 p.p., while for workers with a below-median worker fixed effect the employment probability falls by 0.32 p.p. That is, low-paid workers are 40% more likely to become non-employed than high-paid workers. However, only examining the role of worker fixed effects misses large differences across firm fixed effects. Perhaps surprisingly, among the low-paid workers, those originally employed at high-paying firms are particularly likely to become non-employed. Their employment probability falls by 0.36 p.p. Conversely, the employment probability of low-paid workers at low-paying firms only falls by 0.18 p.p.

Monetary policy shocks not only affect the probability of whether a worker is employed but also induce the reallocation of workers across firms. On average, a one standard deviation monetary policy shock increases the likelihood of changing employers by 0.2 p.p. Job switching is especially concentrated among low-paid workers. These workers are three times more likely than high-paid workers to change employers in response to a monetary policy shock. A natural question that arises is where workers reallocate to: Are workers moving to better paying or worse paying employers? We find that across all workers switching employers, the average wage premium of firms falls by 0.16% after a one-standard deviation contractionary monetary policy shock. In other words, workers reallocate to lower-paying firms. Interestingly, this reallocation response is fairly similar when comparing low-paid to high-paid workers, and when comparing workers at low-paying to those at high-paying firms. However, we do find large differences in the interaction of worker type and firm type. In particular, we find that low-paid workers originally employed by low-paying firms are disproportionately reallocating towards worse-paying firms. In contrast, low-paid workers originally employed by high-paying firms tend to reallocate to similar firm types.

Taken together, our results imply that contractionary monetary policy shocks especially hurt low-paid workers across multiple dimensions. First, they lower their employment probability, especially for those originally employed at high-paying firms. Second, even conditionally on re-employment, monetary policy induces a reallocation of low-paid workers originally employed at worse-paying firms to even worse-paying firms.

Our paper provides new empirical moments which can be useful for the further development of Heterogeneous Agent New Keynesian models. While our findings highlight the role of both worker and firm heterogeneity, existing models either feature only worker heterogeneity (e.g., Gornemann et al., 2021; Dolado et al., 2019; Bergman et al., 2022; Bhandari et al., 2021; Ravn and Sterk, 2020), or only firm heterogeneity (e.g., Ottonello and Winberry, 2020; Meier and Reinelt, 2022). Instead, a New Keynesian model with two-sided heterogeneity would allow studying the positive and normative implications of our evidence.

The paper is organized as follows: Section 1.2 describes the data. Section 1.3 provides evidence on the employment effects of monetary policy. Section 1.4 provides evidence on the reallocation effects of monetary policy. Section 1.5 provides a sensitivity analysis. Section 1.6 concludes.

1.2 Data

In this section, we describe the data and key variables used in our analysis.

1.2.1 Austrian Social Security Data

We use administrative data from the Austrian social security administration that cover the universe of administrative employment and unemployment records for all workers subject to social security from 1999 through 2018.[3] The data include a worker identifier, an establishment identifier, the first and last day of employment and unemployment spells, the worker's age, and the establishment's industry classifier. In the data, we observe only the establishment a worker is employed at, but not the firm. At the same time, most establishments are owned by one-establishment firms. For simplicity, we will refer to

[3] All private sector jobs are subject to social security except self-employed individuals. The data also include many public sector jobs except civil servants ("Beamte"), see Zweimüller et al. (2009) for details.

establishments as firms in the remainder of the paper. For every worker-firm match, we observe annual labor income. On average, we observe 2.7 million workers per year.

We construct a worker panel based on which we estimate worker-level responses to monetary policy shocks. In theory, we could construct a daily panel, since both social security data and monetary policy shocks are available at a daily frequency. Such a panel, however, would include 20 billion observations rendering the regression analysis extremely burdensome if not infeasible. Furthermore, given the presence of various labor market frictions and the typically sluggish response of macroeconomic aggregates to monetary policy shocks we should not expect large employment responses at very short horizons. We therefore construct a quarterly worker panel. We focus on individuals with high labor force attachment by excluding workers below 26 and above 60 years old.[4]

Our sample only consists of employment spells subject to social security and registered unemployment spells.[5] There are several reasons why a worker may disappear from our sample. A worker may drop out of the labor force, move outside of Austria, or find employment not covered by social security such as self-employment. In our analysis, we have to take a stance on how to define the employment status of workers who disappear from our dataset. We decide to only consider the employment and non-employment trajectories of workers who are either employed or registered as unemployed. We think of this choice as conservative, as we may underestimate the employment responses if workers are pushed outside of the labor force in response to monetary policy shocks.[6]

Our final panel has 213.9 million worker-quarter observations and Table 1.1 provides summary statistics. As we use the universe of all employment observations subject to social security, the descriptive statistics mirror the labor market structure of Austria.

1.2.2 Worker and Firm Fixed Effects

Our goal in this paper is to empirically characterize the distributional effects of ECB monetary policy shocks across the joint distribution of worker and firm types. We estimate worker and firm types using the seminal Abowd et al. (1999) wage regression (in short: AKM). In particular, we estimate worker and firm types through the fixed effects in the following annual wage regression

$$wage_{i,j,\tau} = \boldsymbol{F}_{j(i,\tau)} + \boldsymbol{W}_i + \beta X_{i,\tau} + \varepsilon_{i,j,\tau}, \tag{1.2.1}$$

[4] In this step we lose around 36.6 mln observations - the original dataset contained around 250.5 mln observations. Section 1.5 shows that our main results are robust when including all individuals in our sample.

[5] Unemployment benefits are paid only for a specific amount of time. After running out of unemployment benefits, workers continue to receive benefits, although at a lower replacement rate, and are still observed as registered unemployed in our dataset.

[6] Our results are robust to coding workers that drop from our sample as non-employed (see Section 1.5).

Table 1.1: Descriptive statistics

	Mean	Min	P25	P75	Max	Obs
Worker characteristics						
Employment *(0/1)*	0.906	0	1	1	1	226,765,739
Age *(in years)*	41.6	26	34	49	60	213,892,967
Wage *(in 2010€)*	103.1	6.3	65.4	131.2	64249.8	193,650,934
Labor market transitions						
EE *(0/1)*	0.028	0	0	0	1	197,469,000
EU *(0/1)*	0.026	0	0	0	1	197,469,000
UE *(0/1)*	0.248	0	0	0	1	18,791,090
UU *(0/1)*	0.752	0	1	1	1	18,791,090
Firm characteristics						
Firm age *(in years)*	21.2	0	8	33	99	193,650,934
Firm size *(employees)*	1047.7	1	16	540	33222	193,650,934
Worker and firm fixed effects						
Worker fixed effect	0.020	-6.633	-0.199	0.249	2.958	193,650,934
Firm fixed effect	0.008	-5.147	-0.110	0.176	2.901	193,650,934
Monetary policy						
MP shock *(in bp)*	0.37	-21.26	-1.84	2.16	12.69	80

Note: This table provides descriptive statistics for our worker-level panel from 1991Q1 through 2018Q4. Workers are either employed (1) or unemployed (0). Wages are daily wages of employed workers. The labor market transitions are quarterly transitions from employment at one firm to another (EE), from employment to unemployment (EU) and vice versa (UE). The AKM fixed effects are expressed in log real wage units. MP shock describes our baseline shock series in basis points.

where $wage_{i,j,\tau}$ is the log daily wage of worker i, employed in firm j in year τ, $\boldsymbol{F}_{j(i,\tau)}$ is a firm fixed effect, $\boldsymbol{W}_i$ is a worker fixed effect, and $X_{i,\tau}$ is a cubic polynomial of worker age. For each worker and year, we select the dominant employer according to total yearly income. Table 1.1 provides descriptive statistics of the worker and firm fixed effects.

The firm fixed effect $\boldsymbol{F}_{j(i,\tau)}$ for firm j is assumed to be invariant over time and is identified through wage changes of workers moving across firms.[7] Theoretically it is possible that the firm fixed effect is affected by monetary policy shocks. Although monetary policy are at least an order of magnitude smaller in standard deviation than idiosyncratic shocks to firms, to avoid endogeneity concerns, our analysis will mostly use the firm and worker fixed effects estimated from a backward-looking 5-year rolling window. We denote the

[7]The related literature has pointed out that few workers moving in some firms creates a limited mobility bias in the variance of firm fixed effects. However, we do not study the variance of firm fixed effects but rather the point estimates, which are consistently estimated under limited mobility bias. Furthermore, Bonhomme et al. (2022) show that the AKM estimates in Austria are very similar to alternative methods of estimating worker and firm wage effects.

estimated worker and firm fixed effects for the rolling windows by

$$\boldsymbol{W}_{i,\tau}^{rolling} \quad \text{and} \quad \boldsymbol{F}_{j(i,\tau),\tau}^{rolling}. \tag{1.2.2}$$

where the sample used to estimate $\boldsymbol{W}_{i,\tau}^{rolling}$ and $\boldsymbol{F}_{j(i,\tau),\tau}^{rolling}$ ranges from year $\tau - 4$ to τ. To be able to compare the rolling-window estimates over time, we compute the percentile rank of these fixed effects, which we denote by

$$\widetilde{\boldsymbol{W}}_{i,\tau}^{rolling} = \text{percentile}\left(\boldsymbol{W}_{i,\tau}^{rolling}\right) \quad \text{and} \quad \widetilde{\boldsymbol{F}}_{j(i,\tau),\tau}^{rolling} = \text{percentile}\left(\boldsymbol{F}_{j(i,\tau),\tau}^{rolling}\right). \tag{1.2.3}$$

When studying the reallocation of workers across firms, we need a constant measure of firm fixed effects over time. Thus, in Section 1.4 we will use the firm fixed effects estimated in (1.2.1) over the entire sample.

1.2.3 ECB Monetary Policy Shocks

As ECB monetary policy shocks, we consider high-frequency changes in the Overnight Index Swap (OIS) rates around policy meetings of the ECB Governing Council. The OIS is a swap contract exchanging a fixed interest rate for the floating Euro Overnight Index Average (Eonia) on the European interbank market. We exclusively consider scheduled meetings, which mitigates the problem that monetary surprises may convey private central bank information about the state of the economy. The event window starts 10-20 minutes before the press release and ends 10-20 minutes after the press conference. Following Jarociński and Karadi (2020), we further use sign restrictions to separate information effects from conventional monetary policy shocks. The identifying restriction is that monetary policy shocks should move interest rates and stock prices in opposite directions, while central bank information moves them in the same direction.

Our baseline shock series is constructed from high-frequency changes in the 6-months ahead OIS rate provided by Altavilla et al. (2019).[8] While surprises in the 3-month rate become minuscule during the zero lower bound (ZLB) episode, we observe non-negligible surprises in the 6-month rate throughout our sample. We aggregate the daily shocks into quarterly frequency. Daily shocks are assigned fully to the current quarter if they occur on the first day of the quarter. If they occur within the quarter, they are partially assigned to the current and subsequent quarter (Gorodnichenko and Weber, 2016). The monetary policy shock series covers 1999Q1 through 2018Q4. Table 1.1 shows descriptive statistics and Figure 1.7 in the Appendix shows the time series.

As a plausibility check and to provide a benchmark for our subsequent worker-level results, we estimate the responses of macroeconomic aggregates for the Austrian economy to the monetary policy shocks, see Figure 1.8 in the Appendix. We find that a one-standard

[8] Our results are robust to using the 3-months ahead OIS rate, see Section 1.5.

deviation monetary policy shock lowers real GDP by up to 0.4% with the peak effects attained between one and two years after the shock. We observe a similar dynamic for the employment rate which falls by up to 0.3 p.p. for prime-age workers.

1.3 Employment Probability

In this section, we estimate the effects of monetary policy shocks on the employment probability of workers. We find that low-paid workers who are employed in high-paying firms before the shock are most affected by monetary policy.

1.3.1 Average Response

Before studying the distributional employment effects of monetary policy, we estimate the average employment effect across all workers. This provides a benchmark for the subsequent analysis. We estimate the following worker-level panel local projections on around 200 million worker-quarter observations of our baseline sample:[9]

$$e_{i,t+h} = \alpha_i^h + \beta^h \, \varepsilon_t^{\mathrm{MP}} + \delta^h Z_{i,t-1} + v_{i,t+h}^h, \tag{1.3.1}$$

for $h = 0, \ldots, 12$ quarters, where $e_{i,t+h}$ denotes a binary employment variable with

$$e_{i,t+h} = \begin{cases} 1 & \text{worker } i \text{ is employed in quarter } t+h, \\ 0 & \text{else.} \end{cases}$$

We include only workers in the regression that are employed in $t-1$, the quarter preceding the monetary policy shock. This facilitates the comparison with the subsequent analysis, in which we need to condition on employment in $t-1$ in order to study the responses by worker and firm types.[10] On the right-hand side, α_i^h denotes a worker fixed effect (not the AKM worker fixed effect), $\varepsilon_t^{\mathrm{MP}}$ is the monetary policy shock, and $Z_{i,t-1}$ is a vector of control variables, notably a linear time trend and season fixed effects for the four quarters. The coefficient of interest is β^h, which captures the change in the employment probability in response to a monetary policy shock.

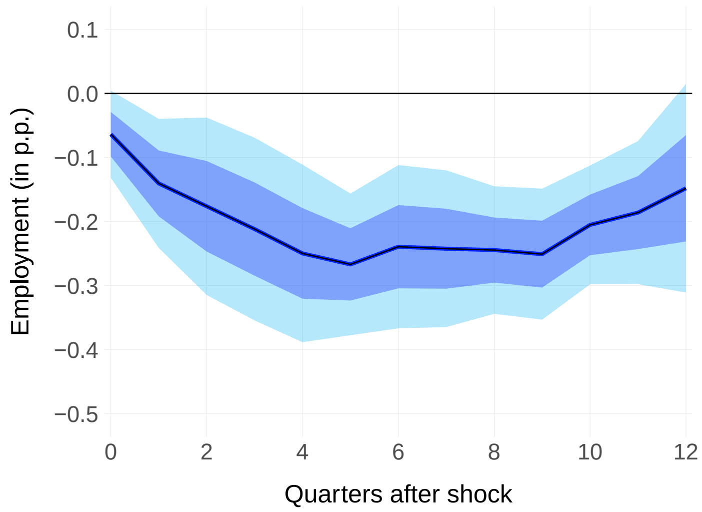
Figure 1.1 shows the average response of the employment probability based on (1.3.1). The solid line shows the point estimates of β^h, normalized to correspond to a one-standard deviation monetary policy shock, and the shaded areas indicate 68% and 95% confidence

[9] The large number of observations together with the two-way clustering implies a very high computational demand of this regression, which makes it infeasible to run this regression on standard personal computers. We thank Baden-Württemberg High Performance Computing (bwHPC) for support of our project.

[10] We study the employment response for workers that are non-employed in period $t-1$ at the end of this subsection.

bands based on standard errors that are two-way clustered by worker and quarter. We find that the employment probability significantly falls. The response gradually builds up and peaks at a 0.27 p.p. lower employment probability five quarters after the shock. The average worker-level response is broadly in line with the aggregate employment response in Figure 1.8.

Figure 1.1: Average employment response (β^h)



Note: The solid line shows the estimated β^h coefficients in equation (1.3.1). The β^h coefficients are standardized to capture the employment probability response to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

While Figure 1.1 shows the employment response of workers employed in the quarter before the monetary policy shock, we also examine the effect on workers who are unemployed before the shock. Figure 1.9 in the Appendix shows that unemployed workers are significantly less likely to become employed after monetary policy shocks. In response to a one standard deviation shock, their employment probability falls by up to 0.89 p.p. In comparison, the average quarterly UE transition rate is 24.8% (see Table 1.1).

1.3.2 Heterogeneity across Worker and Firm Fixed Effects

We next present our empirical results on the distributional employment effects of monetary policy across worker and firm fixed effects. Formally, we estimate the following state-dependent worker-level panel local projections

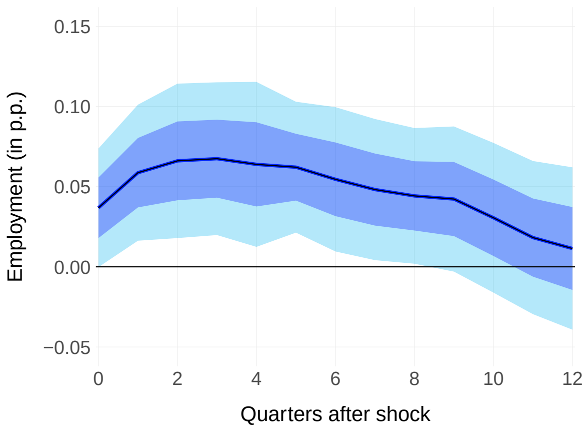
$$
\begin{aligned}
& e_{i,t+h} && (1.3.2)\\
= \quad & \alpha_i^h + \delta^h Z_{i,t-1} + v_{i,t+h}^h \\
& + \beta^h \ \varepsilon_t^{\mathrm{MP}} && (\textit{average effect})\\
& + \gamma^{W,h} \ \varepsilon_t^{\mathrm{MP}} \left(\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling} - \overline{\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling}} \right) && (\textit{worker heterogeneity})\\
& + \gamma^{F,h} \ \varepsilon_t^{\mathrm{MP}} \left(\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling} - \overline{\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling}} \right) && (\textit{firm heterogeneity})\\
& + \gamma^{WF,h} \ \varepsilon_t^{\mathrm{MP}} \left(\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling} - \overline{\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling}} \right) \left(\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling} - \overline{\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling}} \right), && (\textit{interaction})
\end{aligned}
$$

where β^h captures the employment response of a worker with an average worker fixed effect in the year preceding the monetary policy shock (i.e., for $\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling} = \overline{\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling}}$) and an average firm fixed effect for the firm which employed the worker in quarter $t-1$ (i.e., for $\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling} = \overline{\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling}}$). The coefficient $\gamma^{W,h}$ captures the differential employment response of a higher worker fixed effect, $\gamma^{F,h}$ captures the differential employment response of a higher firm fixed effect, and $\gamma^{WF,h}$ captures the differential employment response of the interaction between a higher worker and a higher firm fixed effect.[11] While we study the heterogeneity in our baseline with a linear specification, we show in the appendix (see Figure 1.10) that our results are very similar if we use worker and firm groups instead. Figure 1.2 presents our main results from equation (1.3.2). Panel (a) shows that workers with higher worker fixed effect are significantly less likely to become non-employed after a monetary policy shock (conditional on an average firm fixed effect). The estimated differences are economically meaningful. Workers with a one standard deviation higher worker fixed effect are up to 0.07 p.p. less likely to become non-employed compared to the average employment probability response of up to 0.27 p.p. Turning to the role of firm fixed effects, panel (b) shows that workers employed in firms with a higher firm fixed effect are significantly more likely to become non-employed after a monetary policy shock (conditional on an average worker fixed effect). The magnitudes are similarily economically meaningful as for worker fixed effects. Equation (1.3.2) also contains an interaction effect between the worker and firm fixed effects. Panel (c) shows that the coefficient on the interaction is significantly positive. This means that workers with combinations of high (or low) worker and firm fixed effects are less likely to become non-employed than workers with opposite combinations. Put differently, workers are more likely to become non-employed when their worker fixed effect is in the opposite half of the distribution as their firm fixed effect.

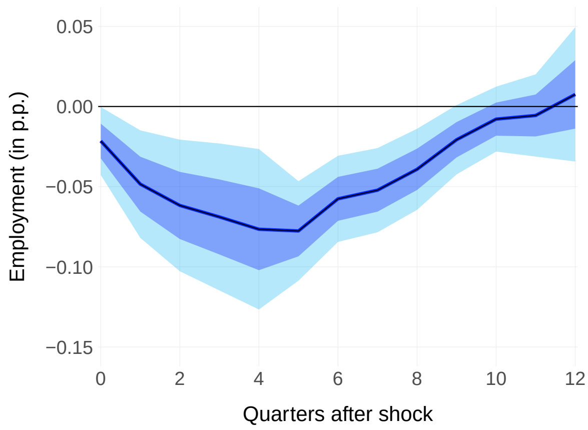
[11]The control vector $Z_{i,t-1}$ is specified as in Section 1.3.1 except that the seasonal fixed effects are interacted with quintile group dummies for worker and firm fixed effects, respectively. This allows us to control for some heterogeneity in the employment seasonality across workers and firms.

Figure 1.2: Employment response across worker and firm fixed effects

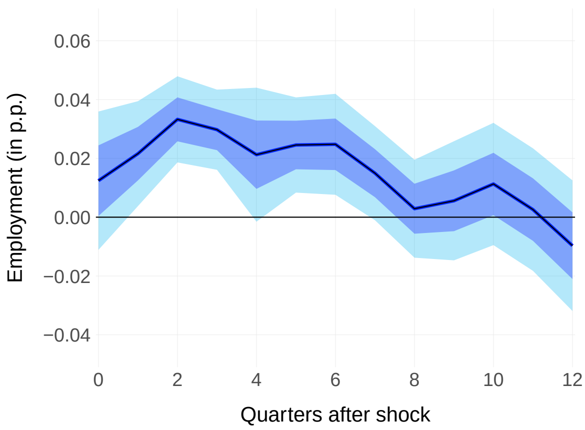
(a) Worker fixed effect ($\gamma^{W,h}$)



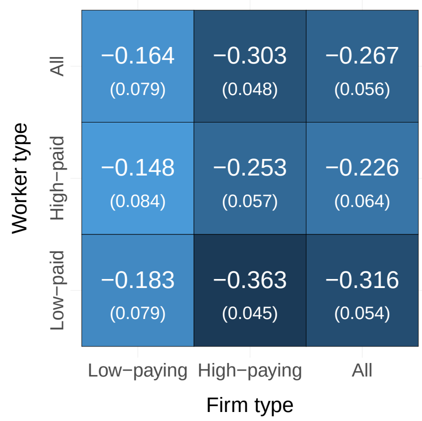
(b) Firm fixed effect ($\gamma^{F,h}$)



(c) Worker-Firm interaction ($\gamma^{WF,h}$)



(d) Group-specific responses



Note: The solid lines in panels (a)-(c) show the estimated differential responses, the γ coefficients in equation (1.3.2). The γ coefficients are standardized to capture the employment probability response to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$ and for a one standard deviation above-average worker and firm fixed effect. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter. Panel (d) shows the total employment response of different worker groups estimated based on β^h, $\gamma^{W,h}$, $\gamma^{F,h}$, $\gamma^{WF,h}$ at $h = 5$ and the associated standard errors are in parantheses. For example, the employment response of high-paid workers in low-paying firms is estimated based on $\beta^h + (p_{75}^W - p_{50}^W)\gamma^{W,h}/\sigma_W + (p_{25}^F - p_{50}^F)\gamma^{F,h}/\sigma_F + (p_{75}^W - p_{50}^W)(p_{25}^F - p_{50}^F)\gamma^{WF,h}/(\sigma_W\sigma_F)$, where p_x^W and p_x^F denote the x-th percentiles of the distribution of worker and firm fixed effects, and σ_W and σ_F are the associated standard deviations.

Panel (d) of Figure 1.2 presents the group-specific total employment responses, based on combining the average (β^h) and the differential ($\gamma^{W,h}, \gamma^{F,h}, \gamma^{WF,h}$) responses. We define low and high-paid workers as workers with a worker fixed effect at the 25th and 75th percentile, respectively. Analogously, we define low and high-paying firms as firm fixed effect at the 25th and 75th percentile across all workers, respectively. The table in panel (d) shows the employment response of different combinations of low and high-paid workers and low and high-paying firms at horizon $h = 5$, when the average employment response peaks. We find that the employment responses differ similarly across firm and worker types (see "All" column and row, respectively). While a monetary policy shock lowers the employment probability by 0.16 p.p. for workers at low-paying firms, it plummets by

0.30 p.p. at high-paying firms. In comparison, the drop is 0.23 p.p. for high-paid workers and 0.32 p.p. for low-paid workers across all firms. What stands out from the table is that low-paid workers at high-paying firms are most affected by monetary policy shocks. The employment probability for them drops by 0.36 p.p. The least affected group is high-paid workers from low-paying firms, for which the employment probability drops by 0.15 p.p. This implies that the most affected group of workers in the table has a 2.4 times higher probability of non-employment than the least affected group.

1.4 Reallocation of Workers across Firms

In this section, we estimate the effects of monetary policy shocks on the reallocation of workers across firms. We find that workers are more likely to switch firms and they tend to switch to worse-paying firms. In particular, low-paid workers employed by low-paying firms before the shock are most likely to switch to worse-paying firms.

1.4.1 Firm Switching Probability

To estimate the average effects of monetary policy shock on the probability that a worker switches between firms, we use equation (1.3.1) but replace the left-hand side by a dummy variable that indicates whether a worker switches firms

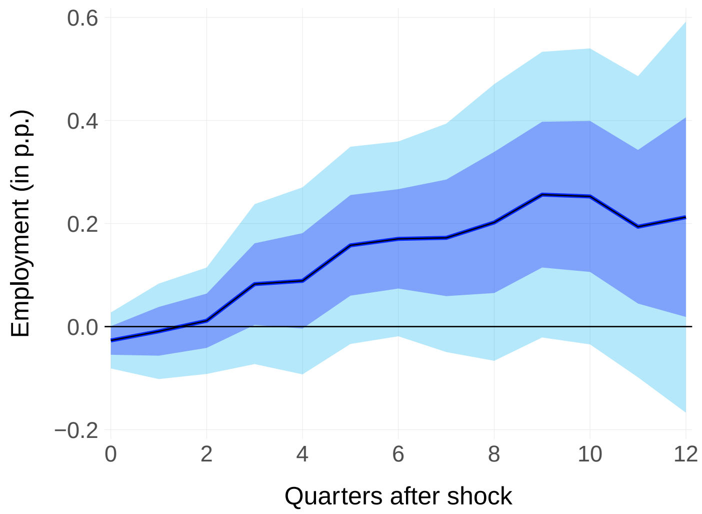
$$e^{switch}_{i,t+h} = \begin{cases} 1 & \text{if a worker is employed in } t+h \text{ by a different firm than in } t-1, \\ 0 & \text{else.} \end{cases} \tag{1.4.1}$$

For $h = 0$, the sample average of $e^{switch}_{i,t+h}$ is the quarterly firm switching probability, the EE transition rate, which is 2.8% (see Table 1.1).

The estimated average response of the firm switching probability to a one standard deviation monetary policy shock is shown in Figure 1.3. The switching probability increases by up to 0.25 p.p. after the shock, which is a sizable increase over the average switching probability. However, the response is only mildly significant, in particular when compared to the response of the employment probability in Figure 1.1.

We again turn to the question of which workers are more prone to change employers. In particular, we use (1.3.2) but replace again the left-hand side by the dummy variable indicating a change in employer from equation (1.4.1). Figure 1.4 provides our findings. Most remarkable is the role of the worker fixed effect. Low-paid workers are significantly more likely to switch firms. A one standard deviation lower worker fixed effect lowers the firm switching probability by up to 0.12 p.p. In contrast, we don't find significant differences across firm fixed effects or along the interaction of worker and firm fixed effects.

Figure 1.3: Average response of firm switching probability



Note: The solid line shows the estimated β^h coefficients in equation (1.3.1) when using (1.4.1) as left-hand side. The β^h coefficients are standardized to capture the firm switching probability response to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

1.4.2 Firm Wages

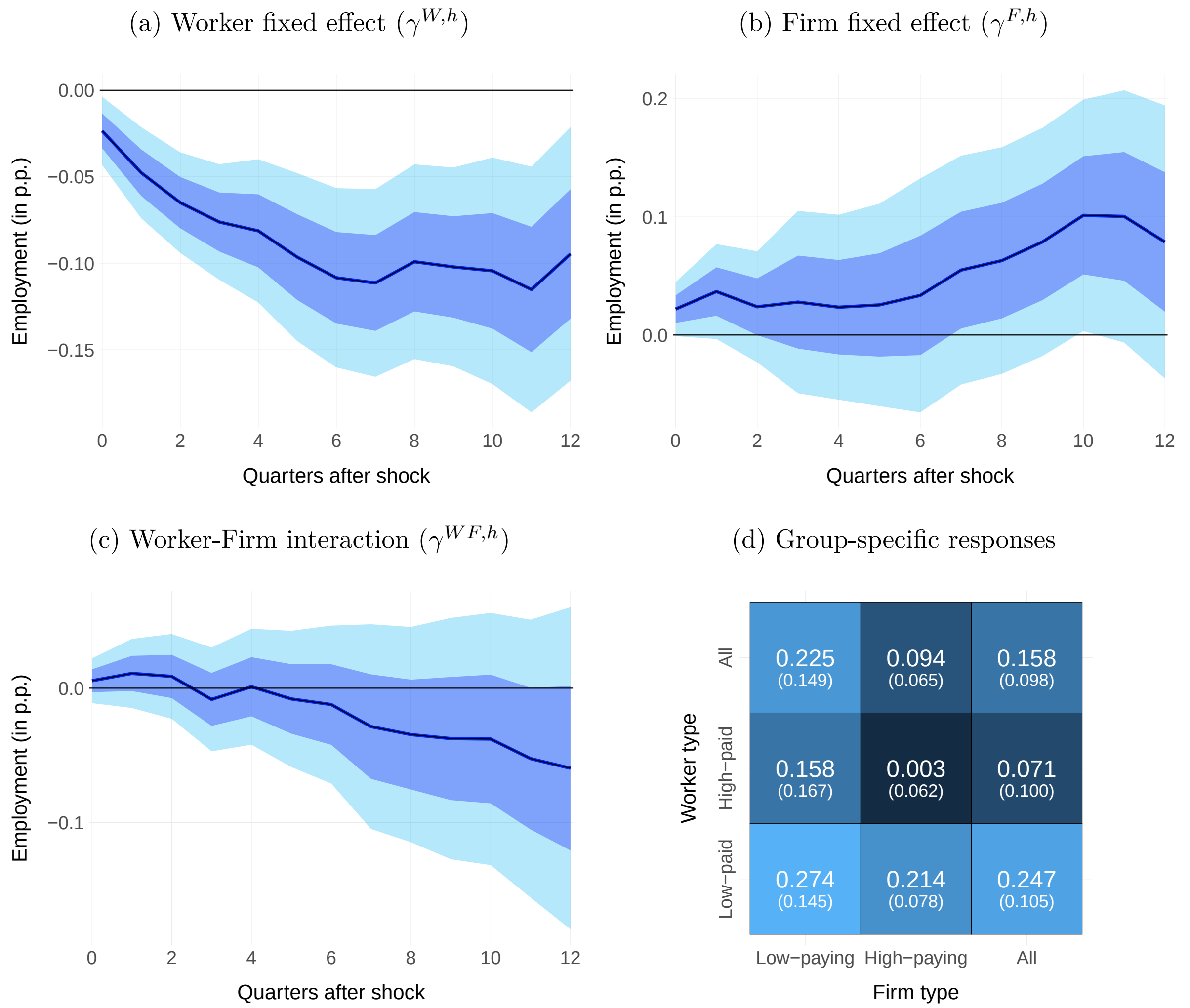
The previous section showed that monetary policy induces workers to switch employers, with the effect concentrated among low-paid workers. This naturally leads to the question where these worker move to, in particular, whether they find better- or worse-paying employers compared to before. Thus, we first ask whether monetary policy on average leads to a reallocation of workers towards lower or higher firm fixed effects. To estimate the average effect of monetary policy shocks on the change in the firm fixed effects of workers that switch firms, we use (1.3.1) but replace the left-hand side by

$$\boldsymbol{F}_{j(i,t+h)} - \boldsymbol{F}_{j(i,t-1)}, \tag{1.4.2}$$

which is the change in the worker-associated firm fixed effect between the original employer in $t-1$ and the employer in $t+h$. Recall that in Section 1.3, we classified workers and firms using the backward-looking fixed effects in order to avoid endogeneity of fixed effects with respect to the monetary policy shocks. In contrast, (1.4.2) features the firm fixed effect estimates over the entire sample, because we cannot otherwise compare firm fixed effects over time. We estimate the regression on changes in the firm fixed effect on the subset of workers switching firms between period $t-1$ and $t+h$.

Figure 1.5 shows that the average response of the firm fixed effect is significantly negative. After a one standard deviation monetary policy shock, the average change in the firm wage premium of workers who switch firms falls by up to 0.16%. These effects are sizeable, as compared to the unconditional average drop in the firm fixed effect of 1.6% for switching

Figure 1.4: Firm switching response across worker and firm fixed effects

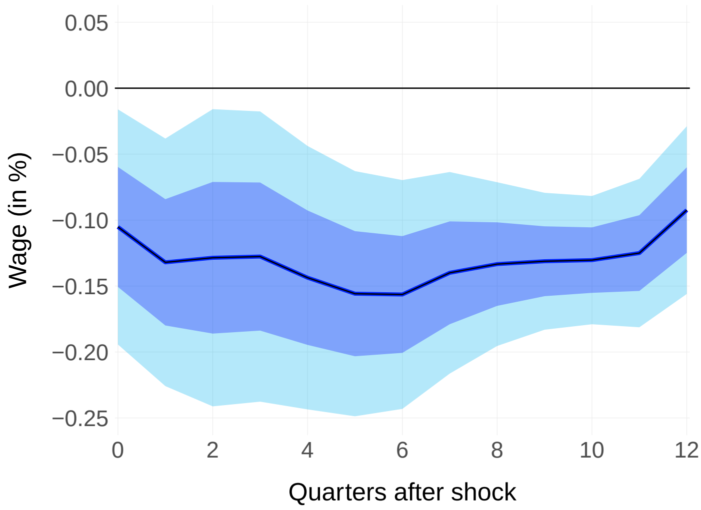


Note: The solid lines in panels (a)-(c) show the differential responses estimated by the γ coefficients in equation (1.3.2) when replacing the left-hand side by (1.4.1). The γ coefficients are standardized to capture the firm switching probability response to a one standard deviation increase in $\varepsilon_t^{\text{MP}}$ given a one standard deviation above-average worker and firm fixed effect. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter. Panel (d) shows the total firm switching response of different worker groups estimated based on β^h, $\gamma^{W,h}$, $\gamma^{F,h}$, $\gamma^{WF,h}$ at $h = 5$ and the associated standard errors are in parentheses. For example, the firm switching response of high-paid workers in low-paying firms is estimated based on $\beta^h + (p_{75}^W - p_{50}^W)\gamma^{W,h}/\sigma_W + (p_{25}^F - p_{50}^F)\gamma^{F,h}/\sigma_F + (p_{75}^W - p_{50}^W)(p_{25}^F - p_{50}^F)\gamma^{WF,h}/(\sigma_W\sigma_F)$, where p_x^W and p_x^F denote the x-th percentiles of the distribution of worker and firm fixed effects, and σ_W and σ_F are the associated standard deviations.

workers.

We next study the heterogeneity of the change in firm fixed effects across workers and firms. In particular, we use (1.3.2) but replace again the left-hand side by (1.4.2). Figure 1.6 provides our findings. Panel (a) shows that the differential responses of changes in the firm fixed effect associated with a higher worker fixed effect are indistinguishable from zero when the original firm fixed effect equals the sample average. Similarly, panel (b) shows that the differential responses of changes in the firm fixed effect associated with a higher firm fixed effect are insignificant when the worker fixed effect equals the sample average. Interestingly, panel (c) shows that there is a strong interaction between the

Figure 1.5: Average response of firm fixed effect



Note: The solid line shows the estimated β^h coefficients in equation (1.3.1) when using (1.4.2) as left-hand side and restricting the sample to workers who switch firms. The β^h coefficients are standardized to capture the change in firm fixed effect to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

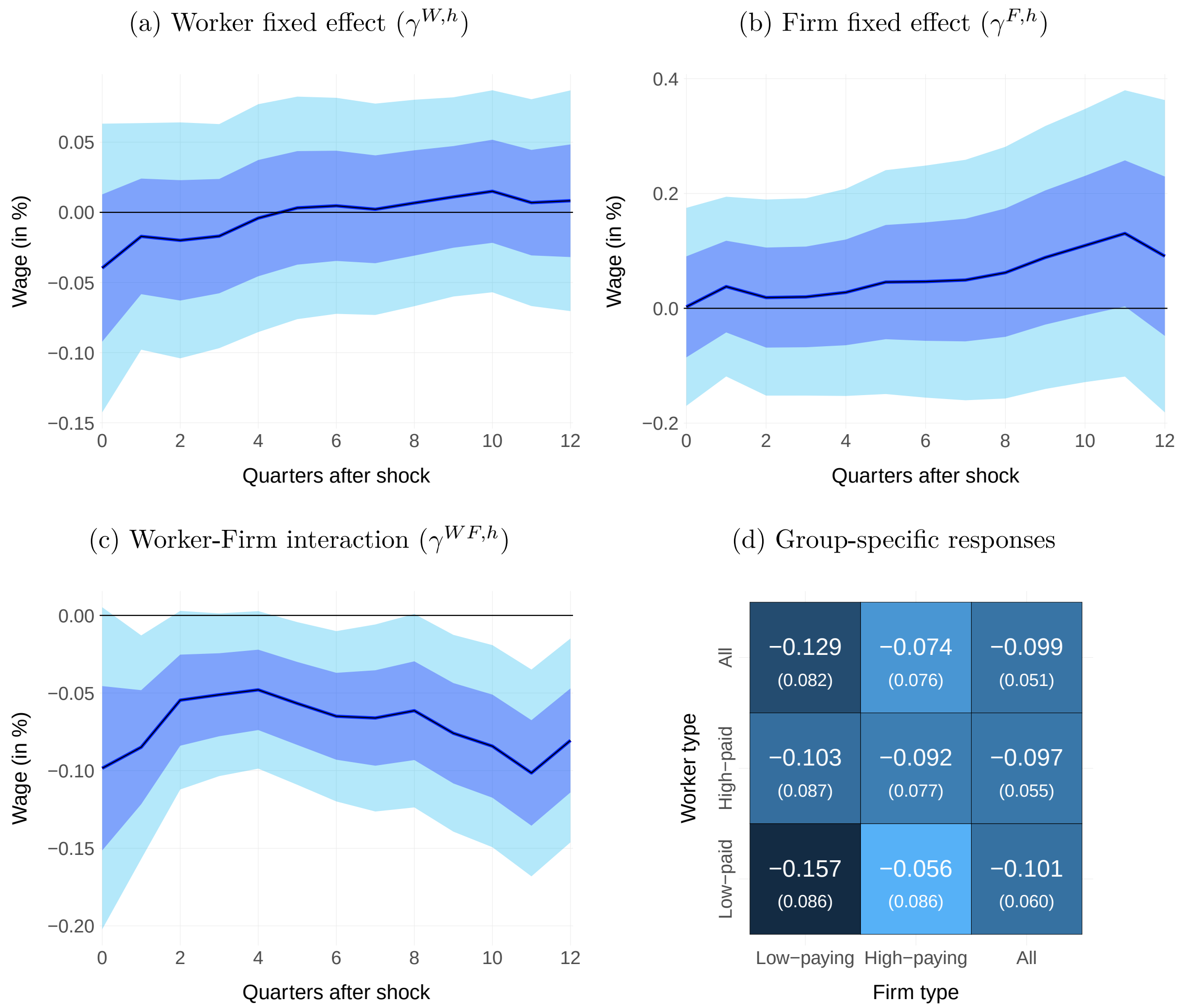
worker fixed effect and the initial firm fixed effect. Taking the average and all differential estimates together, panel (d) shows that low-paid workers employed at low-paying firms before the shock are losing the most from reallocation after monetary policy shocks. Overall, our results show that monetary policy shocks tends to reallocate workers toward worse-paying firms. This effect is particularly pronounced for low-paid workers originally employed by low-paying firms.

1.5 Sensitivity Analysis

In this section, we examine the sensitivity of our empirical findings with respect to an alternative regression specification, alternative monetary policy shocks, control variables, sample, and data treatment.

Dummies for worker and firm fixed effects groups. Our findings on the role of worker and firm fixed effects in Figures 1.2, 1.4, and 1.6 are estimated based on the local projection model in (1.3.2), which features linear interactions between monetary policy shocks and worker and firm fixed effects. We examine the sensitivity of our findings to an alternative semi-parametric regression model, in which we replace the linear interactions by dummies signifying whether worker and firm fixed effects are above the average.

Figure 1.6: Firm fixed effect response across worker and (original) firm fixed effects



Note: The solid lines in panels (a)-(c) show the differential responses estimated by the γ coefficients in equation (1.3.2) when replacing the left-hand side by (1.4.2) and restricting the sample to workers who switch firms.
The γ coefficients are standardized to capture the change in firm fixed effects in response to a one standard deviation increase in $\varepsilon_t^{\text{MP}}$ and for a one standard deviation above-average worker and firm fixed effect. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter. Panel (d) shows the total response of firm fixed effects of different worker groups estimated based on β^h, $\gamma^{W,h}$, $\gamma^{F,h}$, $\gamma^{WF,h}$ at $h = 5$ and the associated standard errors are in parentheses. For example, the firm fixed effect response of high-paid workers in low-paying firms is estimated based on $\beta^h + (p_{75}^W - p_{50}^W)\gamma^{W,h}/\sigma_W + (p_{25}^F - p_{50}^F)\gamma^{F,h}/\sigma_F + (p_{75}^W - p_{50}^W)(p_{25}^F - p_{50}^F)\gamma^{WF,h}/(\sigma_W \sigma_F)$, where p_x^W and p_x^F denote the x-th percentiles of the distribution of worker and firm fixed effects, and σ_W and σ_F are the associated standard deviations.

Formally, we estimate

$$
\begin{aligned}
& e_{i,t+h} && (1.5.1)\\
&= \alpha_i^h + \delta^h Z_{i,t-1} + v_{i,t+h} \\
&\quad + \beta^h\ \varepsilon_t^{\text{MP}} \\
&\quad + \gamma^{W,h}\ \varepsilon_t^{\text{MP}} \times \mathbb{1}\left\{ \widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling} > \overline{\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling}} \right\} \\
&\quad + \gamma^{F,h}\ \varepsilon_t^{\text{MP}} \times \mathbb{1}\left\{ \widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling} > \overline{\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling}} \right\} \\
&\quad + \gamma^{WF,h}\ \varepsilon_t^{\text{MP}} \times \mathbb{1}\left\{ \widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling} > \overline{\widetilde{\boldsymbol{W}}_{i,\tau-1}^{rolling}} \right\} \times \mathbb{1}\left\{ \widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling} > \overline{\widetilde{\boldsymbol{F}}_{j(i,t-1),\tau-1}^{rolling}} \right\},
\end{aligned}
$$

where $\mathbb{1}\{\cdot\}$ is a binary dummy and $Z_{i,t-1}$ is defined as in Section 1.3.

Panel (a) of Figure 1.10 in the Appendix shows the group-specific employment responses estimated from (1.5.1). Our findings change little compared to using linear interactions (see panel (d) in Figure 1.2). The estimated magnitudes are comparable and similarly significant. Importantly, the group with the highest non-employment exposure to monetary policy remain low-paid workers employed at high-paying firms before the shock.

Panel (b) of Figure 1.10 in the Appendix shows the group-specific firm switching responses estimated from (1.5.1). Our findings change little compared to using linear interactions (see panel (d) in Figures 1.4). The estimated magnitudes are comparable and similarly significant. Importantly, the group with the highest firm switching exposure to monetary policy remain low-paid workers employed at high-paying firms before the shock.

Panel (b) of Figure 1.10 shows the non-linear estimates of the group-specific responses of the firm switching probability. To be precise, we estimate (1.5.1) when replacing the left-hand side by the firm switching dummy in (1.4.1). Our findings are similar to using the linear interactions (see panel (d) in Figure 1.4). The group with the highest exposure to monetary policy remain low-paid workers employed at low-paying firms before the shock.

Panel (c) of Figure 1.10 shows the non-linear estimates of firm fixed effect responses for workers switching firms after the shock. To be precise, we estimate (1.5.1) when replacing the left hand side by the change in the firm fixed effect in (1.4.2). Our findings are overall robust to using the linear interactions, compare with panel (d) in Figures 1.6. The group with the highest exposure to monetary policy remain low-paid workers employed at low-paying firms before the shock.

Monetary policy shocks. Our baseline monetary policy shocks are based on the sign-restricted changes in the 6-month OIS rates. We examine the robustness of our results when using instead the changes in the 6-month OIS rates around policy announcement without applying sign restrictions. Figure 1.11 shows that our estimated employment responses have similar point estimates, but are mostly insignificant. This suggests that the raw surprises are strongly contaminated by information effects (Jarociński and Karadi, 2020). We further consider the sign-restricted 3-month OIS rate surprises. Figure 1.12 shows that we obtain very similar effects to the baseline, both in terms of magnitude and significance.

Control variables. We examine the sensitivity of our baseline specification to controlling for a set of standard macroeconomic variables. In particular, we enrich $Z_{i,t-1}$ to include a lagged monetary policy shock and changes in log GDP, log CPI, and the employment rate. Figure 1.13 shows that this does not change our findings much.

Pre-ZLB sample. Every paper using high-frequency identified monetary policy shocks faces the potential problem of the Zero Lower Bound (ZLB). Our baseline results use the longest possible sample including the ZLB. Importantly, because our monetary policy shocks are based on 6-month interest rates, we observe many shocks even during the ZLB episode (see Figure 1.7). Nevertheless, because monetary transmission may have changed we revisit our results in a pre-ZLB sample, ending in 2012Q2 just before the deposit facility rate reached zero. Figure 1.14 in the Appendix shows that the employment responses are robust to using the pre-ZLB sample.

Missing worker observations. Our baseline data treatment only considers workers who are registered as employed or unemployed. Some workers leave our sample for some quarters before returning. Potential reasons are that they stopped receiving unemployment benefits, they left the country, or they became self-employed. We revisit our results when assuming that missing observations between two appearances of a worker in the sample are non-employment spells. Figure 1.15 shows that this change amplifies the average employment response to -0.41 p.p. and increases heterogeneity in worker fixed effects. In contrast, firm fixed effects become less important.

1.6 Conclusion

In this paper, we empirically characterize the distributional effects of ECB monetary policy shocks across workers and firms using Austrian social security records. We focus on the heterogeneity across worker and firm types identified by a Abowd et al. (1999) regression, which is the workhorse model to estimate the worker and firm components of wages.

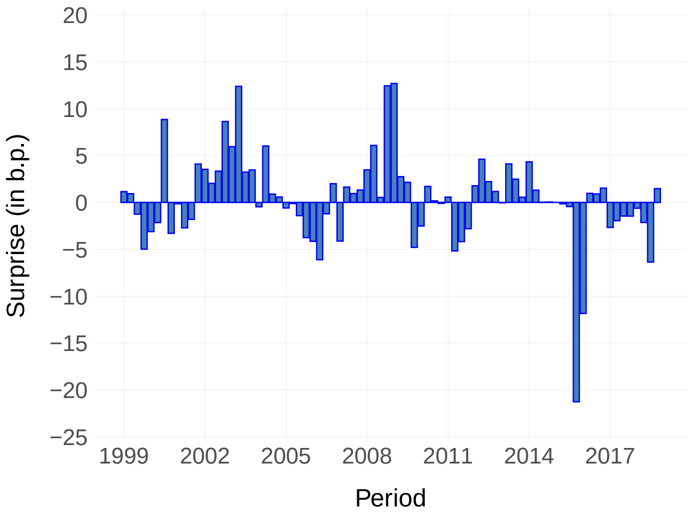
We document three novel results. First, we document which type of workers and firms face the highest decline in employment in response to a contractionary monetary policy shock. Individuals who are low-paid and employed at high-paying firms face the strongest employment declines. Second, monetary tightening increases the rate at which workers reallocate across firms, in particular for low-paid workers. Third, we document that monetary policy shocks lead to a reallocation of workers to worse-paying firms, with low-paid workers from low-paying firms especially prone to falling off the firm wage ladder. While all low-paid workers are especially exposed to contractionary monetary policy shocks, we document large differences across low-paid workers depending on the type of firm they are employed at before the shock.

Our results have implications for inequality, allocative efficiency, and transmission of monetary policy. For inequality, we show that the collapse of a job ladder is driven by the poorest workers. At the bottom of the income distribution, income is driven by labor earnings and its extensive margin (e.g., Amberg et al., 2022). Hence, the lower employment probabilities and the reallocation down a firm wage ladder for the low-paid worker increases income inequality after a monetary shock. For allocative efficiency, if worker fixed effects correspond to workers' skills and productivity, and if the firm fixed effects correspond to firms' productivity, reallocation towards lower-paying firms could contribute to a drop in aggregate productivity, as is well-documented in the literature (e.g., Jordà et al., 2020; Meier and Reinelt, 2022; Baqaee et al., 2022). For the transmission of monetary policy, our results suggest that studying monetary models with two-sided heterogeneity is important. Moreover, our results suggest that a key moment is how the marginal propensity to consume is distributed across both worker and firm types.

1.7 Appendix

1.7.1 Monetary policy shocks

Figure 1.7: Monetary policy shocks series

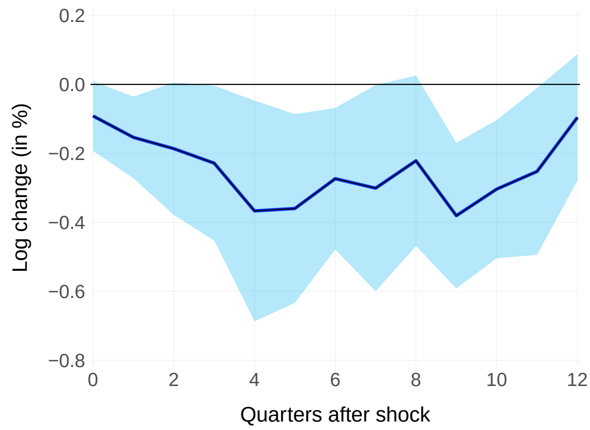


Note: The monetary policy shock series is based on the changes in the 6-month OIS rates around ECB policy announcements from Altavilla et al. (2019) after applying sign restrictions as in Jarociński and Karadi (2020).

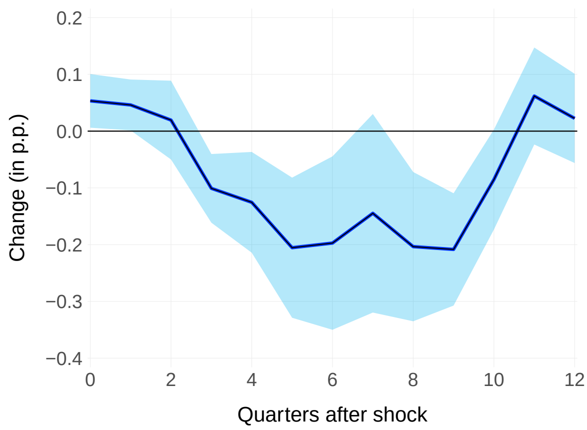
1.7.2 Additional results

Figure 1.8: Macroeconomic responses to monetary policy shocks

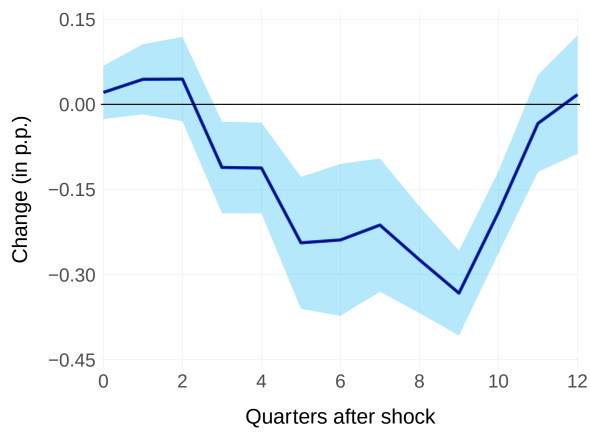
(a) Gross Domestic Product



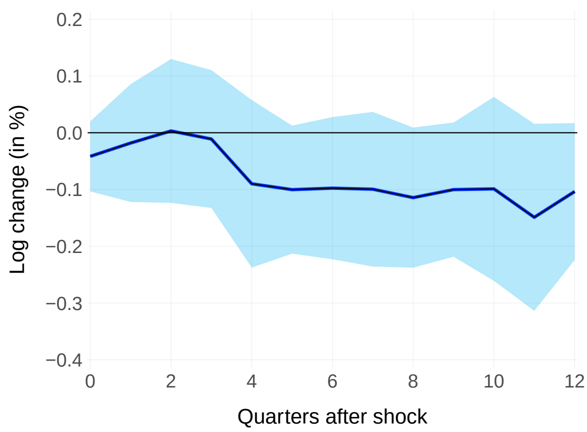
(b) Employment rate, 15+ years



(c) Employment rate, 25-59 years

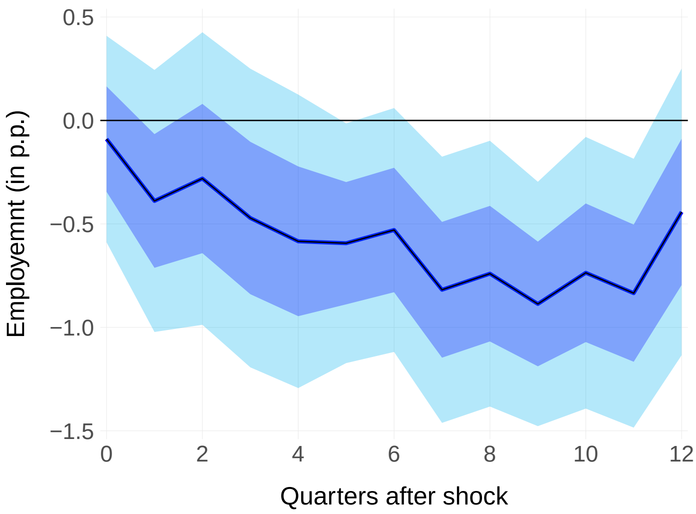


(d) Consumer Price Index



Note: The solid lines show the estimated β^h coefficient in the local projection $y_{t+h} = \alpha + \beta^h\ \varepsilon_t^{\mathrm{MP}} + \delta^h\ Z_{t-1} + v_{t+h}$, where Z_{t-1} contains a linear time trend, one lag of the shock $\varepsilon_t^{\mathrm{MP}}$ and four lags of the employment rate, GDP growth, and CPI growth. The left hand side y_{t+h} is $\Delta^h \log GDP_{t+h}$ in panel (a), ER_{t+h} in panels (b)-(c), and $\Delta^h \log CPI_{t+h}$ in panel (d). The β^h coefficients are standardized to capture the response to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$. The inner and outer shaded areas respectively indicate 68% and 95% Newey-West confidence bands.

Figure 1.9: Employment probability of initially unemployed workers

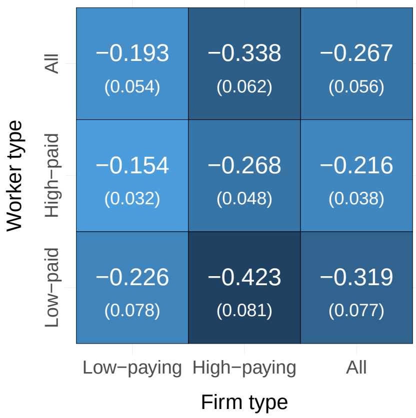


Note: The solid line shows the estimated β^h coefficients in equation (1.3.1) for workers that are unemployed in $t-1$. The β^h coefficients are standardized to capture the employment probability response to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

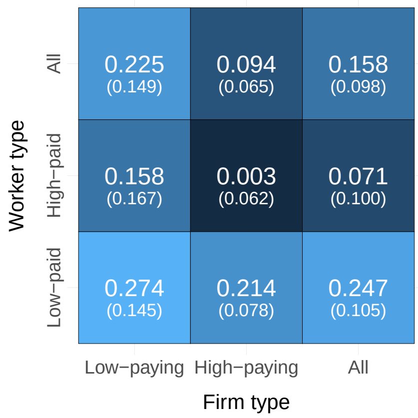
1.7.3 Sensitivity analysis

Figure 1.10: Group-specific responses using the non-linear specification

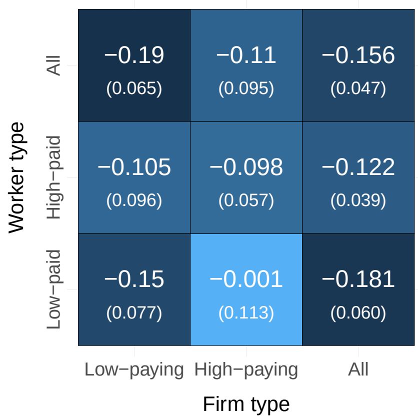
(a) Response of employment probability



(b) Response of firm switching probability

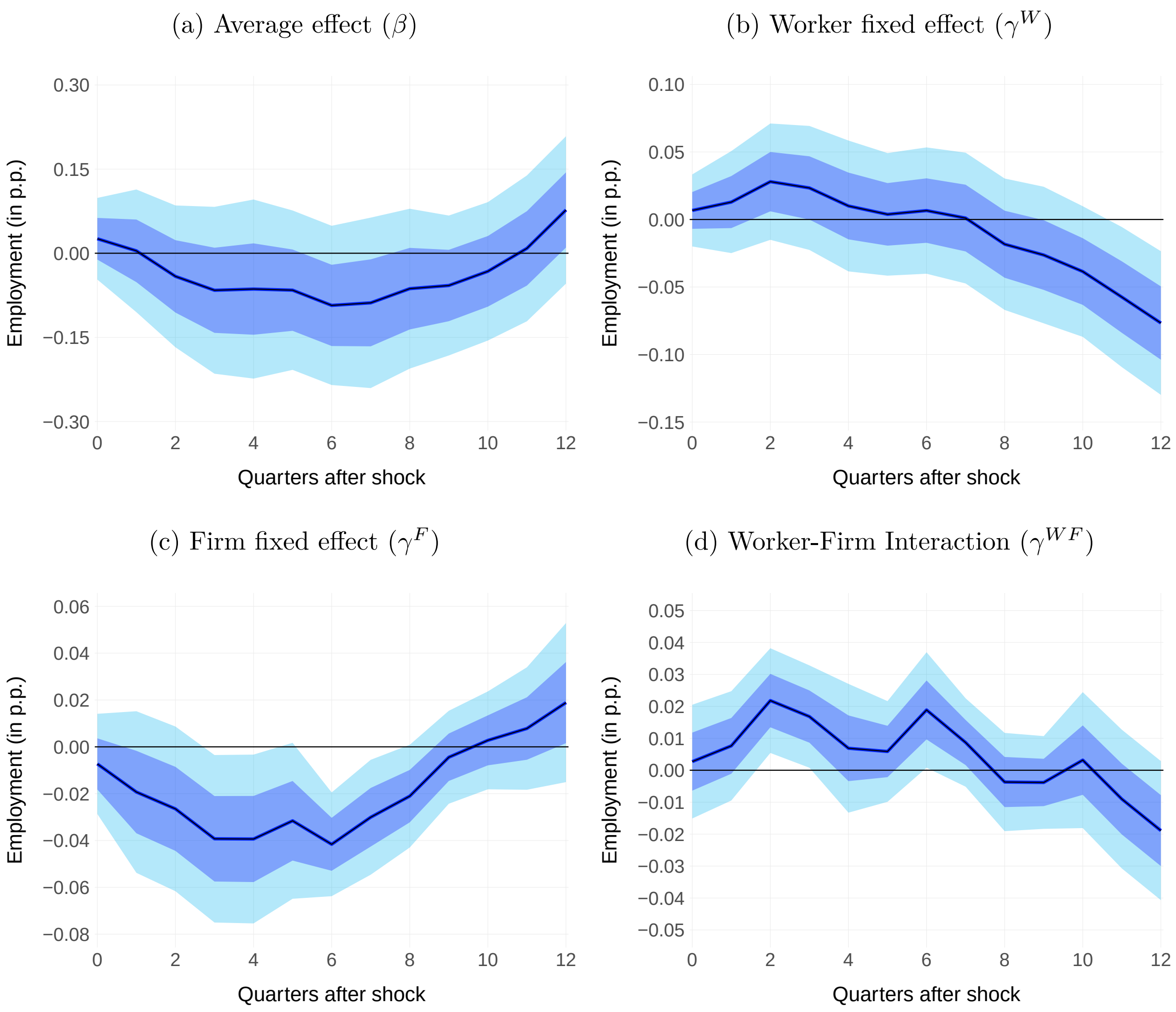


(c) Response of firm fixed effect



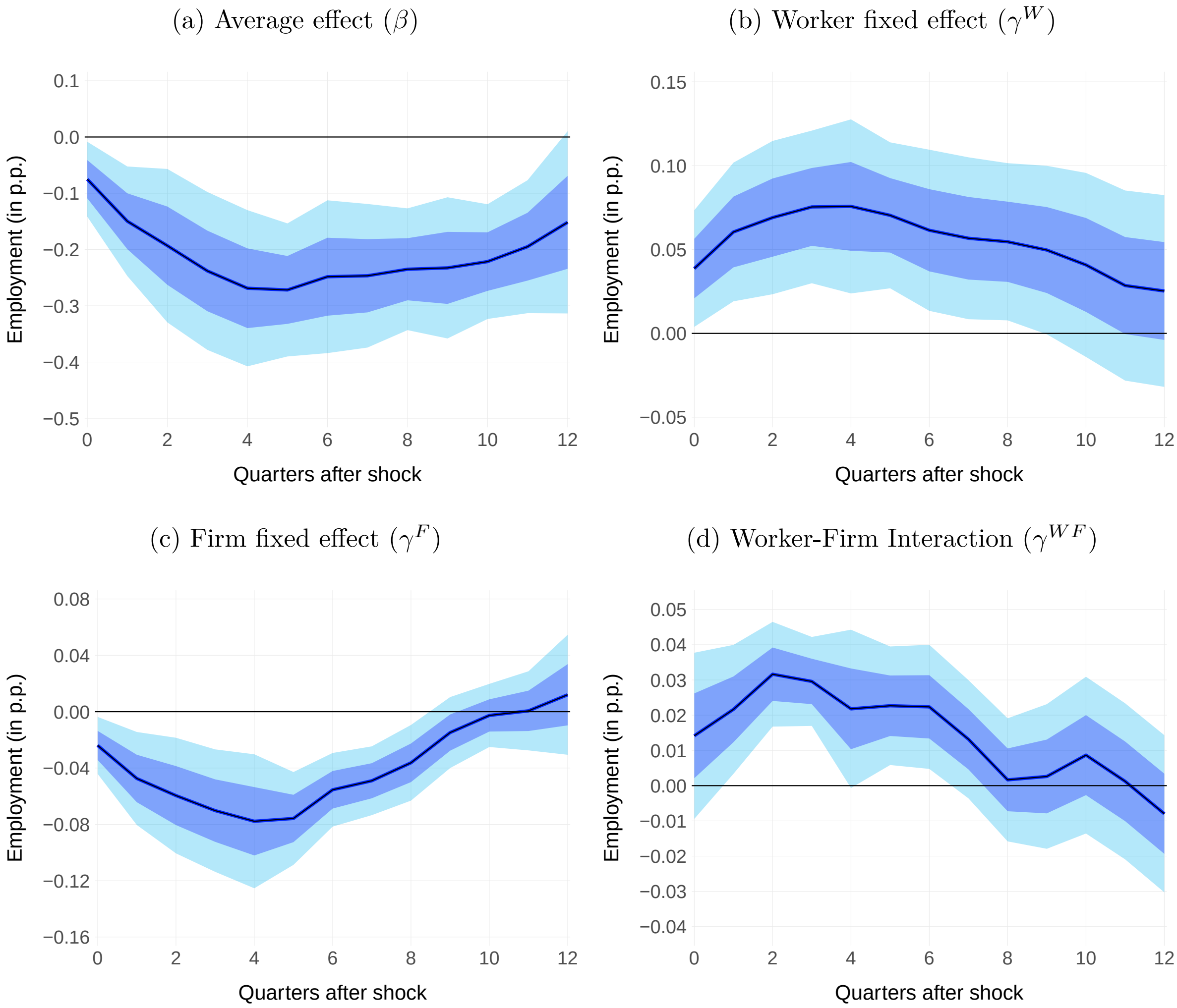
Note: Panel (a) shows the employment responses to a one standard deviation monetary policy shock of different worker groups estimated based on (1.5.1) at $h = 5$ with the associated standard errors are in parantheses. In panels (b) and (c), the left hand side of (1.5.1) is replaced by (1.4.1) and (1.4.2), respectively.

Figure 1.11: Employment response using surprises in 6-month OIS rate



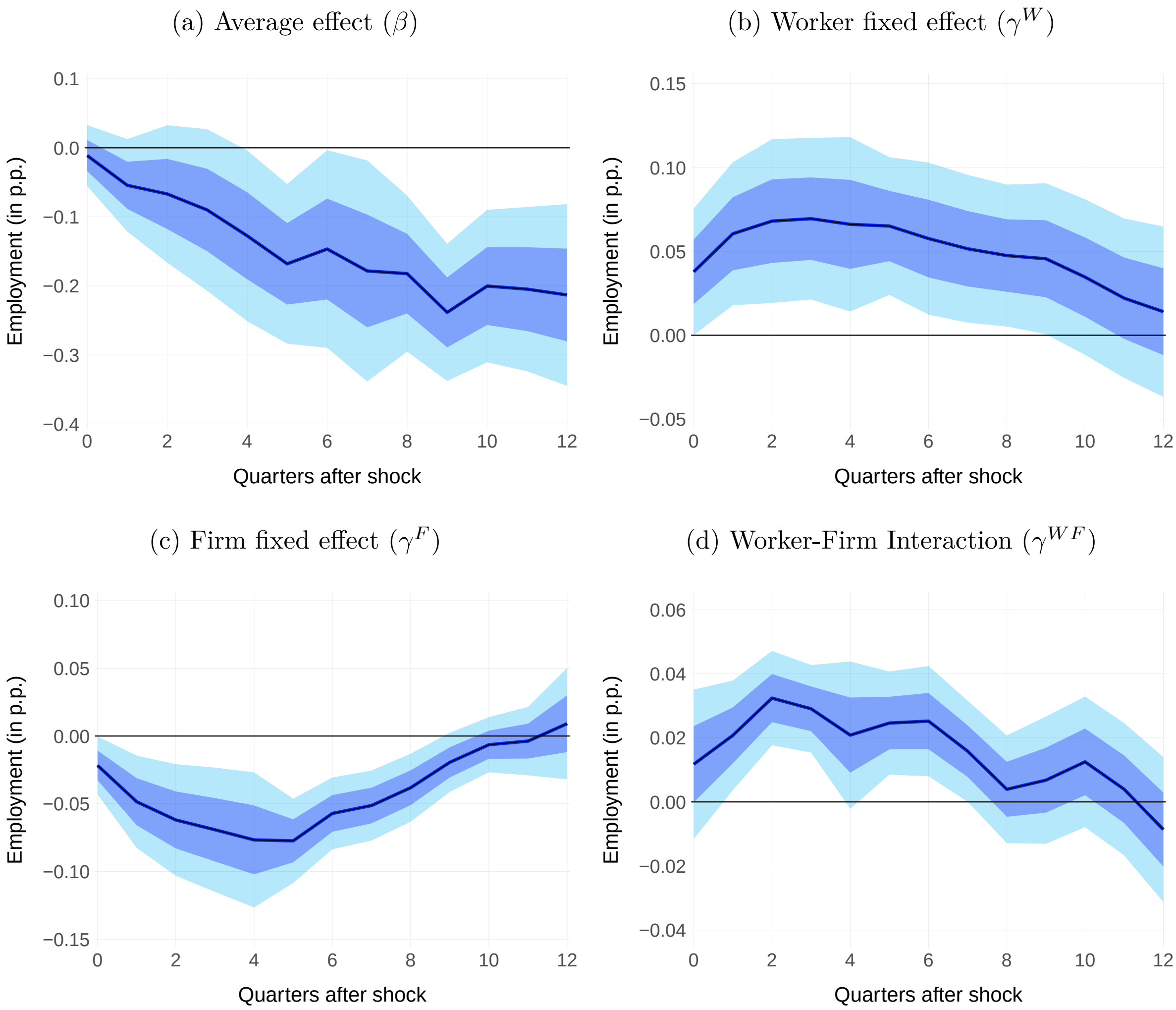
Note: The solid line in Panel (a) shows coefficients β^h in equation (1.3.1) when ε_t are surprises in the 6-month OIS rate. The solid lines in panels (b)-(d) show the estimated γ coefficients in equation (1.3.2) when ε_t are surprises in the 6-month OIS rate. The coefficients are standardized to correspond to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$ and a one standard deviation increase in firm and worker fixed effects. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

Figure 1.12: Employment response using sign-restricted surprises in 3-month OIS rates



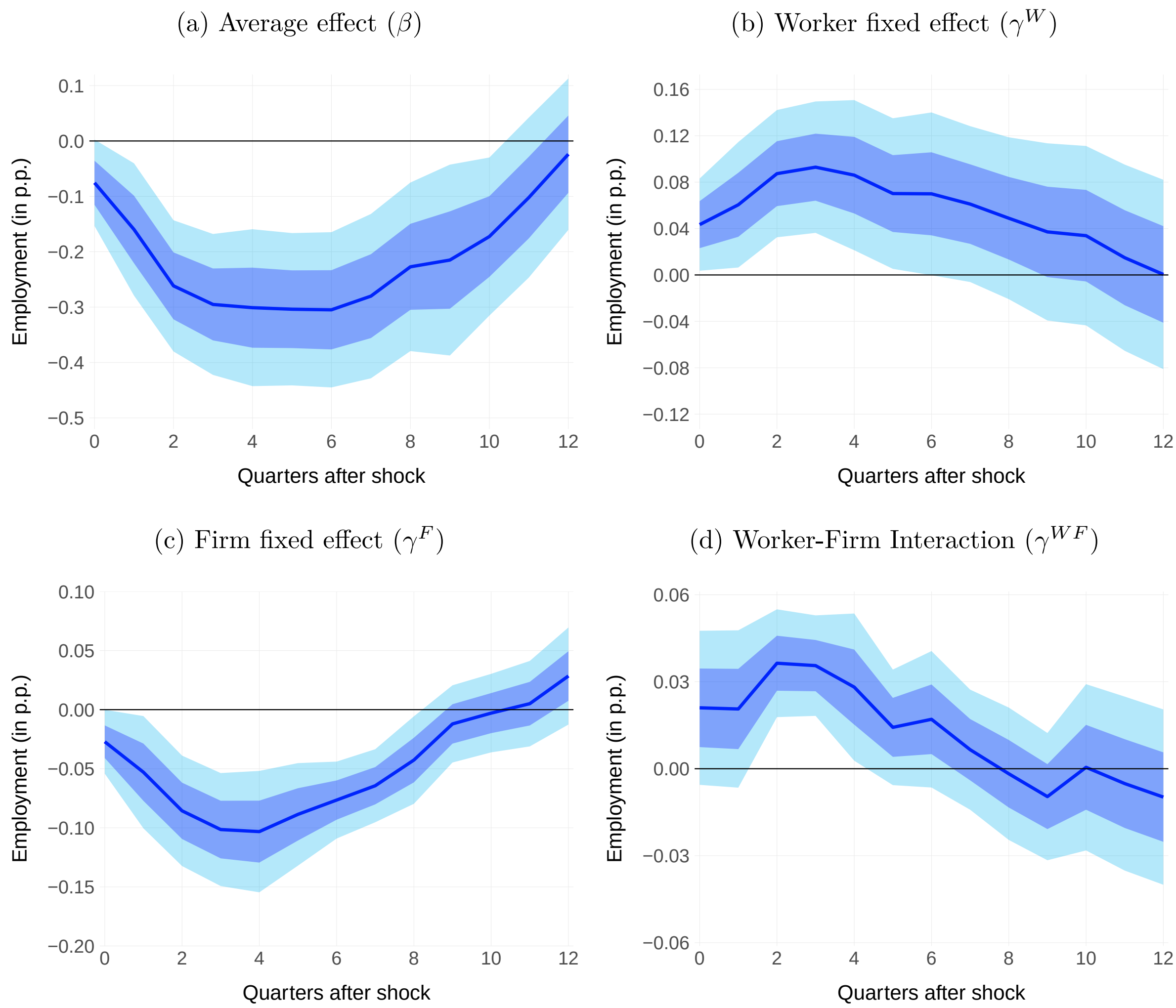
Note: The solid line in Panel (a) shows coefficients β^h in equation (1.3.1) when ε_t are sign-restricted surprises in the 3-month OIS rate. The solid lines in panels (b)-(d) show the estimated γ coefficients in equation (1.3.2) when ε_t are sign-restricted surprises in the 3-month OIS rate. The coefficients are standardized to correspond to a one standard deviation increase in $\varepsilon_t^{\text{MP}}$ and a one standard deviation increase in firm and worker fixed effects. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

Figure 1.13: Robustness: Macro controls



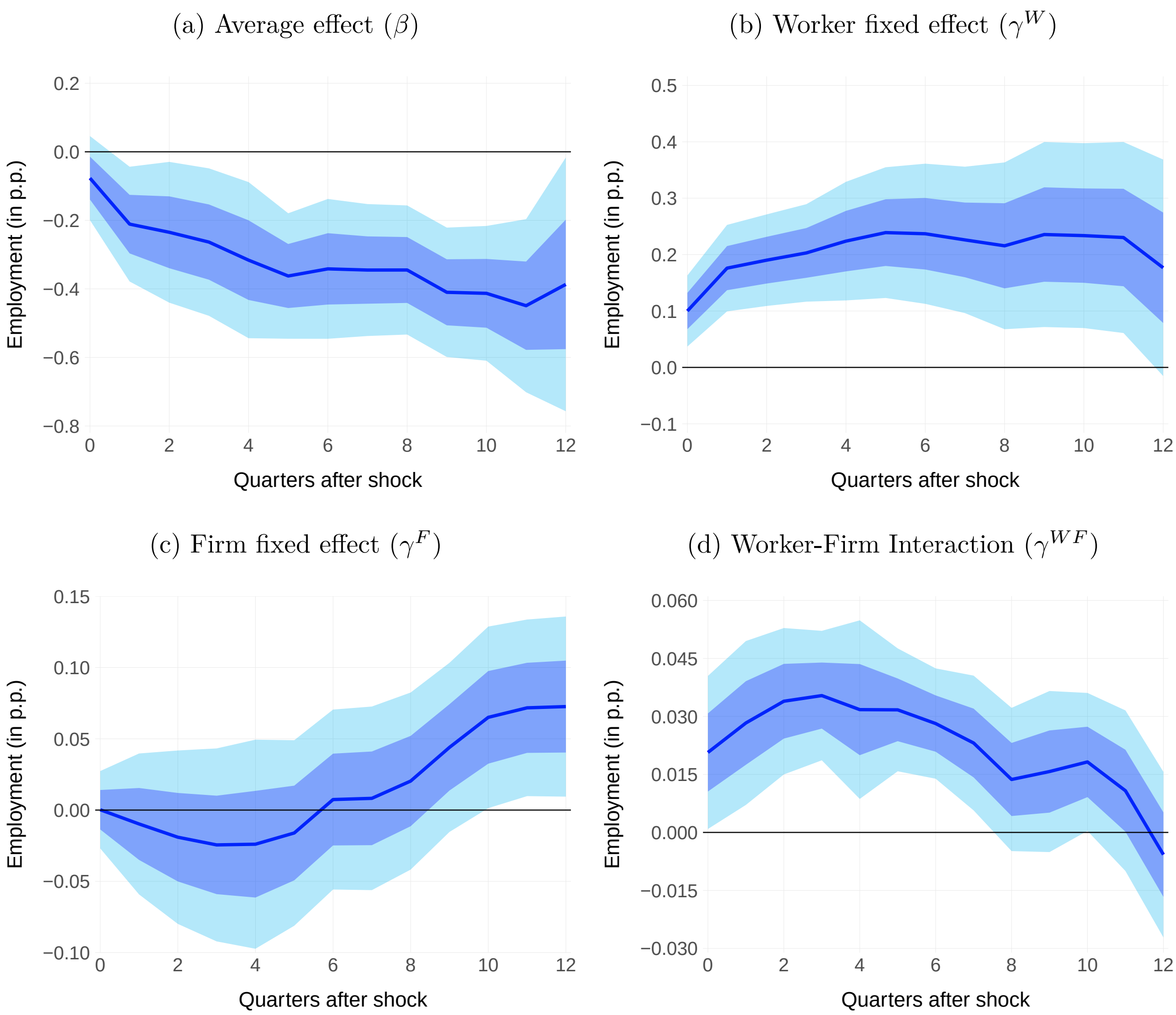
Note: The solid line in Panel (a) shows coefficients β^h in equation (1.3.1) when we add to $Z_{i,t-1}$ lagged monetary policy shock, GDP, employment rate and inflation. The solid lines in panels (b)-(d) show the estimated γ coefficients in equation (1.3.2) when we add to $Z_{i,t-1}$ lagged monetary policy shock, GDP, employment rate and inflation. The coefficients are standardized to correspond to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$ and a one standard deviation increase in firm and worker fixed effects. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

Figure 1.14: Employment response for the pre-ZLB period



Note: The solid line in Panel (a) shows coefficients β^h in equation (1.3.1) for observations until 2012Q2. The solid lines in panels (b)-(d) show the estimated γ coefficients in equation (1.3.2) for observations until 2012Q2. The coefficients are standardized to correspond to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$ and a one standard deviation increase in firm and worker fixed effects. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

Figure 1.15: Employment response when filling missing observations



(a) Average effect (β)

(b) Worker fixed effect (γ^W)

(c) Firm fixed effect (γ^F)

(d) Worker-Firm Interaction (γ^{WF})

Note: The solid line in Panel (a) shows coefficients β^h in equation (1.3.1) when we fill missing observations as non-employed. The solid lines in panels (b)-(d) show the estimated γ coefficients in equation (1.3.2) when we fill missing observations as non-employed. The coefficients are standardized to correspond to a one standard deviation increase in $\varepsilon_t^{\mathrm{MP}}$ and a one standard deviation increase in firm and worker fixed effects. The inner and outer shaded areas respectively indicate 68% and 95% confidence bands two-way clustered by worker and quarter.

Chapter 2

Financial Frictions, Markups, and Trade Liberalization: Stylized Facts

with Andrii Tarasenko and Volodymyr Vakhitov

2.1 Introduction

While the allocation of resources is found to be far from the first-best efficient around the world[1], episodes of trade liberalization can improve welfare and allocative efficiency in the economy[2]. However, the presence of resource misallocation can also affect the incidence of trade policy and dampen the gains from trade liberalization [3]. Among the factors that create such distortions, financial frictions[4] and variable markups[5] are commonly studied in the literature and found to be the important ones.

In the presence of backward-looking collateral constraints, firms are restricted in financing their capital needs. As a result, firms with binding borrowing constraints can not allocate the effective amount of resources and produce below the optimal level. In the episodes of trade liberalization, exporters' sales abroad are affected on both extensive (i.e. distorted entry) and intensive (i.e. lower sales) margins. Lower profits result in a worse ability to pay the fixed cost of exporting, as well as requires accumulating assets that cause gradual expansion on the foreign market upon entry[6].

On the other hand, in an environment with variable markups, the most productive firms face lower demand elasticity and set higher markups over marginal cost[7]. While firms with higher markups are more efficient, we should expect that these firms should benefit from trade liberalization more. Higher price-cost markups cause incomplete pass-through of cost shock since a decrease in marginal cost only partially propagates to a price set by a firm and its sales.

How could these channels interact in the episode of trade liberalization? If two firms have the same level of productivity, but one of them is financially-constrained and has a higher effective cost of capital, another will have a higher markup and thus would experience lower pass-through of cost shocks caused by trade liberalization. In this case, the presence of variable markups will weaken the reallocation of sales towards unconstrained firms, which are usually modeled in the literature as having lower capital intensity.

The dynamic effects of trade liberalization in the presence of both financial frictions and variable markups are missing in the literature. By far, the questions of the effects of trade on resource misallocation under financial frictions and variable markups were studied in static models, but less attention was paid to the long-run consequences of trade

[1]See, for example, Hsieh and Klenow (2009), Restuccia and Rogerson (2008), Gopinath et al. (2017) for general references. Ryzhenkov (2016) estimate misallocation-induced productivity losses for the economy of Ukraine.

[2]See, e.g. Melitz (2003).

[3]See, e.g. Berthou et al. (2020), Caliendo et al. (2022), Bai et al. (2019).

[4]See e.g. Moll (2014), Midrigan and Xu (2014), Gopinath et al. (2017), Brooks and Dovis (2020), Manova (2012), Leibovici (2021), Kohn et al. (2023).

[5]See e.g. Edmond et al. (2023), Edmond et al. (2015), Baqaee and Farhi (2019), Arkolakis et al. (2018).

[6]See e.g. Kohn et al. (2016), Kohn et al. (2020).

[7]See e.g. Edmond et al. (2023), Klenow and Willis (2016).

liberalization for resource allocation. In this project, we explore the joint role of variable markups and financial frictions in welfare gains and between-firm factor reallocation following trade liberalization.

We consider an episode of unilateral trade liberalization between the European Union and Ukraine. Autonomous Trade preferences for Ukrainian goods were in force between April 2014 and December 2015, after which full implementation of the Deep and Comprehensive Free Trade Area (DCFTA) with bilateral trade liberalization started. Autonomous Trade preferences implied the reduction of most tariffs on Ukrainian industrial goods according to the initial levels of DCFTA implementation. We model this event as a unilateral reduction in variable trade costs by the EU.

The stylized facts we provide in Chapter 2 are indicative that after a unilateral levying of import tariffs by the European Union for imports from Ukraine, sales of Ukrainian exporters to the EU reallocated within sectors towards firms with higher capital intensity and higher labor share. These stylized facts could be explained by a small open-economy model with variable markups and financial frictions that we develop motivated by this evidence in Chapter 3. We find that unilateral trade liberalization increases both welfare and total factor productivity in the domestic economy. Improvement occurs since the allocation of resources improves - dispersion of markups and the effective cost to capital decreases. We also find evidence that eliminating financial frictions increases gains from trade, while gains in an environment with constant markups are lower.

Overview of Chapter 2. In Chapter 2, we use firm-level data that include financial statements and customs records of Ukrainian manufacturing establishments and document a number of stylized facts on the reallocation of export sales among manufacturing firms that happened upon the unilateral trade liberalization with the EU. First, the aggregate capital-labor ratio of Ukrainian exporters to the EU increased between 2013 and 2016, the years when unilateral trade liberalization was in force. At the same time, the aggregate capital-labor ratio of firms that did not export to the EU followed the opposite path and decreased. Applying a dynamic decomposition by Melitz and Polanec (2015) to an aggregate capital-labor ratio for each group of firms, we study contributions of changes in average within-firm capital-labor ratio, reallocation of sales among incumbents, as well as entry-exit of firms. We find that within-sector reallocation of export sales towards more capital-intensive firms was an important driver behind an aggregate change. At the same time, within-sector reallocation that occurred for non-exporters to the EU was less significant in magnitude. Applying Melitz and Polanec (2015) decomposition to an aggregate labor-output ratio, we find suggestive evidence that export sales also reallocated towards firms with higher labor-output ratios, which might be suggestive of the reallocation of sales towards firms with lower markups.

Overview of Chapter 3. In Chapter 3, we develop a small open-economy model that is calibrated to the Ukrainian firm-level data on manufacturing. The economy is populated by the unit mass of entrepreneurs that own intermediate producers and supply labor to a frictionless labor market. When investing in capital, entrepreneurs face backward-looking collateral constraint. In the domestic market, both domestic intermediate producers and importers from abroad face variable demand elasticity that gives rise to variable markups. For simplification, we assume that the elasticity of demand abroad is constant and foreign firms are financially-unconstrained. In a steady state, markups and the effective cost of capital are negatively correlated. Since the choke price prevents the least-productive and potentially-unconstrained firms from producing, most non-exporters are financially-constrained. On average, exporters face a lower effective cost of capital and are less financially constrained, as well as set higher markups in the domestic market.

We model a trade liberalization as a unilateral reduction in iceberg trade cost for domestic exporters by 10%, and find that it increases welfare and productivity in the economy, as well as reduces dispersion of both markups and effective cost of capital. However, the model fails to capture the reallocation of sales towards high-capital-intensive firms, which could indicate that trade liberalization is not the only force behind the reallocation of sales documented in Chapter 2. For example, the higher cost of capital after 2014 tightened borrowing constraint of firms and could contribute to the reallocation toward capital-intensive firms.

In order to understand how financial frictions and variable markups affect the gains from trade, we compare the benchmark model with variations, where we close one of the channels. In a model that features variable markups but no financial frictions, we find evidence of complementarity between international trade and the financial market since both welfare and total factor productivity increase more after trade liberalization. In a model with financial frictions but constant markups, gains from trade are lower since we find that resource allocation worsens after a unilateral reduction in trade costs.

Literature review. A project presented in Chapters 2 and 3 contributes to three major flows of literature.

First, we contribute to the literature that studies how financial development and financial frictions affect the participation of firms in international trade and the gains from trade liberalization. It has been established that misallocation caused by financial frictions can slow down the reallocation of resources in response to efficiency-improving events (see, e.g., Buera and Shin, 2013; Moll, 2014). Financial development is also found to be an important determinant of the comparative advantage of countries and affects the gains from trade liberalization (see, e.g., Manova, 2012; Leibovici, 2021; Alfaro et al., 2022). Financially-constrained firms produce under the optimal level that affects both selection into exporting, as well as dynamics of sales in the exporting market (see, e.g., Kohn et al., 2016, 2020, 2023). A sluggish response to trade liberalization and large currency devaluations is explained by the presence of frictions in financial markets, limiting access of firms with insufficient assets to export markets. With backward-looking collateral constraints, many firms cannot export unconstrained amounts due to binding borrowing constraints; over time, firms plow back additional profits into new assets, softening borrowing constraints and growing their export revenues over time. Brooks and Dovis (2020) model trade liberalization using backward-looking and forward-looking financial constraints, and show that when the forward- looking financial constraint is used, trade liberalization reduces misallocation in contrast to the model with backward-looking financial constraints. Tetenyi (2022) addresses how financing frictions shape the effects of trade liberalization and shows that financial liberalization increases gains from trade liberalization only if capital markets are integrated.

Second, this paper contributes to the studies of how variable markups affect the economy after trade liberalization. Variable markups distort the allocation of resources and reduce welfare in the economy (see, e.g., Baqaee and Farhi, 2019; Edmond et al., 2023). While trade liberalization increases competition that reduces the dispersion of markups and improves the allocation of resources (see, e.g., Edmond et al., 2015; Feenstra and Weinstein, 2017), welfare gains in the presence of variable markups are not necessarily lower of higher as compared to a constant markup case (see, e.g., Arkolakis et al., 2018; Demidova, 2017; Edmond et al., 2015). Variable markups lead to a variation in how different firms adjust to changes in trade policy. De Loecker and Warzynski (2012) find that exporters charge higher markups and their markups increase upon entering into exporting. Higher markups imply that changes in trade cost translate less into output prices (see, e.g., Amiti et al., 2014; De Loecker et al., 2016). For example, De Loecker et al. (2016) study how prices and markups react to trade liberalization and find evidence of incomplete pass-through of tariff reductions to consumers in terms of lower prices. Indeed, as shown by Gopinath and Itskhoki (2010), firms with higher markups are less likely to adjust their prices in the presence of price-adjustment costs. Cavenaile et al. (2022), in an endogenous growth model, show that innovations in productivity account for an increase in markups in response to a reduction in trade costs.

Third, this study is the closest to recently developing literature on the interaction of financial frictions and variable markups. Most of the studies look at the closed economy case (see, e.g., Galle, 2020; Tsiflis, 2022; Boar and Midrigan, 2022; Giuliano and Zaourak, 2017), while only selected papers consider an open economy case. Giuliano and Zaourak (2017) find that variable markups could dampen an increase in misallocation induced by the credit crunch in the presence of financial frictions. Tsiflis (2022) provides evidence that variable markups make financial frictions more costly in terms of allocative efficiency, as compared to a case of constant markups. Boar and Midrigan (2022) conclude that dispersion in markups generates dispersion in marginal products that reduces output and factor prices, as well as increases inequality. Altomonte et al. (2017) and Altomonte et al. (2023) find that financial frictions affect firms' investment in intangible capital and markups, with a former to provide evidence that the size of collateral is an important determinant of pass-through of cost shocks to prices. Galle (2020) show in an oligopolistic setting that financial constraints dampen an increase in allocative efficiency due to increased competition since capital in financially-constrained firms grows slower. Kim and Lee (2022) study an episode of depreciation while modeling imports of inputs and abstract from exporting, and find that financially-constrained firms increase prices more and reduce markups less.

To the best of our knowledge, gains from trade liberalization in a dynamic setting with financial frictions and variable markups remain understudied and the aim of this project is to fill the existing gap in the literature.

Structure of Chapter 2. In Section 2, we describe the data used for analysis. In Section 3, we document a number of stylized facts on the reallocation of sales among Ukrainian manufacturing firms exporting to the EU. Section 4 contains a discussion of results and provides an overview of potential channels that can explain the stylized facts.

Structure of Chapter 3. In Section 1, we develop a small open economy model motivated by stylized facts in Chapter 2. Section 2 describes the calibration approach and contains a description of the economy in a steady state. In Section 3, we study the effects of trade liberalization and look at how financial constraints and variable markups shape the effects of trade liberalization. Section 4 concludes Chapters 2 and 3.

2.2 Data Description

In this section, we describe the procedure of sample construction, construction of variables, and describe trends observed in the data sample.

Sample construction. We construct a firm-level sample using a universe of Ukrainian firms' financial statements and customs records from 2011 to 2019. Financial statements contain annual balance sheets and income statements, as well as a number of employees and an industry identifier. Customs records contain shipment-level information on the exporter, value, time, destination, and product code. The following criteria for inclusion in a sample are applied.

First, we keep only the firms that operated in manufacturing, Section C of KVED/NACE (divisions 10-33)[8]. Second, we keep only the firms that did not change their primary 4-

[8] Ukrainian Classification of Types of Economic Activities, 2010 edition, (KVED-2010) based on NACE Rev. 2 and has been implemented since January 1, 2012.

digit KVED industry. Third, we drop firms registered in the Autonomous Republic of Crimea, Sevastopol, Donetsk oblast, and Luhansk oblast[9], in order not to let starkly different trends faced by these firms to bias our results. Fourth, the following criteria of inclusion to the sample are applied: drop firms with output (net sales) of less than UAH 500 th. (in 2012 prices), capital and assets of less than UAH 100 th. (in 2012 prices), as well as employment of less than 10 workers[10]. Finally, firms that existed in a sample for less than 2 years and firms with gaps in a panel are excluded from the final sample. As a result, we end up with 37,956 annual observations for 5,522 unique firms.

Construction of variables. Tangible fixed assets serve as a measure of capital owned by a firm. Following a common approach applied to the Ukrainian firm-level data, we construct a measure of capital in period t as an average of tangible assets at the beginning of t and at the end of t. Because of the episodes of high inflation during the period under study, we deflate the beginning value of tangible assets by producer price index in $t-1$ and the end-period value by PPI in t.

We deflate all the monetary variables using respective price indices. Sales of a firm are deflated using the consumer price index as a proxy for output prices (2012 is a base year), while assets and capital - using the producer price index for a respective sector (2012 is a base year)[11]. We also convert export values into Ukrainian hryvnia (UAH) using either value in UAH provided in the original data, or USD/UAH exchange rate on the transaction day. After converting the values to UAH, we deflate them with the consumer price index (using 2012 as a base year). We categorize a firm as an exporter to the EU if a firm exported to at least one of the EU-28 members in a given year.

Given the nature of the financial market in Ukraine[12], detecting whether a firm is financially-constrained is a non-trivial task. Moreover, we have only a selected list of financial variables that do not allow calculating measures commonly studied in the literature, e.g., Rajan and Zingales (1998), Manova (2012) or Alfaro et al. (2022). As a result, we define a firm as financially-constrained if it has limited assets to external financing as measured by a below-median leverage[13] and a below-median ratio of financial cost to total assets[14].

Descriptive statistics. Since for the stylized facts, we consider a window between 2013 and 2016, Table 2.1 contains the average values for selected variables over the period of

[9]The regions of Ukraine that are fully or partially occupied since 2014

[10]Employed in our data is an average number of employees in a given year as reported in financial statements of firms.

[11]Both consumer and producer price indices are obtained from State Statistic Service of Ukraine

[12]Numerous surveys of firms indicate that the inability to get banking financing is the major obstacle for exporting, in particular, and production, overall.

[13]$Leverage = (Short\text{-}Term\ Debt + Long\text{-}Term\ Debt)/Total\ Assets$

[14]$FinCost\text{-}to\text{-}Asset = Financial\ Cost/Total\ Assets$

Table 2.1: Selected Descriptive Statistics of a Sample

Indicator	**2013**	**2014**	**2015**	**2016**
Main characteristics				
Sales, mean, UAH th.	99,373.2	110,126.9	99,994.2	98,043.7
Capital, mean, UAH th	37,973.6	40,560.7	36,949.3	31,144.1
Assets, mean, UAH th	104,284.6	114,769.1	114,613.3	107,512.8
Employment, mean, persons	194.3	191.0	184.8	181.7
Capital-Labor ratio, simple average, UAH th	103.6	103.8	90.3	79.5
Capital-Labor ratio, sales-weighted, UAH th	365.7	430.0	430.1	368.1
Wage Bill-Output ratio, mean	0.45	0.22	0.20	0.19
International trade				
Share of exporters, %	46.8	48.3	51.4	52.4
Share of exporters to the EU, %	24.7	29.5	33.0	35.7
Share of exports in sales, all destinations, %	30.3	31.9	30.9	29.8
Share of exports in sales, %	17.6	17.3	18.8	19.2
Financial constraints				
Leverage, mean	0.150	0.158	0.158	0.148
Share of financially constrained firms, %	38.0	37.3	37.1	36.2

Note: This table provides average values for selected variables in the firm-level panel between 2013 and 2016.

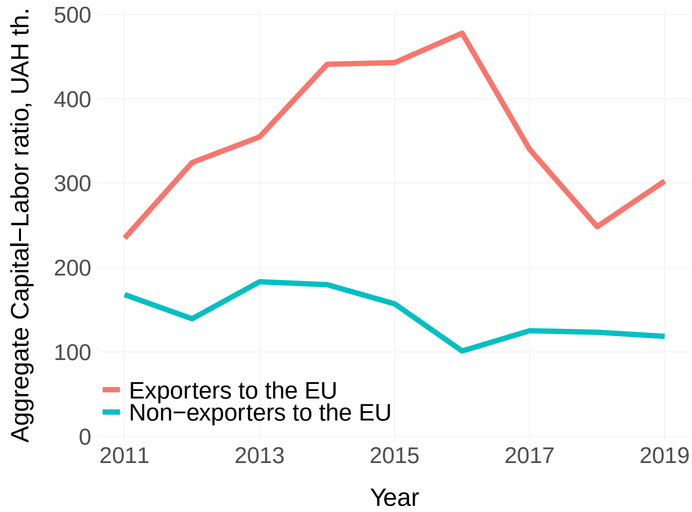
interest. An average firm in 2013 had 99 UAH mln in sales and 104 UAH mln in assets, employed 194 workers, and capital worth 38 UAH mln. After 2014, the average firm shrunk in terms of outputs and inputs (see Table 2.1). While an average capital-labor ratio decreased from 103.6 UAH th. in 2013 to 79.5 in 2016 UAH th., an aggregate capital intensity, measured as a sales-weighted capital-labor ratio, increased. The overall share of exporters increased between 2013 and 2016 from 46.8% to 52.4% of manufacturing firms, with more firms reallocating their sales to the market of the European Union - from 24.7% to 35.7%. The average Exports-to-Sales ratio of exporters to all destinations decreased from 30.3% to 29.8%, but exporters to the EU increased their export intensity from 17.6% of total sales obtained from exporting to the EU to 19.2%.
A share of financially-constrained firms decreased from 38.0% in 2013 to 36.2% in 2016, while the average leverage varied between 0.148-0.158.

2.3 Facts on Reallocation

In this subsection, we document a set of stylized facts about the dynamics of the aggregate capital intensity and reallocation of sales among manufacturing firms.

Fact 1. The aggregate capital intensity of Exporters to the EU increases. First, we look at the aggregate capital intensity of exporters to the EU and the rest of Ukrainian manufacturing firms. To do so, we calculate a ratio of tangible capital to the size of employment for each firm and aggregate the resulting ratios by calculating the sales-weighted mean. As shown, in Table 2.1, a simple average capital-labor ratio decreased, while a sales-weighted aggregate capital intensity gradually increased after 2013. However, this total change masks a heterogeneity in trends based on the exporter to the EU status.

Figure 2.1: The aggregate capital intensity of exporters to the EU vs. non-exporters to the EU



Note: This chart shows the evolution of the aggregate capital-to-labor ratio of both a set of exporters to the EU and a set of firms that were not exporting to the EU. The aggregate capital intensity of exporters to the EU is the export sales-weighted average of capital intensities. The aggregate capital intensity of non-exporters to the EU is a total sales-weighted average of capital intensities.

In Chart 2.1, we plot the export sales-weighted aggregate capital intensity of exporters to the EU and the total sales-weighted capital intensity of firms that did not export to the EU. Before 2014, exporters to the EU had a higher capital intensity compared to firms not exporting to the EU. Moreover, the aggregate capital intensity of exporters to the EU increased between 2013 and 2016. While the aggregate capital intensity of exporters was UAH 354.7k in 2013, it increased with time and reached UAH 477.6k in 2016. In Figure 2.3 in Appendix, we also plot total sales-weighted capital intensity for exporters to the EU and see that this measure also demonstrates an increase after 2013.
Increasing aggregate capital intensity is not observed for those firms that did not export to the EU. According to Figure 2.1, the sales-weighted capital intensity of these firms decreased from UAH 183.1k to UAH 101.0k over the same period. Hence, while the capital intensity of exporters increased between 2013 and 2016, non-exporters experienced the opposite trend.

Fact 2. The increase in aggregate capital intensity of exporters is driven by the reallocation of sales among incumbents. What can explain such a drastic increase in the aggregate capital intensity of exporters? In order to understand this, we perform a dynamic decomposition of an aggregate capital-labor ratio following Olley and Pakes (1996) and Melitz and Polanec (2015), as shown in (2.3.1):

$$\begin{aligned}
\Delta\left[\frac{K}{L}\right]_{XEU} = & \underbrace{\Delta\left[\frac{\bar{K}}{L}\right]_{SXEU}}_{\text{Within-firm}} + \\
& \underbrace{+\Delta\sum_{j}\sum_{i\in SXEU_j}(\omega_j^0\omega_{ji}-\bar{\omega})\left(\frac{K_{ji}}{L_{ji}}-\frac{\bar{K}}{L}\right)}_{\text{Within-sector reallocation}} + \underbrace{\sum_{j}\left(\sum_{i\in SXEU_j}\omega_{ji}\frac{K_{ji}}{L_{ji}}\right)^1\Delta\omega_j +}_{\text{Between-sector reallocation}} \\
& \underbrace{+\,\omega_{Ex}\left(\left[\frac{K}{L}\right]^0_{XEUEx}-\left[\frac{K}{L}\right]^0_{SXEU}\right)}_{\text{Exit}} + \underbrace{\omega_{En}\left(\left[\frac{K}{L}\right]^1_{SXEU}-\left[\frac{K}{L}\right]^1_{XEUEn}\right)}_{\text{Entry}},
\end{aligned} \tag{2.3.1}$$

where XEU is a set of exporters to the EU: incumbents $SXEU$, entrants $XEUEn$ and exiting firms $XEUEx$. $\frac{K}{L}$ is a sales-weighted capital-labor ratio, $\frac{\bar{K}}{L}$ - unweighted mean, and $\frac{K_{ji}}{L_{ji}}$ is capital-labor ratio of firm i in sector j. ω is the export sales share either for a firm i in sector j, or a set of exiting and entering firms. We consider changes between period 0 and period 1[15].

Conceptually, in this decomposition, we look at the drivers behind the increase in aggregate capital intensity and decompose the change into five components: change in the unweighted mean of surviving firms, within-sector reallocation among surviving firms, between-sector reallocation among surviving firms, the contribution of an entry into the EU market and contribution of an exit from the EU market.

Results of decomposition (2.3.1) are shown in Table 2.2. The unweighted average capital intensity of surviving exporters to the EU after the initial increase decreased between 2013 and 2016, which can be explained by increased interest rates in the Ukrainian economy that made exporters more constrained on average. In a model with backward-looking financial constraints, such a phenomenon might result from the tightening of collateral constraints. The negative contribution of entry implies that new exporters were less capital-intensive compared to the existing exporters, while the positive contribution of exit means that the exit of exporters with lower capital intensity positively contributed to the evolution of the aggregate capital-labor ratio. The main contribution to an increase in the aggregate capital-labor ratio comes from the reallocation of export sales among incumbents. Specifically, we observe positive reallocation of sales towards (i) more capital-intensive firms within sectors, and (ii) more capital-intensive sectors between sectors.

As a robustness check, we also perform a dynamic decomposition of the total sales-

[15]See Appendix 2.5.1 for a detailed description of terms

Table 2.2: Dynamic decomposition of an aggregate capital-labor ratio of exporters to the European Union

Period	Unweighted mean of incumbents	Incumbents: Within-sector reallocation of sales	Incumbents: Between-sector reallocation of sales	Entry	Exit	Total
2013-2014	6.4	15.2	71.7	-10.4	3.1	86.0
2013-2015	-7.4	27.1	73.8	-12.0	6.4	88.0
2013-2016	-25.2	42.3	92.2	-2.3	15.8	122.9

Note: This table contains results of dynamic Melitz-Polanec decomposition of an aggregate capital-labor ratio of exporters to the EU in Equation (2.3.1). Each row contains results for a separate exercise with period 0 being 2013 and period 1 being the last year of a respective period. Column "Total" contains the change in aggregate export sales-weighted capital-labor ratio, column "Unweighted mean of incumbents" contains the within-firm component of change in (2.3.1), column "Incumbents: Within-sector reallocation of sales" - within-sector reallocation of sales among firms, column "Incumbents: Between-sector reallocation of sales" - between-sector reallocation of sales, column "Entry" - entry, column "Exit" - exit. Shares are calculated using export sales only.

weighted capital-labor share of exporters to the EU. According to results in Table 2.5, between-sector reallocation becomes less important, while reallocation of sales towards more capital-intensive exporters within the sector remains positive and significantly contributes to the evolution of the aggregate capital intensity.

To conclude, within-sector reallocation towards more-capital intensive firms is an important driver of the higher capital intensity of exporters to the EU after an episode of trade liberalization. But does this happen only for the exporters or the same pattern of reallocation was also observed for non-exporters to the EU?

Fact 3. Firms not exporting to the EU did not experience as strong reallocation of sales as exporters. To answer this question, we perform dynamic Melitz and Polanec (2015) decomposition of an aggregate capital-labor ratio of manufacturing firms that did not export to the EU. Decomposition follows 2.3.1 with an exception that we consider a set of non-exports to the EU, NX, and use total sales for weights.

According to results provided in Table 2.3, an average unweighted capital intensity decreased during 2013-2016, the pattern was also observed for the exporters to the EU. Hence, all the firms, irrespective of their export status, experienced a reduction in average capital intensity that could be a reflection of the monetary tightening implemented by the National Bank of Ukraine in response to a surge in inflation that happened after 2014. However, reallocation among survivors was different. First, we do not observe reallocation towards capital-intensive sectors - sales reallocated towards less capital-intensive industries. Second, within-sector reallocation towards capital-intensive firms still occurs but is weaker as compared to exporters to the EU.

Table 2.3: Dynamic decomposition of an aggregate capital-labor ratio of firms not exporting to the EU

Period	Unweighted mean of incumbents	Incumbents: Within-sector reallocation of sales	Incumbents: Between-sector reallocation of sales	Entry	Exit	Total
2013-2014	5.7	0.6	2.1	14.06	-25.9	-3.4
2013-2015	-8	8.7	-15.5	27.7	-39.1	-26.2
2013-2016	-17.5	12.8	-22.7	-2.34	-52.3	-82

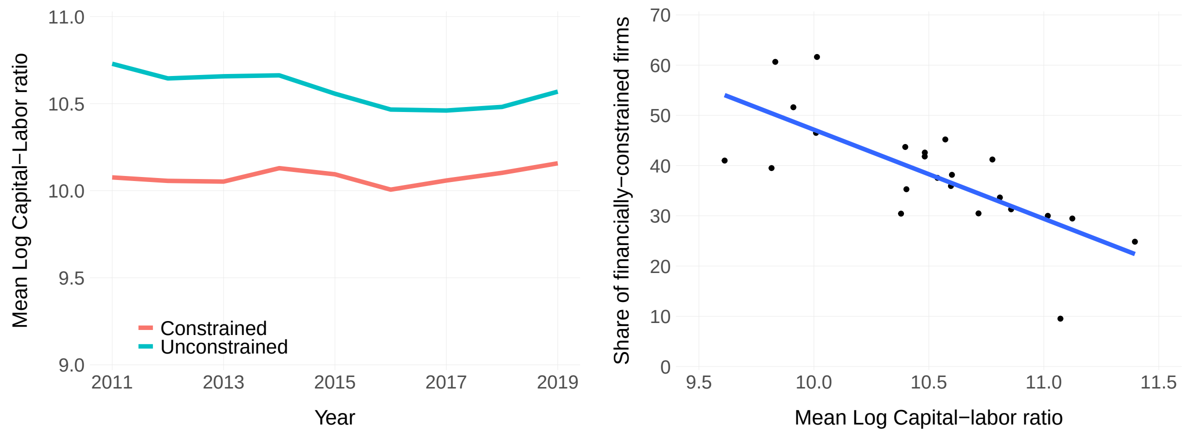
Note: This table contains results of dynamic Melitz-Polanec decomposition of an aggregate capital-labor ratio in Equation (2.3.1) for a set of non-exporters to the EU. Each row contains results for a separate exercise with period 0 being 2013 and period 1 being the last year of a respective period. Column "Total" contains the change in aggregate export sales-weighted capital-labor ratio, column "Unweighted mean of incumbents" contains the within-firm component of change in (2.3.1), column "Incumbents: Within-sector reallocation of sales" - within-sector reallocation of sales among firms, column "Incumbents: Between-sector reallocation of sales" - between-sector reallocation of sales, column "Entry" - entry, column "Exit" - exit. Shares are calculated using total sales.

Fact 4. Capital-intense firms/sectors are less financially constrained. Capital-intensive firms tend to be less financially constrained. First, we look at how the capital intensity of constrained and unconstrained firms differ in the data. We calculate a simple average of the capital-labor ratio for financially-constrained and financially-unconstrained firms according to the definition described in Section 2.2. Panel (a) of Figure 2.2 plots the evolution of average capital intensities for both groups of firms. We can see that financially-constrained firms have a higher capital-labor ratio in all the years available in the sample. For example, the mean log capital-labor ratio was 10.5 in 2013, with 10.2 for financially-constrained and 10.8 for unconstrained firms.
Second, we also look at how financial constraints and capital intensity correlate at the sectoral level, since capital-intensive sectors rely more on external finance (see, e.g., Manova, 2012; Leibovici, 2021). To do so, we compare the average capital-labor ratio with a share of financially-constrained firms at the level of KVED divisions (2-digit codes) in the reference year of 2013. Panel (b) of Figure 2.2 shows that sectors with more than 40% of financially constrained firms have, on average, mean log capital-labor ratio below 10, while sectors with less than 30% of constrained firms have, on average, mean log capital-labor ratio above 11. Overall, a linear trend shows a negative correlation between the two measures, which is equal to -0.73.

Taking stock so far, we can make the following conclusions. After trade liberalization, export sales to the EU substantially reallocated towards capital-intensive firms. Given that financially-constrained firms are less capital-intensive, this might be indicative of the reallocation towards unconstrained firms. However, the data reveals that export sales also reallocated toward firms with lower markups.

Figure 2.2: Capital intensity and financial constraints

(a) Firms (b) Sectors



Note: Panel (a) shows the evolution of an average capital-labor ratio (in logs) for financially-constrained and financially-unconstrained firms, as defined in Section 2.2. Panel (b) plots an average capital intensity vs. a share of financially-constrained firms in a sector in year 2013.

Fact 5. Export sales reallocated toward firms with high labor share. Additionally, we perform a dynamic decomposition of the labor share ratio, measured as a ratio of the wage bill and social contributions to the net sales of firms. Similarly to the case of capital intensity, we decompose export sales-weighted aggregate labor share of exporters to the EU using (2.3.2)[16]:

$$
\begin{aligned}
\Delta\left[\frac{WL}{PQ}\right] &= \underbrace{\Delta\left[\frac{\bar{WL}}{PQ}\right]_S}_{\text{Within}} \\
&+ \underbrace{\Delta \sum_j \sum_{i\in S_j} (\omega_j^0 \omega_{ji} - \bar{\omega}) \left(\frac{W_{ji}L_{ji}}{P_{ji}Q_{ji}} - \frac{\bar{WL}}{PQ}\right)}_{\text{Within-sector reallocation}} + \underbrace{\sum_j \left(\sum_{i\in S_j} \omega_{ji} \frac{W_{ji}L_{ji}}{P_{ji}Q_{ji}}\right)^1 \Delta\omega_j}_{\text{Between-sector reallocation}} \\
&+ \underbrace{\omega_{Ex}\left(\left[\frac{WL}{PQ}\right]^0_{Ex} - \left[\frac{WL}{PQ}\right]^0_S\right)}_{\text{Exit}} + \underbrace{\omega_{En}\left(\left[\frac{WL}{PQ}\right]^1_S - \left[\frac{WL}{PQ}\right]^1_{En}\right)}_{\text{Entry}},
\end{aligned}
\tag{2.3.2}
$$

where $\frac{WL}{PQ}$ is a ratio of wage bill to sales, while the rest of the terms follow descriptions in (2.3.1) and Appendix 2.5.1.

Results of decomposition (2.3.2) are in Table 2.4. Overall, the aggregate labor share decreased between 2013-2016. This decrease was driven by a lower simple average labor share of incumbents, between-sector reallocation of sales towards industries with lower share relative wages, as well as the negative contribution of the net entry.

However, in line with the case of capital intensity, we also observe a positive contribution of within-sector reallocation towards firms with higher labor share in output. This pattern

[16] See Appendix 2.5.1 for details.

in within-sector reallocation could indicate that export sales (and total sales, as shown in Table 2.6) reallocated towards firms with relatively lower markups. In line with the works of De Loecker and Warzynski (2012) and Edmond et al. (2023), we can make two assumptions, under which labor share is inversely related to a markup: (i) labor is a static input subject to no adjustment cost, and (ii) labor output elasticity is similar across firms within industries. In this case, the markup of a firm can be expressed as:

$$\mu_{ijt} = \frac{P_{ijt}Q_{ijt}}{W_{ijt}L_{ijt}} \times \alpha_j, \tag{2.3.3}$$

where $P_{ijt}Q_{ijt}$ is total sales of a firm i in industry j, $W_{ijt}L_{ijt}$ is a wage bill of a firm, and α_j is labor output elasticity in industry j. Given that labor output elasticity is constant within sectors under this specification, the higher labor share of a firm implies that this firm is expected to have a lower markup. Hence, if we make two assumptions above, a pattern of reallocation of sales toward firms with higher labor share might be suggestive of the fact that after unilateral trade liberalization, exporters with lower markups could expand their sales after a reduction in trade costs.

Table 2.4: Dynamic decomposition of the labor-output ratio of exporters to the EU

Period	Unweighted mean of incumbents	Incumbents: Within-sector reallocation of sales	Incumbents: Between-sector reallocation of sales	Entry	Exit	Total
2013-2014	-0.0233	0.0188	-0.0224	-0.0017	-0.0003	-0.0274
2013-2015	-0.0346	0.0289	-0.0328	-0.0025	0.0013	-0.0390
2013-2016	-0.0360	0.0288	-0.0299	-0.0113	0.0092	-0.0371

Note: This table contains results of dynamic Melitz-Polanec decomposition of an aggregate labor share of exporters to the EU in Equation (2.3.2). Each row contains results for a separate exercise with period 0 being 2013 and period 1 being the last year of a respective period. Column "Total" contains the change in aggregate export sales-weighted labor share ratio, column "Unweighted mean of incumbents" contains the within-firm component of change in (2.3.2), column "Incumbents: Within-sector reallocation of sales" - within-sector reallocation of sales among firms, column "Incumbents: Between-sector reallocation of sales" - between-sector reallocation of sales, column "Entry" - entry, column "Exit" - exit. Shares are calculated using export sales only.

2.4 Discussion of Results

What can explain an intense reallocation of sales towards firms with greater capital intensity?

Incomplete pass-through due to capital misallocation. In a previous section, we find that exporters with higher capital intensity and better access to external financing primarily expanded their total sales overall and export sales in particular. This happens since financially-unconstrained firms can completely pass through a reduction in trade cost into their marginal cost, while financially-constrained firms face incomplete pass-through. Financially-unconstrained firms can allocate an optimal mix of resources and produce at the optimal level. As a result, upon reduction in trade costs and increase in foreign demand, they can completely pass-through cost shock to higher sales at the foreign market. Financially-constrained firms, because of the binding borrowing constraint, produce under the optimal level. Moreover, some firms might become financially-constrained after trade liberalization. As a result, they can increase output after trade liberalization substituting missing capital with labor, which increases their marginal cost.

Cost-push shocks to cost of capital. In addition to the reduction of an aggregate capital-labor ratio of firms that did not export to the EU, we observe a decrease in a within-firm capital-labor ratio of both exporters and non-exporters. Hence, even for the exporters to the EU, reallocation towards capital-intensive firms occurred at the same time when firms became on average less capital-intensive. This might point to the domestic cost-push shocks to the cost of capital as a second force which could strengthen the reallocation we observe in the data[17]. In theory, these shocks should further tighten the borrowing constraints of financially-constrained exporters, that are already more constrained and satisfy higher foreign at the expense of domestic sales.

Incomplete pass-through due to variable markups. The presence of variable markups would lead to a weaker response to trade liberalization and cost-push shocks of firms with greater markups (see, e.g., Edmond et al., 2023; De Loecker et al., 2016). In the model that features variable markups and financial frictions, if two firms have the same level of productivity, but one of them has a greater cost of capital due to worse access to finance, the other would have greater markup and thus would experience lower pass-through of cost shocks. Thus, variable markups could potentially weaken the reallocation towards more capital-intensive firms.

While the former two channels are well-studied in the financial constraints literature (see, e.g., Midrigan and Xu, 2014; Kohn et al., 2020; Brooks and Dovis, 2020), the latter is not, despite the evidence that trade liberalization affects markups of both exporters and non-exporters (see, e.g., Edmond et al., 2015; Melitz and Ottaviano, 2008). The reason is that most dynamic models with financial constraints assume monopolistic competition with CES demand, with firms setting constant markups over marginal costs. The existing dynamic models that feature both financial frictions mainly abstract from exporting decisions of firms (see, e.g., Galle, 2020; Tsifiis, 2022; Giuliano and Zaourak, 2017), or

[17]Indeed, between 2013 and 2015, the National Bank of Ukraine increased its policy rate from 6.5% to 30.0%.

look only at the importing dimension and the effects of exchange rate depreciation (see, e.g., Kim and Lee, 2022).

To analyze the role of variable markups in explaining the resource reallocation following the unilateral trade liberalization by the European Union for Ukrainian goods, we build a small open-economy model with variable markups and financial frictions.

2.5 Appendix

2.5.1 Melitz-Polanec dynamic decomposition of capital-labor ratio

To decompose the aggregate capital intensity of exporters, we perform a dynamic decomposition following Olley and Pakes (1996) and Melitz and Polanec (2015) into a change in an average capital-labor ratio of incumbents (survivors), within-sector reallocation of sales among incumbents, between-sector reallocation of market shares, the contribution of entering and exiting firms. The resulting decomposition is of the following form:

$$\Delta\left[\frac{K}{L}\right]_{XEU} = \underbrace{\Delta\left[\frac{\bar{K}}{L}\right]_{SXEU}}_{\text{Within-firm}} + \underbrace{\Delta\sum_j\sum_{i\in SXEU_j}(\omega_j^0\omega_{ji}-\bar{\omega})\left(\frac{K_{ji}}{L_{ji}}-\frac{\bar{K}}{L}\right)}_{\text{Within-sector reallocation}} + \underbrace{\sum_j\left(\sum_{i\in SXEU_j}\omega_{ji}\frac{K_{ji}}{L_{ji}}\right)^1\Delta\omega_j}_{\text{Between-sector reallocation}} +$$
$$+\underbrace{\omega_{Ex}\left(\left[\frac{K}{L}\right]^0_{XEUEx}-\left[\frac{K}{L}\right]^0_{SXEU}\right)}_{\text{Exit}} + \underbrace{\omega_{En}\left(\left[\frac{K}{L}\right]^1_{SXEU}-\left[\frac{K}{L}\right]^1_{XEUEn}\right)}_{\text{Entry}}$$

Next, we provide the intuition behind each of the terms.

The left-hand side of the formula is a change of the export sales-weighted aggregate capital-labor ratio of exporters between periods 0 and 1, where $\frac{K}{L}$ is an aggregate capital intensity, and XEU is a set of all exporters to the EU.

The first term of the right-hand side, "within-firm", shows a change in the unweighted mean of capital-labor ratio between period 0 and period 1, where $\frac{\bar{K}}{L}$ is an unweighted mean of firm-level capital intensity, and $SXEU$ is a set of surviving exporters (incumbents) that exported in both periods.

The second term of right-hand side, "within-sector reallocation", provides a contribution of within-sector reallocation among surviving firms in this sector, where j is a sector, $i \in SXEU_j$ is a surviving exporter to the EU that operates in sector j, ω_j^0 is share of sector j in total exports to the EU in period 0, ω_{ji} is a share of firm i in sector's j exports to the EU, $\bar{\omega}$ is a mean market share of surviving firms, $\frac{K_{ji}}{L_{ji}}$ is a capital-labor ration of firm i in sector j, $\frac{\bar{K}}{L}$ is an unweighted mean of firm-level capital intensity.

The third term of the right-hand side, "between-sector reallocation", represents contribution of reallocation of sales across sectors, where $\left(\sum_{i\in SXEU_j}\omega_{ji}\frac{K_{ji}}{L_{ji}}\right)^1$ is a weighted average of capital-labor ratios of all surviving firms in sector j in period 1, $\Delta\omega_j$ is a change in exports share of sector j.

The fourth term, "exit," contains a contribution of exiting firms, where ω_{Ex} is a share in sales in period 0 of firms exiting in period 1, $\left[\frac{K}{L}\right]^0_{XEUEx}$ is an aggregate capital-labor ratio of exiting firms in period 0, $\left[\frac{K}{L}\right]^0_{SXEU}$ is an aggregate capital-labor ratio of surviving firms in period 0.

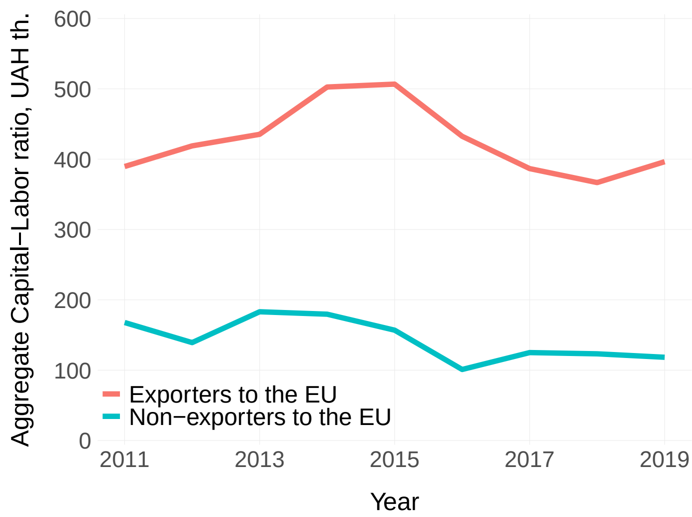
The fifth term, "entry", contains a contribution of entering firms, where ω_{En} is a sales share in period 1 of firms entering in period 1, $\left[\frac{K}{L}\right]^{0}_{XEUEn}$ is an aggregate capital-labor ratio of entering firms in period 1, $\left[\frac{K}{L}\right]^{0}_{SXEU}$ is an aggregate capital-labor ratio of surviving firms in period 1.

In Section 2.3, we apply Melitz and Polanec (2015) decomposition for a number of exercises. Above, we describe the decomposition of the export-sales ratio of the aggregate capital intensity of exporters to the EU. Later, we modify this decomposition in the following way. For total-sales weighted aggregate capital intensity of exporters, we calculate sales shares using total sales instead of export sales. For the aggregate capital intensity of non-exporters, we calculate sales shares using the total sales of firms and consider a set of non-exporters to the EU NX instead of exporters XEU.

Finally, for the dynamic decomposition of a labor share, we modify a capital-labor ratio, $\frac{K}{L}$, with a labor-sales ratio, $\frac{WL}{PQ}$, but follow the same definition of the terms.

2.5.2 Additional Results

Figure 2.3: Aggregate capital intensity of exporters to the EU vs. non-exporters to the EU



Note: This chart shows the evolution of the aggregate capital-to-labor ratio of both a set of exporters to the EU and a set of firms that are not exporting to the EU. Aggregate capital intensity is the total sales-weighted average of capital intensities.

Table 2.5: Dynamic decomposition of the capital-labor ratio of exporters to the EU

Period	Unweighted mean of incumbents	Incumbents: Within-sector reallocation of sales	Incumbents: Between-sector reallocation of sales	Entry	Exit	Total
2013-2014	6.4	16.3	63.7	-26.2	7.1	67.3
2013-2015	-7.4	32.1	61.3	-29.0	14.4	71.4
2013-2016	-25.2	32.4	-4.2	-29.5	23.8	-2.8

Note: This table contains results of dynamic Melitz-Polanec decomposition of an aggregate capital-labor ratio of exporters to the EU in Equation (2.3.1). Each row contains results for a separate exercise with period 0 being 2013 and period 1 being the last year of a respective period. Column "Total" contains the change in aggregate export sales-weighted capital-labor ratio, column "Unweighted mean of incumbents" contains the within-firm component of change in (2.3.1), column "Incumbents: Within-sector reallocation of sales" - within-sector reallocation of sales among firms, column "Incumbents: Between-sector reallocation of sales" - between-sector reallocation of sales, column "Entry" - entry, column "Exit" - exit. Shares are calculated using total sales.

Table 2.6: Dynamic decomposition of labor share of exporters to the EU

Period	Unweighted mean of incumbents	Incumbents: Within-sector reallocation of sales	Incumbents: Between-sector reallocation of sales	Entry	Exit	Total
2013-2014	-0.0233	0.0202	-0.0115	0.0032	-0.0011	-0.0112
2013-2015	-0.0346	0.0306	-0.0202	0.0024	-0.0017	-0.0226
2013-2016	-0.0360	0.0298	-0.0210	0.0002	-0.0000	-0.0250

Note: This table contains results of dynamic Melitz-Polanec decomposition of an aggregate labor share of exporters to the EU in Equation (2.3.2). Each row contains results for a separate exercise with period 0 being 2013 and period 1 being the last year of a respective period. Column "Total" contains the change in aggregate export sales-weighted labor share ratio, column "Unweighted mean of incumbents" contains the within-firm component of change in (2.3.2), column "Incumbents: Within-sector reallocation of sales" - within-sector reallocation of sales among firms, column "Incumbents: Between-sector reallocation of sales" - between-sector reallocation of sales, column "Entry" - entry, column "Exit" - exit. Shares are calculated using total sales.

Chapter 3

Financial Frictions, Markups, and Trade Liberalization: Quantitative Exploration

WITH ANDRII TARASENKO AND VOLODYMYR VAKHITOV

3.1 Model

Motivated by stylized facts, presented in 2, we build a small open-economy model with financial frictions and variable markups.

The model generally builds on Kohn et al. (2020) with a number of modifications. First, contrary to Kohn et al. (2020), we assume that financial markets are not internationally-integrated and entrepreneurs can buy only bonds denominated in units of the domestic final good. Second, final good producers aggregate intermediate varieties into a final good using Kimball (1995) aggregator similar to Gopinath et al. (2020) and Klenow and Willis (2016) that gives rise to variable demand elasticities. Under these conditions, monopolistically-competitive firms would maximize profits by setting variable markups. Third, we assume that domestic firms sell to one foreign market and we abstract from other destinations. Both domestic producers and importers set variable markups in the domestic market. In order to simplify the problem and retain the assumption of Ukraine as a small open economy, we assume constant elasticity demand abroad. Fourth, contrary to Kohn et al. (2020), all exporters face similar trade costs. Finally, we explicitly model foreign firms importing to the domestic economy and assume that they are financially-unconstrained.

3.1.1 Economic Environment

Final Good Producers

The final good is produced by perfectly-competitive final good producers that purchase both varieties produced by domestic intermediate producers and imported varieties produced by foreign intermediate producers. We denote the aggregate production of the final good in country d at time t by Y_{dt} and assume that it can be used either for consumption or investment in capital.

Final good producers use a bundle of differentiated intermediate inputs $y_{dt}(\omega)$ with $\omega \in \Omega_{dt}$, where Ω_{dt} is the set of intermediate input varieties, available for the purchase in the country d at time t. Similarly to Gopinath et al. (2020), we partition Ω_{dt} into the set of domestically-produced varieties Ω_{ddt} and the set of imported varieties, Ω_{dmt}. We normalize $|\Omega_{ddt}| = 1$.

Varieties are aggregated into the final good using the Kimball (1995) aggregator:

$$\frac{1}{|\Omega_{ddt}|}\int_{\Omega_{ddt}} \Upsilon\left(\frac{|\Omega_{ddt}|y_{dt}(\omega)}{Y_{dt}}\right) d\omega + \frac{1}{|\Omega_{dmt}|}\int_{\Omega_{dmt}} \Upsilon\left(\frac{|\Omega_{dmt}|y_{dmt}(\omega)}{Y_{dt}}\right) d\omega = 1, \qquad (3.1.1)$$

where $y_{dt}(\omega)$ is an output supplied by a domestic entrepreneur to the domestic market, and $y_{dmt}(\omega)$ is an import of a foreign firm to the domestic market.

We denote $q_d = \frac{y_d}{Y_d}$ and make use of the specification of $\Upsilon(q)$ from Klenow and Willis

(2016):

$$\Upsilon(q) = 1 + (\sigma - 1)\exp\left(\frac{1}{\varepsilon}\right)\varepsilon^{\frac{\sigma}{\varepsilon}-1}\left[\Gamma\left(\frac{\sigma}{\varepsilon},\frac{1}{\varepsilon}\right) - \Gamma\left(\frac{\sigma}{\varepsilon},\frac{q^{\frac{\varepsilon}{\sigma}}}{\varepsilon}\right)\right]$$

We assume, that $\sigma > 1$, $\varepsilon \geq 0$ and $\Gamma(s,x)$ being incomplete Gamma function:

$$\Gamma(s,x) := \int_x^\infty t^{s-1}e^{-t}dt$$

If $\varepsilon \geq 0$, firms with greater relative quantity, q, set higher markups.
Taking the prices of ω as given and normalizing prices of the final good to 1, final good producers choose $y_{dt}(\omega)$ to maximize profits:

$$P_{dt}Y_{dt} - \int_{\Omega_{dt}} p_{dt}(\omega)y_{dt}(\omega)d\omega \tag{3.1.2}$$

s.t.

$$\frac{1}{|\Omega_{ddt}|}\int_{\Omega_{ddt}}\Upsilon\left(\frac{|\Omega_{ddt}|y_{dt}(\omega)}{Y_{dt}}\right)d\omega + \frac{1}{|\Omega_{dmt}|}\int_{\Omega_{dmt}}\Upsilon\left(\frac{|\Omega_{dmt}|y_{dmt}(\omega)}{Y_{dt}}\right)d\omega = 1, \tag{3.1.3}$$

where a price index P_{dt} is

$$P_{dt} := \int_{\Omega_{ddt}} p_{dt}(\omega)\frac{y_{dt}(\omega)}{Y_{dt}}d\omega + \int_{\Omega_{dmt}} p_{dmt}(\omega)\frac{y_{dmt}(\omega)}{Y_{dt}}d\omega \tag{3.1.4}$$

At the optimum, an inverse demand function is

$$p_{dt}(\omega) = \Upsilon'\left(\frac{y_{dt}(\omega)}{Y_{dt}}\right)\frac{P_{dt}}{D_{dt}} = \frac{\sigma-1}{\sigma}\exp\left(\frac{1-\left[\frac{y_{dt}(\omega)}{Y_{dt}}\right]^{\frac{\varepsilon}{\sigma}}}{\varepsilon}\right)\frac{P_{dt}}{D_{dt}} \tag{3.1.5}$$

where D_{dt} is a demand index defined as

$$D_{dt} = \int_{\Omega_{ddt}}\Upsilon'\left(|\Omega_{ddt}|\frac{y_{dt}(\omega)}{Y_{dt}}\right)\frac{y_{dt}(\omega)}{Y_{dt}}d\omega + \int_{\Omega_{dmt}}\Upsilon'\left(|\Omega_{dmt}|\frac{y_{dmt}(\omega)}{Y_{dt}}\right)\frac{y_{dmt}(\omega)}{Y_{dt}}d\omega \tag{3.1.6}$$

Entrepreneurs

Preferences. The domestic economy is populated by a continuum of unit measure of infinitely-lived risk-averse entrepreneurs that maximize lifetime utility from consuming final goods. Entrepreneurs in a country d maximize the constant relative risk aversion (CRRA) utility function from consuming a final good with a coefficient of relative risk aversion ν:

$$\sum_{t=0}^{\infty}\beta^t\frac{C_{idt}^{1+\nu}}{1+\nu}, \tag{3.1.7}$$

where C_{idt} is an individual consumption of a final good by a domestic entrepreneur i in period t, and β is a discount factor.

Technology. Each entrepreneur i owns an intermediate input firm producing a variety ω. We do not model an occupational choice and assume that each entrepreneur i supplies a unit of labor to a competitive labor market that is used by intermediate producers for production and paying the fixed cost of exporting.
Intermediate good producers use the Cobb-Douglas production function in labor and capital to produce variety for both domestic and export markets:

$$y_{dt}(\omega) + \tau_{dft} y_{ft}(\omega) = z_{dt}(\omega) k_{dt}(\omega)^{\alpha} l_{dt}(\omega)^{1-\alpha}, \tag{3.1.8}$$

where $y_{dt}(\omega)$ is the output produced for a domestic market, $y_{ft}(\omega)$ is the output produced for a foreign market, τ_{dft} is an iceberg-type cost of transporting the good from home to the foreign location, α is a capital-output elasticity, $z_{dt}(\omega)$ is the productivity of an intermediate producer, $l_{dt}(\omega)$ is labor employed by a firm, and $k_{dt}(\omega)$ is capital that follows a law of motion:

$$k_{dt+1}(\omega) = (1-\delta) k_{dt}(\omega) + x_{dt}(\omega) \tag{3.1.9}$$

with δ denoting a depreciation rate and $x_{dt}(\omega)$ denoting the investment of the entrepreneur in the capital of their intermediate producer. Productivity $z_t(\omega)$ follows log-normal AR(1) process with the standard deviation of productivity shocks equal to σ_{ε}:

$$\log z_t = (1-\rho_z)\mu_z + \rho_z \log z_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim \mathcal{N}(0, \sigma_{\varepsilon}^2) \tag{3.1.10}$$

We assume that each entrepreneur owns an asset endowment $a_{dt}(\omega)$ that determines the amount of money firms can potentially borrow

$$d_{dt}(\omega) = (1 + R_{dt})(k_{dt}(\omega) - a_{dt}(\omega)) \tag{3.1.11}$$

In addition to a natural borrowing limit, each intermediate producer can borrow up to a fraction of their capital according to a backward-looking collateral constraint:

$$d_{dt}(\omega) \leq \theta k_{dt}(\omega), \tag{3.1.12}$$

where θ shows a fraction of capital that can be used as collateral and represents the degree of enforceability of contracts in the economy. There are no financial frictions when $\theta = \infty$.
We denote the marginal cost of the firm as $MC_{dt}(\omega)$ and derive the system of first-order

conditions for profit maximization problem with respect to capital and labor:

$$W_{dt} = MC_{dt}(\omega)(1-\alpha)k_{dt}(\omega)^{\alpha}l_{dt}(\omega)^{-\alpha} \tag{3.1.13}$$

$$R_{dt} = MC_{dt}(\omega)\alpha k_{dt}(\omega)^{\alpha-1}l_{dt}(\omega)^{1-\alpha} - \delta - \lambda_{dt}(\omega) \tag{3.1.14}$$

Here $\lambda_{dt}(\omega)$ indicates the value of the Lagrange multiplier, which satisfies the complementary slackness condition:

$$\lambda_{dt}(\omega)\left(\frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega) - k_{dt}(\omega)\right) = 0 \tag{3.1.15}$$

For an unconstrained firm $\lambda_{dt}(\omega) = 0$, but for a firm for which collateral constraint binds, $\lambda_{dt}(\omega) > 0$. Similarly to Kohn et al. (2020), we think of such firms as having an effective cost of capital equal to $R_{dt} + \delta + \lambda_{dt}(\omega)$, i.e. a sum of an interest rate, a depreciation rate and a shadow price of relaxing borrowing constraint. Using first-order conditions of a cost-minimization problem for labor and capital, we show a decreasing relationship between the effective cost of capital and the capital-labor ratio:

$$\frac{W_{dt}}{R_{dt} + \delta + \lambda_{dt}(\omega)} = \frac{(1-\alpha)k_{dt}(\omega)}{\alpha l_{dt}(\omega)} \tag{3.1.16}$$

Cost-minimization also allows obtaining the closed-form expression for the marginal costs of the firm:

$$MC_{dt}(\omega) = \left(\frac{W_{dt}}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_{dt}+\delta+\lambda_{dt}(\omega)}{\alpha}\right)^{\alpha}\frac{1}{z_{dt}(\omega)} \tag{3.1.17}$$

In equilibrium, firms set variable markups over marginal costs:

$$p_{dt}(\omega) = \frac{\sigma}{\sigma - \left(\frac{y_{dt}(\omega)}{Y_{dt}}\right)^{\frac{\sigma}{\varepsilon}}}MC_{dt}(\omega) = \mu_{dt}(\omega)MC_{dt}(\omega) \tag{3.1.18}$$

Financial frictions shape factor allocation in important ways. Meeting an unconstrained demand level by a constrained firm requires too much capital, relative to the amount it could acquire through self-financing and borrowing on the financial markets. Meeting the demand is possible by hiring more workers, but this comes at the expense of lower labor productivity and greater marginal cost. Facing such a tradeoff, in equilibrium, the constrained firm hires more labor and produces less output, compared to the unconstrained firm with similar productivity.

Financial markets. Contrary to Kohn et al. (2020), we assume that financial markets are not internationally integrated[1], and financial intermediaries trade only one-period

[1]This assumption is motivated by the fact that Ukrainian firms and individuals have limited access

non-contingent bonds denominated in units of domestic final goods at the interest rate R_{dt}. Financial intermediaries are price-takers and the supply of bonds is perfectly-elastic. Each period entrepreneurs repay the debt from the last period $d_{dt}(\omega)$, and borrow a new amount due next year $\frac{d_{dt+1}(\omega)}{1+R_{dt}}$ subject to a natural borrowing limit and a backward-looking borrowing constraint (3.1.12). Entrepreneurs use new debt and assets to internally transform invested final good into capital for production: $k_{dt+1}(\omega) = a_{dt+1}(\omega) + \frac{d_{dt+1}(\omega)}{1+R_{dt}}$.

International trade. We assume that the economy is open and international trade occurs in a fashion of Melitz (2003). Intermediate producers can trade internationally and pay fixed and variable trade cost. A firm's export choice at time t is denoted by $e_{dt}(\omega)$:

$$e_{dt}(\omega) = \begin{cases} 1, & \text{if } \pi_{eft}(\omega) > \pi_{edt}(\omega) - F \cdot W_{dt} \\ 0, & \text{otherwise} \end{cases} \tag{3.1.19}$$

where $e_{dt}(\omega)$ is equal to 1 if the firm exports and 0 if the firm sells only domestically, while the total profits of the exporter are denoted by $\pi^{e}_{dt}(\omega)$ and total profits of non-exporter - by $\pi^{ne}_{dt}(\omega)$. Firms have to pay a fixed cost F in units of labor every period in which they decide to export. Exporters are also subject to iceberg-type trade costs in the spirit of Krugman (1991) (in the sense of a fraction of foreign output melts on the road). An unconstrained firm makes exporting decision as a firm in an environment without financial frictions. In this case, domestic profits are similar on both sides of the inequality, and a comparison of profits on the exporting market with the associated fixed costs is sufficient to make exporting decision. For a financially-constrained firm, domestic profits might be lower if it exports, compared with the situation, when it does not export. Even if exporting profits cover fixed costs, the resulting decrease in domestic profits might not justify entering a foreign market if the firm is constrained.

Dynamic problem of entrepreneurs. The timing of the model follows the one in Kohn et al. (2020). At the beginning of the period, entrepreneurs repay an old debt, hire labor, produce variety, make exporting decision and sell to the markets, as well as decide on the next-period assets a_{t+1}. The demand system is such that even in the absence of fixed costs on the domestic market, very unproductive entrepreneurs face no demand. If that happens, we treat the entrepreneur as holding an inactive firm and only consuming their labor income. If a firm exports, a fixed cost of exporting is also paid during the same period. At the end of the period, entrepreneurs observe a new realization of productivity, issue new debt, as well as make a choice of capital for the next period, k_{t+1}, given the new level of assets, determined using the policy function.

to foreign financial markets.

A problem of entrepreneur at period t consists of choosing sequences of consumption C_{idt}, investment $x_{dt}(\omega)$, export choice $e_{dt}(\omega) \in \{0,1\}$, quantities $y_{dt}(\omega)$ and $y_{ft}(\omega)$ for both markets (if exporting), as well as prices $p_{dt}(\omega)$ and $p_{ft}(\omega)$ for each market to maximize a lifetime utility, subject to (i) borrowing constraint as described by a backward-looking collateral constraint and a natural borrowing limit, (ii) law of motion for capital, (iii) production technology, (iv) demand schedules at the domestic market and abroad, and (v) budget constraint expressed in the units of the domestic final good:

$$C_{idt} + x_{dt}(\omega) + d_{dt}(\omega) + e_{idt}(\omega)W_{dt}F = \tag{3.1.20}$$
$$W_{dt} + p_{ht}(\omega)y_{ht}(\omega) + e_{dt}(\omega)p_{ft}(\omega)y_{ft}(\omega) - W_{dt}l_{dt}(\omega) - (R_{dt}+\delta)k_{dt}(\omega) + \frac{d_{dt+1}(\omega)}{1+R_{dt}}$$

Rest of the World

We assume that a domestic economy is a small open economy and changes in factor and final good prices there do not affect foreign variables [2]. We assume, that domestic producers are able to observe foreign factor prices W_{ft} and R_{ft} as well as foreign price index P_{ft}. We set P_{dt} as a numeraire, normalizing it to 1. With the domestic price index and real exchange rate held fixed, a price index abroad is set as $P_{ft} = \xi_t P_{dt}$. Following the Local Currency Paradigm, we express all variables in the domestic currency.
We assume that firms abroad are unconstrained (i.e. $\theta \sim \infty$). This allows us not to model foreign entrepreneurs since firms are not limited by the net worth of the owner. We also assume out markup dispersion on the foreign market. Assuming, that $\Upsilon(q) = q^{\frac{\sigma-1}{\sigma}}$ will lead to constant markups abroad. Although these assumptions seem restrictive, levying either of these will lead to changes in the domestic market affecting foreign firms through competitive forces, which remains at odds with the assumption of Ukraine being a small open economy.
Final producers abroad solve the following problem

$$\max P_{ft}Y_{ft} - \int_{\Omega_{ft}} p_{it}(\omega)y_{it}(\omega)d\omega \tag{3.1.21}$$

s.t.

$$\frac{1}{\mid \Omega_{fft} \mid}\int_{\Omega_{fft}} [q_{ft}(\omega) \mid \Omega_{fft} \mid]^{\frac{\sigma-1}{\sigma}} d\omega + \frac{1}{\mid \Omega_{fet} \mid}\int_{\Omega_{fet}} [q_{fet}(\omega) \mid \Omega_{fet} \mid]^{\frac{\sigma-1}{\sigma}} d\omega = 1, \tag{3.1.22}$$

where

$$q_{ft}(\omega) = \frac{y_{ft}(\omega)}{Y_{ft}} \tag{3.1.23}$$

[2]Given that the model is based on Ukrainian manufacturing and abstracts from agriculture, this is a reasonable assumption.

Again, we assume, that the measure of varieties, available at the foreign market is Ω_{ft}, and it can be partitioned into the set of varieties, produced at the foreign location (Ω_{fft}) as well as the set of varieties, imported from the domestic location (Ω_{fet}). The resulting demand can be written as $y_{ft}(\omega) = \frac{A_{ft}}{P_{ft}^{-\sigma}} p_{ft}^{-\sigma}(\omega)$ where A_{ft} is the function of EU output aggregator as well as parameters, they remain fixed by the assumption that Ukraine is a small open economy. Profit maximization yields price, which is a constant markup over marginal costs, equalizing it with the inverse demand, we are able to arrive at a closed-form expression for the demand of a domestic producer of the variety ω at the foreign market:

$$y_{ft}(\omega) = \frac{A_{ft}}{P_{ft}^{-\sigma}} \left[\frac{\sigma}{\sigma - 1} \frac{W_{dt}^{1-\alpha}(R_{dt} + \delta + \lambda_{dt}(\omega))^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} \frac{\tau_{dft}}{z_t(\omega)} \right]^{-\sigma}$$

Finally, we assume that all the markets abroad clear.

3.1.2 Recursive Formulation of Domestic Entrepreneur's Problem

Based on the dynamic problem and the timing of the model, we describe a recursive formulation of the entrepreneur's problem in stationary equilibrium. First, assume that $V(k, d, z)$ is a value function of an entrepreneur with a capital k, debt d, and productivity z, who makes a consumption-saving choice and maximizes profits of an intermediate producer owned by them. Next, assume that $\pi(k, z)$ is a profit function of an intermediate good producer with a capital k and productivity z that allocates a mix of production inputs, makes exporting decision, as well as chooses production levels and prices for both domestic and foreign markets (if she chooses to export). At the end of the period, an entrepreneur with assets a observes a new productivity realization z, makes a choice of capital k and debt $\frac{d}{1+R_d}$ for the next period - we assume that value function, in this case, is $g(a, z)$.
A problem of domestic entrepreneur has the following recursive formulation:

$$\begin{aligned} V(k, d, z) = \max_{c, a' > 0} & \frac{c^{1+\nu}}{1+\nu} + \beta \mathbb{E}[g(a', z')] \\ \text{s.t. } & c + a' + d = W_d + (1-\delta)k + \pi(k, z) \end{aligned}$$

where

$$\begin{aligned} \pi(k, z) = & \max_{p_d, p_f, y_d, y_f, k, l, e} p_d y_d + e p_f y_f - W_d l - (R_d + \delta)k - eFW_d \\ & \text{s.t. } \tau_{df} y_f + y_d = z k^{\alpha} l^{1-\alpha} \end{aligned}$$

$$y_f = \frac{A_f}{P_f^{-\sigma}} \left[\frac{\sigma}{\sigma - 1} \frac{W_d^{1-\alpha}(R_d + \delta + \lambda)^{1-\alpha}}{(1-\alpha)^{1-\alpha}\alpha^\alpha} \frac{\tau_{df}}{z} \right]^{-\sigma}$$
$$y_d = \left[1 - \varepsilon \ln \left(\frac{p_d D_d}{P_d} \frac{\sigma}{\sigma - 1} \right) \right]^{\frac{\sigma}{\varepsilon}} Y_d$$

and

$$\begin{aligned} g(a', z') &= \max_{k', d'} V(k', d', z') \\ \text{s.t. } k' - \frac{d'}{1+R} &= a' \\ d' &\leq \theta k' \end{aligned}$$

3.1.3 Stationary Competitive Equilibrium

Let $S := Z \times A$ denote the state space of entrepreneurs consisting of productivity and assets, such that $Z = R^+$ and $A = R^+$, as well as $S \to [0, 1]$. S gives the domain for solving the optimal policy function of domestic entrepreneurs. Let $s \in S$ be an element of the state space, where an element of state space s consists of a value of assets and a value of productivity. We assume that the domestic real interest rate R_d and price index P_d are constant. Foreign variables such as real interest rate, R_f, wage rate W_f, absorption ξA_f, as well as a real exchange rate ξ, are fixed. Moreover, the sizes of sets Ω_{dd} and Ω_{dm} are given.

Definition of equilibrium. A *recursive stationary competitive equilibrium* consists of prices $\{W_d\}$, policy functions $\{c, d', k_d', l_d, e_d, y_d, y_f, p_d, p_f, e_m, y_m, p_m, Y_d, D_d\}$, value functions v and g, as well as a measure $\phi : S \to [0, 1]$ such that

1. policy and value functions solve entrepreneurs' problem

2. policy functions solve the final good producers' problem

3. labor market clears
$$\int_{s \in S} [n(s) + e(s)F]\phi(s)ds = 1$$

4. final goods market clears[3]

$$\int_{s \in S} [c(s) + x(s)]\phi(s)ds = Y_d$$

5. outputs satisfy Kimball aggregator

$$\frac{1}{|\Omega_{dd}|} \int_{\Omega_{dd}} \Upsilon \left(\frac{|\Omega_{dd}| y_d(\omega)}{Y_d} \right) d\omega + \frac{1}{|\Omega_{dm}|} \int_{\Omega_{dm}} \Upsilon \left(\frac{|\Omega_{dm}| y_{dm}(\omega)}{Y_d} \right) d\omega = 1$$

[3]Asset market clears due to the Walras law

6. measure ϕ is stationary

The Appendix contains a numerical algorithm applied to find a stationary equilibrium of the model.

3.1.4 Alternative Modelling Assumptions

Since we are interested in studying the contribution of financial constraints and variable markups to the gains from trade, we contrast a baseline model described above, with two counterfactual economies.

No financial constraints. First, we shut down a channel of financial frictions. Relaxing this assumption implies a frictionless borrowing such that $\theta = \infty$. This change means that firms now are not constrained by the wealth of the entrepreneur anymore. The numerical algorithm generally follows the same steps as in a baseline model, except for no need to solve for optimal choices of constrained domestic firms.

No variable markups. Second, we assume out variable markups in the domestic market. In this case, we assume that the domestic final producer aggregates intermediate varieties using a CES aggregator that implies no variation in markups at the domestic market. The model implies an expression for $\Upsilon(q)$ becomes $\Upsilon(q) = q^{\frac{\sigma-1}{\sigma}}$, where $q_t(\omega) = \frac{y_t(\omega)}{Y_t}$. A modified numerical algorithm used to find equilibrium is described in an Appendix.

3.2 Quantitative Results

3.2.1 Calibration

We calibrate a model to replicate the features of the Ukrainian firm-level data for the manufacturing sector in 2013, a year before trade liberalization with the EU. One period in a model corresponds to one year. Next, we describe how we calibrate a set of externally- and internally-calibrated parameters.

Externally-Calibrated Parameters. The first set of parameters is calibrated externally, using estimates from the literature or estimates from the data (see Table 3.1 for a summary). A real interest rate for the domestic economy is equal to 0.06. We calculate the real interest rate as a sum of the J.P. Morgan Emerging Markets Bond (EMBI) Spread for Ukraine in the year 2013 and a real return on the US 1-year Treasury Bill in 2013. The real interest rate for the foreign market is set to 0.01 since the policy rate in the euro area reached Zero Lower Bound in 2012. A discounting rate β is set at 0.93 to pin down a real interest rate in 2013. The depreciation rate is set using a standard value of 0.1. Following a common practice in literature, we set a parameter of output elasticity of capital, α, equal to 1/3. A coefficient of relative risk aversion is set at the standard value of -2. Since we do not observe data for importers and can not directly estimate markups and a relationship between markups and firm size, we use parameters for the average demand elasticity and superelasticity from the literature. We set value of average demand elasticity, $\bar{\sigma}$, equal to 5, following Gopinath and Itskhoki (2010) and Klenow and Willis (2016). While demand elasticity in the model is firm-specific, $\bar{\sigma}$ affects the level of markups in the economy. In case of constant markups, this choice of $\bar{\sigma}$ implies an aggregate markup equal to 1.25. Demand elasticity varies with a relative size of a firm, and superelasticity determines the elasticity of former to latter. To calibrate a value of superelasticity, we borrow from Tsiflis (2022) and set it at 0.32, which lies between the value set by Edmond et al. (2023) and Gopinath and Itskhoki (2010)[4]. In order to calibrate the persistence of the productivity process, we use a procedure for estimating firm-level productivity by Blundell and Bond (1998) on our sample of manufacturing firms and recover a coefficient for a lagged output. The estimate implies a value of ρ equal to 0.631. We set the real exchange rate ξ at 0.1 using the data on the nominal exchange rate of the Ukrainian Hryvnia to the Euro and respective CPIs. Finally, we need to determine a measure of varieties available in the domestic market, $|\Omega_{dt}|$. We use similar normalization to Gopinath and Itskhoki (2010) and assume that $|\Omega_{dt}| = 1 + \gamma_{dmt}$ with the measure-one of domestically-produced varieties and measure γ_{dmt} of varieties imported from abroad and sold at home. We calibrate γ_{dmt} using data on domestic absorption of manufacturing goods and imports of manufacturing goods from the EU. An estimated share of imported goods in total absorption is equal to 0.08. We recover γ_{dmt} from $0.08 = \frac{\gamma_{dmt}}{1+\gamma_{dmt}}$ and obtain a value of γ_{dmt} equal to 0.09.

Table 3.1: Externally-Calibrated Parameters

Name	Parameter	Value	Source
Real interest rate, domestic	R_d	0.06	EMBI Spread + US rate
Real interest rate, foreign	R_f	0.01	Zero-lower bound
Depreciation rate	δ	0.1	Standard
Capital elasticity	α	0.33	Kohn et al. (2020)
Coefficient of relative risk aversion	ν	-2	Kohn et al. (2020)
Average demand elasticity	$\bar{\sigma}$	5	Gopinath and Itskhoki (2010), Klenow and Willis (2016)
Superelasticity	$\frac{\varepsilon}{\bar{\sigma}}$	0.32	Tsiflis (2022)
Measure of imported varieties	γ_{dm}	0.09	Data
Real exchange rate	ξ	0.1	Data
Persistence parameter of a productivity process	ρ_z	0.63	Estimated using Blundell and Bond (1998) approach

Internally-Calibrated Parameters. We are left with several parameters that we cal-

[4]Normally, we would calibrate superelasticity regressing markups on market shares as in Edmond et al. (2023); however, due to the lack of data on importers we use an estimate from the literature.

ibrate internally - the fixed cost of exporting F, iceberg transportation cost, τ_{df} and τ_{fd}, standard deviation of productivity shocks, σ_ε, tightness of financial constraint, θ, as well as term capturing foreign variables, A_f. We calibrate these parameters while matching moments from the model to respective moments observed in data (see Table 3.2 for a summary).

Table 3.2: Internally-Calibrated Parameters

Parameter	Value	Target moment	Data	Model
F	0.44	Share of exporters	0.25	0.25
τ_{df}	1.81	Exports intensity	0.18	0.21
τ_{fd}	1.79	Imports penetration	0.08	0.32
σ_ϵ	0.86	Standard deviation of log sales	1.74	2.38
θ	0.51	Credit/GDP	0.46	0.73
A_f	1012.7	Relative absorption	32.0	34.0

We start with the moments from the firm-level data. On an extensive margin, we find that 25% of Ukrainian manufacturing firms were exporting to the EU in 2013. On intensive margin, in a sample of exporters to the EU, revenues from exporting to the EU, on average accounted for 18% of total sales. The standard deviation of log sales in the sample is equal to 1.74 in 2013. Using aggregate data, we calculate imports penetration as a ratio of manufacturing imports from the EU to total domestic manufacturing absorption in Ukraine and manufacturing imports from the EU and get a ratio equal to 0.08. Relative absorption is measured as a sum of total domestic manufacturing absorption in the EU and total manufacturing exports from Ukraine to the EU divided by a sum of total domestic manufacturing absorption in Ukraine and total manufacturing imports to Ukraine from the EU[5]. The resulting ratio that we target is equal to 32.0. Finally, using data from the State Statistics Service of Ukraine, we calculate the Credit-to-GDP ratio as a share of short-term credit of Ukrainian manufacturing firms in 2013 to the contribution of manufacturing to GDP and get the value of 0.46.

3.2.2 Steady State

Using calibration described in Table 3.1 and 3.2, equilibrium is reached with equilibrium wage $W_d = 0.70$, domestic absorption $Y_d = 2.98$ and demand index $D_d = 1.54$. In this subsection, we describe some properties of the steady state, including how markups and effective cost of capital are related to exporter decision and financially-constrained status.

[5]Domestic manufacturing absorption in the EU is obtained from the World Input-Output Database (see Timmer et al. (2015) for a description), domestic manufacturing absorption is obtained from the Input-Output Table of Ukraine, manufacturing exports of Ukraine to the EU is obtained from the firm-level data, manufacturing imports of the EU to Ukraine is obtained from Comtrade database.

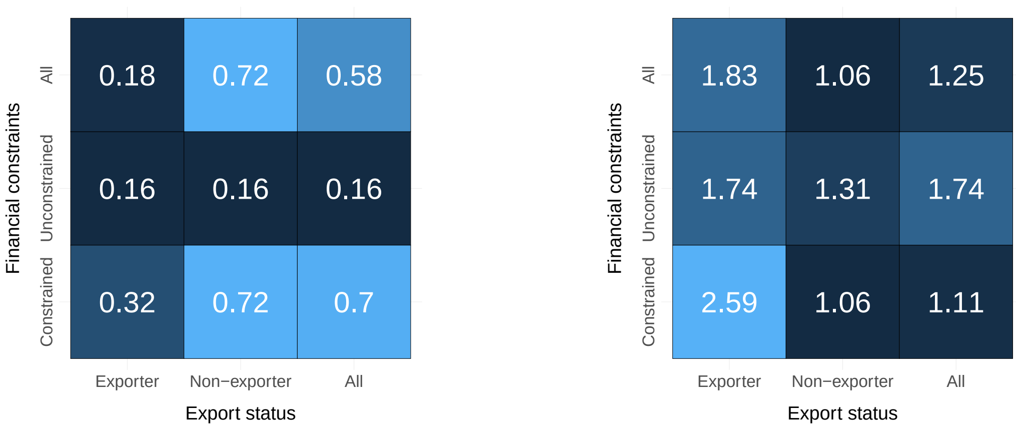
Production and Choke Price. In the presence of the Kimball aggregator, there exists a choke price, above which entrepreneurs do not produce. This creates an entry barrier to the domestic market since only the most productive firms can set low enough prices and produce. As a result, in the steady state of the calibrated economy, around 33% of entrepreneurs produce, while the rest are out of the domestic market due to potentially high prices and only supply labor for operating intermediate producers.

Cost of capital. Panel (a) of Figure 3.1 shows heterogeneity in the effective cost of capital. The majority of active firms in a steady state are financially-constrained. To specify, 77% of active firms have an effective cost of capital greater than 0.16, a sum of a real interest rate and a depreciation rate. The average cost of capital among producing firms is 0.58. However, the average figure masks heterogeneity across the firms. To start with, 23% of all active firms, both exporters and non-exporters, are unconstrained and face a cost of capital equal to 0.16. On the other hand, the average effective cost of capital for constrained firms is equal to 0.70. Looking from another perspective, exporters, on average, have a lower cost of capital - 0.17 vs 0.72 for non-exporters. The least productive producers that potentially would be unconstrained cannot overcome the entry barrier caused by a choke price. As a result, more than 99% of non-exporters are constrained. On the other hand, the most productive firms select into exporting. We find that 90% of exporters are unconstrained, while the exporters at the top of productivity distribution are constrained.

Markups. Panel (b) of Figure 3.1 shows average markups for different groups of firms - from the perspective of both exporting and financially-constrained status. First, the average markup of domestic intermediate producers is equal to 1.25. Second, we find that an average markup for exporters is greater than the one for non-exporters, 1.83 vs. 1.06, which is in line with Edmond et al. (2015) that exporters tend to set higher markups. On the other hand, the markups of constrained firms, 1.11, are lower as compared to unconstrained, 1.74. Binding borrowing constraint limits a firm's ability to allocate an optimal mix of resources and reduces its revenue productivity. Lower productivity results in higher demand elasticity and, as a result, lower markup (see, e.g., Edmond et al., 2023). Analyzing markups by the joint exporter-constrained status, we find that constrained non-exporters set lower markups than unconstrained ones. However, for exports we observe an opposite picture - constrained firms set higher markups. This could be explained by the fact that, among exporters, the most financially-constrained firms are the most productive ones that have higher markups in the domestic market. Finally, the average markup of foreign importers is 1.46 and higher than the average markup of domestic firms, since foreign firms should be productive enough to pay both fixed and variable costs of exporting.

Figure 3.1: Average markup and effective cost of capital in a steady state

(a) Effective cost of capital (b) Markup



Note: Panel (a) shows an average markup of at the domestic market for each of the groups of domestic exporters and non-exporters. Panel (b) shows an average effective cost of capital for each of the groups of domestic exporters and non-exporters.

Correlation between markups and cost of capital. How are markups and effective cost of capital related among intermediate producers in a steady state? To answer this question, we calculate the conditional correlation between markup, μ, and the shadow price of capital, λ, conditional on firms being active and producing:

$$r(\mu(s), \lambda(s)) = \frac{\int_{s \in S} \mathbb{1}\{q(s) > 0\}(\mu(s) - \bar{\mu})(\lambda(s) - \bar{\lambda})\phi(s)ds}{\sqrt{\int_{s \in S} \mathbb{1}\{q(s) > 0\}(\mu(s) - \bar{\mu})^2\phi(s)ds} \cdot \sqrt{\int_{s \in S} \mathbb{1}\{q(s) > 0\}(\lambda(s) - \bar{\lambda})^2\phi(s)ds}} \tag{3.2.1}$$

where $\bar{\mu} = \int_s \mathbb{1}\{q(s) > 0\}\mu(s)\phi(s)ds$ is an average markup and $\bar{\lambda} = \int_s \mathbb{1}\{q(s) > 0\}\lambda(s)\phi(s)ds$ is an average shadow cost of capital. The resulting correlation for all active intermediate good producers is equal to -0.79, which indicates a strong negative relationship between markups and the shadow price of capital. In addition, we also check correlation for exporters only, applying Equation (3.2.1) but calculating moments conditional on export status, i.e. substituting $\mathbb{1}\{q(s) > 0\}$ with $\mathbb{1}\{e(s) = 1\}$. The resulting correlation calculated separately for exporters is positive and equal to 0.50. These findings are in line with the picture we see in Panel (b) of Figure 3.1 since the most productive exporters are more financially-constrained and have higher markups.

3.3 Effects of Trade Liberalization

3.3.1 Baseline Model

Before unilateral trade liberalization, the average overall tariff protection of the EU against Ukrainian goods was around 5.0% (both simple average and trade-weighted)[6], with average tariff protection for Ukrainian manufacturing, depending on industry/product group, varied between 0 and 20%.

We model trade liberalization, as a unilateral 10-percent reduction in iceberg trade cost for domestic exporters, τ_{df}. To study the effects of trade liberalization, we compare the initial, pre-liberalization, steady state with a new steady state with a lower value for τ_{df}, but keeping the rest of the parameters fixed. Table 3.3 contains a summary of both steady states. Overall, trade liberalization increases welfare and productivity, as well as improves the allocation of resources.

Welfare effects. We find that trade liberalization is welfare-improving. The total consumption of entrepreneurs increases from 2.777 to 2.920, or by 5.15%. On the one hand, consumption increased since both labor income and profits of entrepreneurs increased. Real wages increased from 0.699 to 0.831, or by 18.87%, reflecting higher demand for labor. Profits that entrepreneurs earn from owing intermediate producers increase from 0.481 to 0.484, or by 0.62%. On the other hand, in a steady state, total consumption is equal to a difference between aggregate output and savings, while total savings are equal to an aggregate investment, $C = Y - S = Y - I$. As a result of trade liberalization, both aggregate output and investment increased. Higher absolute change in aggregate output, from 2.979 to 3.155, as compared to absolute change in savings from 0.201 to 0.235, contributed to an increase in consumption the most.

To determine changes in welfare, we follow Leibovici (2021) and Edmond et al. (2023) and compute changes in consumption-equivalent units (CEU)[7]. Conceptually, we calculate how much a permanent state-invariant increase in consumption would make individuals indifferent between a steady state with trade liberalization and a steady state without trade liberalization. Following Leibovici (2021), we assume an alternative one-period utility function $u(c) = \log((1 + \Delta)c)$ and calculate changes in welfare as:

$$\Delta = \exp\left\{(1-\beta)\left[\int_{s\in S} g_1(s)\phi(s)ds - \int_{s\in S} g_0(s)\phi(s)ds\right]\right\} - 1, \tag{3.3.1}$$

[6]See Report Autonomous Trade Preferences: Impact on Ukrainian Exports by the Institute for Economic Research and Policy Consulting for a detailed description of the changes

[7]Most traditional estimates of gains from trade are applied in a static framework. Since our model is dynamic, we use a consumption-equivalent units approach. Note that since we study the effects of trade liberalization comparing two steady states and abstract from a transition path, our estimates of welfare gains are conservative, as shown by Alessandria et al. (2021).

where Δ is a proportional change in lifetime consumption that makes a randomly-chosen individual independent between the steady states, $g_0(s)$ is a value function in an initial steady state, and $g_1(s)$ is a value function in a steady state after trade liberalization. We find that total welfare in the economy after trade liberalization increases since entrepreneurs would require 2.28% higher lifetime utility to give up trade liberalization.

Table 3.3: Effects of trade liberalization

Name	Before	After	Change
Iceberg trade cost for UA	1.81	1.62	-10%
Change in welfare			+2.28 %
Real wage	0.70	0.83	+18.87%
GDP	1.14	1.33	+16.36 %
TFP	1.21	1.30	+7.31%
Exports	0.75	0.98	+30.08%
Consumption	2.78	2.92	+5.13%
Total absorption	2.98	3.16	+5.91%
Investment	0.20	0.24	+16.81%
Total profits	0.48	0.48	+0.71%
Credit/GDP	0.73	0.82	+13.08%
Active firms	0.33	0.37	+0.04
Share of exporters	0.25	0.27	+0.02
Share of constrained	0.77	0.76	-0.02
Average export intensity	0.21	0.23	+0.02
K/L aggregate, simple	0.92	1.43	+56.12%
K/L exporters, simple	2.21	2.64	+19.32%
K/L non-exporters, simple	0.49	0.99	+102.03%
K/L aggregate, weighted	2.13	2.50	+17.55%
K/L exporters, weighted	2.14	2.51	+17.02%
K/L non-exporters, weighted	0.50	1.02	+102.44%
Effective cost of capital	0.58	0.36	-39.23%
Standard deviation of cost of capital	0.25	0.13	-47.11%
Average domestic markup	1.25	1.23	-2.33%
Standard deviation of markups	0.36	0.32	-12.08%
Markup-cost of capital correlation	-0.77	-0.62	-21.49%

Note: The table shows the results of an exercise modeling a unilateral trade liberalization. Column "Before" contains moments, equilibrium prices, and policy functions for the initial, pre-liberalization, steady state. Column "After" contains moments, equilibrium prices, and policy functions for the post-liberalization steady state. Column "Change" shows differences in indicators between post- and pre-trade liberalization steady states.

Allocative efficiency. A unilateral trade liberalization also increases both total factor productivity (TFP), by 7.3%, and gross domestic product (GDP), by 16.7% [8]. This increase comes together with an improvement in allocative efficiency since the dispersion

[8] GDP is measured as a sum value added of domestic firms supplied to both markets minus imported value added. TFP is calculated as $TFP = VA/(K^{\alpha}L^{1-\alpha})$, where VA is the total value added of domestic intermediate goods producers.

of shadow price of capital and markups decreases upon trade liberalization. To check this, we calculate a standard deviation as

$$sd(x(s)) = \sqrt{\int_{s \in S} \mathbb{1}\{q(s) > 0\}(x(s) - \bar{x})^2 \phi(s) ds}, \tag{3.3.2}$$

where $x(s) = \{\mu(s), \lambda(s)\}$ is either markup or a shadow price of relaxing borrowing constraint, and $\bar{x} = \int_{s \in S} \mathbb{1}\{q(s) > 0\} x(s) \phi(s) ds$ is an average of a variable.
Results imply that the standard deviation of markups decreases from 0.36 to 0.32, while the standard deviation of the shadow price of capital drops from 0.25 to 0.13. Moreover, the correlation between markups and cost of capital in a post-liberalization steady state, calculated as (3.2.1), goes down from -0.77 to -0.62 overall and from 0.50 to 0.44 for exporters. While in the presence of variable markups and financial frictions, the allocation of resources in the economy is distorted before policy changes, trade liberalization improves the allocation of resources.

Exporters' sales and reallocation. In response to trade liberalization, exports expand by 30.1% due to both net entry of new exporters, as well as higher average export intensity.
In Chapter 2, we establish that the export sales reallocated after trade liberalization towards firms with higher capital intensity and lower markups. The model implies that an aggregate sales-weighted capital intensity of exporters increases by 17.0%, while a simple average of capital-labor ratios increase by 19.3%. This implies, that between-firm reallocation of sales together with a net entry of firms has a negative effect on the evolution of aggregate capital intensity. In addition, we also look at the correlation between the capital-labor ratio and sales, following the same approach as in Equation (3.2.1). We find that, on average, the positive correlation between capital-labor share and sales decreases after trade liberalization from 0.24 to 0.11. Moreover, calculating conditional correlation for exporters only, we find a negligible negative correlation that becomes stronger after liberalization - the correlation between the capital-labor ratio and export sales moves from -0.012 to -0.014, while the correlation with total sales goes from -0.009 to -0.012. Hence, contrary to the data, we find that exporter sales reallocate towards less capital-intensive exporters. We also find that, on average, sales reallocate toward firms with lower markups - positive correlation decreased from 0.14 to 0.12. For the exporters, we find that reallocation occurs towards firms with lower markups - correlation of markup at the domestic market and export sales decreased from 0.080 to 0.075, while markup and total sales - from 0.085 to 0.078. It is worth mentioning, that the model fails to capture a decrease in the aggregate capital intensity of non-exporters, implying that the patterns observed in the data are not explained only by trade liberalization.

Financial constraints and markups. Increase in consumption, described above, leads to an increase in demand in the domestic market, in addition to higher demand abroad. As a result, more unconstrained firms are able to start producing due to higher demand, and new exporters start selling abroad because of trade liberalization. This implies the lower effective cost of capital in the economy, as well as an increase in the credit-to-GDP ratio, by 13.08%. Higher demand fuels entry, while entry intensifies competition in the domestic market. This increases the elasticity of demand for entrepreneurs and reduces markups for all intermediate good producers, which we also observe while comparing average markups in two steady states.

3.3.2 Counterfactual Analysis

How do financial frictions and variable markups affect gains from trade? In order to answer this question, we compare results in a baseline economy to alternative specifications where we close one of the channels.

Contribution of Financial Frictions. We start with studying the contribution of financial frictions and modify the baseline model to assume that all the firms in the domestic economy are financially-unconstrained, i.e. $\theta \sim \infty$[9]. Table 3.4 contains a comparison of selected variables.

To start with, we can see suggestive evidence for complementarity between trade liberalization and the financial market. In a model without financial frictions, welfare increases by 5.38%, as compared to a baseline result of 2.28%. We can also observe a stronger increase in real wages and consumption, TFP, and GDP. Hence, in a model without financial frictions, welfare and productivity gains from trade are greater.

Due to the absence of financial frictions and variation in the effective cost of capital, the capital-labor ratios of firms are greater on average and equal among groups of firms when all firms are unconstrained. After trade liberalization, an increase in aggregate capital intensity is driven by a within-firm increase in the average capital-labor ratio and both increase more since firms do not face collateral constraint. However, we can see that the allocation of resources does not change significantly and even worsens. While the standard deviation of markups in an initial steady state was equal to 0.256, after trade liberalization it gradually increases up to 0.260. Moreover, since the most productive firms are not restricted by a financial constraint, they can grow bigger now, facing lower elasticity of demand, which results in a higher average markup of domestic firms. Indeed, the correlation between the sales and markups is positive and increasing for all the firms, in total, and for exporters, in particular, indicating the reallocation of sales towards firms with higher markups. Since firms are unconstrained, the initial credit-to-GDP

[9]Note, that we do not re-calibrate an alternative model.

Table 3.4: Baseline Model vs. Model without Financial Constraints

Variable	Baseline			No Fin Frictions			$\Delta_b - \Delta_f$
	Before	After	Δ_b	Before	After	Δ_f	
Change in welfare			+2.28%			+5.38%	-3.10p.p.
Real wage	0.70	0.83	+18.87%	1.89	2.30	+21.32%	-2.45 p.p.
Consumption	2.78	2.92	+5.13%	3.53	4.03	+14.26%	-9.13 p.p.
Investment	0.20	0.24	+16.81%	0.58	0.70	+21.09%	-4.28 p.p.
Total absorption	2.98	3.16	+5.92%	4.11	4.73	+15.23%	-9.31 p.p.
Total profits	0.48	0.48	+0.71%	0.84	0.97	+15.31%	-14.60 p.p.
Exports	0.75	0.98	+30.08%	2.96	3.72	+25.29%	+4.79p.p.
GDP	1.14	1.33	+16.36%	2.99	3.60	+20.36%	-4.00 p.p.
TFP	1.21	1.30	+7.31%	2.06	2.32	+12.56%	-5.25 p.p.
Credit/GDP	0.73	0.82	+13.08%	1.87	1.94	+3.55%	+9.53 p.p.
K/L aggregate, simple	0.92	1.43	+56.12%	5.85	7.10	+21.32%	+34.8 p.p.
K/L exporters, simple	2.21	2.64	+19.32%	5.85	7.10	+21.32%	-2.00 p.p.
K/L non-exporters, simple	0.49	0.99	+102.03%	5.85	7.10	+21.32%	+80.71 p.p.
K/L aggregate, weighted	2.13	2.50	+17.55%	5.85	7.10	+21.32%	-3.77 p.p.
K/L exporters, weighted	2.14	2.51	+17.02%	5.85	7.10	+21.32%	-4.30 p.p.
K/L non-exporters, weighted	0.58	1.02	+102.44%	5.85	7.10	+21.32%	+81.08 p.p.
Effective cost of capital	0.58	0.36	-39.23%	0.16	0.16	+0%	-39.23 p.p.
Sd of cost of capital	0.25	0.13	-47.11%	0	0	+0.00%	-47.11 p.p.
Average domestic markup	1.25	1.23	-2.33%	1.15	1.39	+21.48%	-23.81 p.p.
Sd of markups	0.36	0.32	-12.08%	0.256	0.260	+1.56%	-13.64 p.p.

Note: The table shows the results of an exercise modeling a unilateral trade liberalization in a baseline model and a model without financial frictions. Column "Before" contains moments, equilibrium prices, and policy functions for the initial, pre-liberalization, steady state. Column "After" contains moments, equilibrium prices, and policy functions for the post-liberalization steady state. Columns Δ_b and Δ_f show differences in indicators between post- and pre-trade liberalization steady states, while column $\Delta_b - \Delta_f$ show a difference in effects between models.

ratio is higher than in the baseline economy and thus increases relatively less after trade liberalization.

Contribution of Variable Markups. Now, we compare the baseline economy with a model that features only financial frictions and abstracts from variable markups - all the firms in the domestic market do not set constant markups due to the CES aggregator used by a final good producers[10]. Table 3.5 presents a comparison of unilateral trade liberalization effects in two models.

Comparing the models, welfare gains of trade liberalization are lower in an environment with constant markups. Trade liberalization is still welfare-improving, but its growth in consumption-equivalent units is lower, as compared to the baseline economy - 1.19% vs. 2.28%. Consumption increases less since, on the one hand, real wages are less responsive to trade liberalization, and total output growth increases consumption by less.

Both average and aggregate capital intensity for exporters increase, by +24.72% and +21.33% respectively, but faster growth of the former implies a negative contribution to reallocation of sales among firms and net entry. Indeed, both export sales of reallocate towards less capital-intensive firms - the correlation between sales and capital intensity

[10]Note, that we do not re-calibrate an alternative model.

Table 3.5: Baseline Model vs. Model without Variable Markups

Variable	Baseline			No Kimball			$\Delta_b - \Delta_f$
	Before	After	Δ_b	Before	After	Δ_f	
Change in welfare			+2.28%			+1.19%	+1.09 p.p.
Nominal wage	0.70	0.83	+18.87%	0.92	1.01	+9.90%	+8.97 p.p.
Domestic price index	1	1	+0.00%	0.08	0.08	+0.71%	-0.71 p.p.
Consumption	2.78	2.92	+5.13%	3.27	3.41	+4.44%	+0.69 p.p.
Investment	0.20	0.24	+16.81%	0.24	0.29	+21.39%	-4.58 p.p.
Total output	2.98	3.16	+5.92%	3.51	3.70	+5.60%	+0.32 p.p.
Total profits	0.48	0.48	+0.71%	0.34	0.38	+9.90%	-9.19 p.p.
Exports	0.75	0.98	+30.08%	0.17	0.19	+10.41%	+19.67 p.p.
GDP	1.14	1.33	+16.36%	0.19	0.20	+5.94%	+10.42 p.p.
TFP	1.21	1.30	+7.31%	0.15	0.15	-0.51%	+7.82 p.p.
Credit/GDP	0.73	0.82	+13.08%	7.61	9.69	+27.36%	-14.28 p.p.
K/L aggregate, simple	0.92	1.43	+56.12%	2.88	3.18	+10.49%	-45.63 p.p.
K/L exporters, simple	2.21	2.64	+19.32%	3.66	4.56	+24.72%	-5.40 p.p.
K/L non-exporters, simple	0.49	0.99	+102.03%	2.85	3.13	+9.90%	+92.13 p.p.
K/L aggregate, weighted	2.13	2.50	+17.55%	2.44	2.96	+21.33%	-3.77 p.p.
K/L exporters, weighted	2.14	2.51	+17.02%	2.45	2.96	+21.39%	-4.37 p.p.
K/L non-exporters, weighted	0.58	1.02	+102.44%	2.80	3.07	+9.50%	+92.94 p.p.
Effective cost of capital	0.58	0.36	+39.23%	0.17	0.17	+0.33%	+38.90 p.p.
Sd of cost of capital	0.25	0.13	-47.11%	0.82	0.92	+12.48%	-59.59 p.p.
Average domestic markup	1.25	1.23	-2.33%	1.25	1.25	+0.00%	-2.33 p.p.
Sd of markups	0.36	0.32	-12.08%	0	0	+0.00%	-12.08 p.p.

Note: The table shows the results of an exercise modeling a unilateral trade liberalization in a baseline model and a model with constant markups. Column "Before" contains moments, equilibrium prices, and policy functions for the initial, pre-liberalization, steady state. Column "After" contains moments, equilibrium prices, and policy functions for the post-liberalization steady state. Columns Δ_b and Δ_f show differences in indicators between post- and pre-trade liberalization steady states, while column $\Delta_b - \Delta_f$ show a difference in effects between models.

of exporters goes from -0.074 to -0.084.

Both TFP and GDP grow slower in an economy. This could be explained by the fact that capital misallocation in the economy increases after trade liberalization. While the average cost of capital increased by less than half a percent, a standard deviation of the shadow cost of capital increases from 0.82 to 0.92. Given that exporters do not experience incomplete pass-through in the domestic market anymore, they expand their sales relatively more and become more financially-constrained.

Taking Stock Together. Counterfactual analysis implies that removing financial frictions in the economy increases gains from trade liberalization while removing variable markups assumption reduces gains from trade liberalization. However, in both cases, aggregate capital intensity increases faster for exporters compared to the baseline model. Removing financial frictions, more productive exporters that become unconstrained can invest in more capital facing higher demand. Removing variation in markups, the productive unconstrained firms are not smaller relative to the CES case anymore and expand their capital and sales more. However, what the model does not capture is the reallocation of both export and total sales of exporters towards more capital-intensive firms, as indicated by a lower correlation between sales and capital-labor ratio, and suggested by slower growth of aggregate capital intensity as compared to the average one (since part of this difference is explained by between-firm reallocation of sales).

3.4 Conclusions

In Chapters 2 and 3, we study how financial frictions and variable markups shape the economy's response to unilateral trade liberalization. In Chapter 2, we provide a set of stylized facts on the reallocation of sales after unilateral trade liberalization by the European Union for imports from Ukraine. Analyzing a panel of Ukrainian manufacturing firms, we find that the aggregate capital intensity of exporters to the EU increased after 2013, the last year before trade liberalization, while the aggregate capital intensity of firms not exporting to the EU did not increase and even decreased. Within-sector reallocation of sales towards more capital-intensive firms was an important contributing factor to this increase. Further analysis also showed that sales reallocated towards firms with larger labor shares, which might be indicative of the reallocation towards firms with lower markups.

Motivated by this evidence, in Chapter 3 we develop a small open-economy model calibrated to Ukrainian manufacturing data and study how financial frictions and variable markups shape gains from trade liberalization and whether they could explain the patterns observed in the data. We find that upon trade liberalization, welfare and productivity increase in the economy. Trade liberalization improves the allocation of resources in the economy since the dispersion of both the effective cost of capital and markups decreases.

However, the model fails to capture the reallocation of export sales towards more capital intense firms and firms with lower markups. Such discrepancy between the model that the data could be explained by the fact that unilateral trade liberalization was not the only shock affecting exporters to the EU. In Chapter 2, we suggest that patterns of reallocation could be explained by considering trade liberalization together with an increase in the interest rate. Moreover, during the period of trade liberalization, Ukrainian hryvnia experienced episodes of depreciation that made Ukrainian exports cheaper and acted as another stimulus for now cheaper Ukrainian goods to enter the EU market. If we aim to better explain the patterns we see in Chapter 2, studying trade liberalization in connection to an increase in the cost of borrowing and depreciation of the domestic currency is a natural direction of further research.

Additionally, in a counterfactual analysis, we find evidence of complementarity between international trade and financial markets - when all the firms become financially-unconstrained, welfare and productivity gains from trade increase. However, when markups on the domestic economy become constant in the presence of financial frictions, welfare gains of trade liberalization become lower, partly due to an increase in misallocation.

3.5 Appendix

3.5.1 Numerical Algorithm for solving the Benchmark Model

We describe an algorithm to solve a benchmark model described in Section 3.1. We start with the static problem and then proceed to the dynamic problem. Unlike in the CES version, many terms do not have closed-form expressions; therefore, we can only determine the equilibrium allocations, using numerical algorithms. We start by discretizing the state space for domestic entrepreneurs, using the productivity grid, G_z, and asset grid G_a (since asset holdings are irrelevant for the decisions of foreign entrepreneurs, we only determine their static choices, given the productivity grid G_z). The Cartesian product of the two gives the domain for solving the optimal policy function of domestic entrepreneurs. Approximation of the autoregressive productivity process through the procedure by Tauchen (1986) gives the associated transition matrix. We use the same grid for solving the problem of exporter and non-exporter on the domestic market. Therefore, in order to avoid confusion, in this part we add a subscript e or d to distinguish between the solutions to the problem of exporting firm or firm, selling only domestically for each point of $z_{dt}(\omega)$ and $a_{dt}(\omega)$. Solutions to the problem of the importer are provided with the subscript m. We proceed using the following steps:

1. For each point of a domestic productivity and asset grid, we determine the solutions to 2 problems: the problem of the domestic exporter and the problem of the domestic non-exporter. Given the knowledge of W_{dt}, Y_{dt}, P_{dt}, R_{dt}, D_{dt}, for each value of productivity($z_{dt}(\omega)$) and assets($a_{dt}(\omega)$), the solution to the problem of non-exporter gives numerical solutions to markup ($\mu_{ddt}(\omega)$), the relative and absolute values of output($y_{ddt}(\omega)$, $q_{ddt}(\omega)$), the marginal cost of a firm $MC_{ddt}(\omega)$, domestic profits ($\pi_{ddt}(\omega)$), domestic markup($\mu_{ddt}(\omega)$), optimal levels of labor and capital ($l_{dt}(\omega)$, $k_{dt}(\omega)$) and the effective cost of capital ($CC_{dt}(\omega)$), needed to serve domestic demand. For an unconstrained firm, this effective cost of capital equals to $R_{dt} + \delta$, but it is larger for the constrained firm. Solution to the exporter problem, given the knowledge of Y_{dt}, P_{dt}, R_{dt}, D_{dt}, W_{dt}, A_{ft}, P_{ft}, τ_{dft} for each value of productivity($z_{dt}(\omega)$) and assets($a_{dt}(\omega)$) provides the numerical solutions to the absolute value of foreign and domestic output ($y_{eft}(\omega), y_{edt}(\omega)$), domestic relative output($q_{edt}(\omega)$), foreign and domestic price ($p_{eft}(\omega), p_{edt}(\omega)$), foreign and domestic marginal costs($MC_{eft}(\omega)$, $MC_{edt}(\omega)$), domestic and export profits ($\pi_{edt}(\omega)$, $\pi_{eft}(\omega)$), optimal levels of labor and capital ($l_{et}(\omega)$, $k_{et}(\omega)$) and the effective cost of capital ($CC_{et}(\omega)$), consistent with profit maximization on two markets;

2. For each point of a foreign productivity grid, we only solve the importer problem on the domestic market as unconstrained foreign firms make production decisions across destinations independently. Given W_{ft}, Y_{dt}, D_{dt}, R_{ft}, τ_{fdt}, for each value of

$z_{ft}(\omega)$ in a grid, we numerically determine the solutions to absolute and relative imported output $(y_{mdt}(\omega),\ q_{mdt}(\omega))$, price $(p_{mdt}(\omega))$, marginal costs $(MC_{mdt}(\omega))$, profits on the domestic market $(\pi_{mdt}(\omega))$, domestic markup$(\mu_{mdt}(\omega))$ and the optimal value of labor and capital $(l_{mt}(\omega),\ k_{mt}(\omega))$.

3. Given the $\pi_{et}(\omega) = \pi_{edt}(\omega) + \pi_{eft}(\omega) - F$, $\pi_{dt}(\omega) = \pi_{ddt}(\omega)$, we solve for the policy function of domestic firm. The resulting profits are $\pi(z_{dt}(\omega), a_{dt}(\omega)) = \max(\pi_{et}(\omega), \pi_{dt}(\omega))$. Given $\pi_{mdt}(\omega)$ and F, we solve for the policy function of an importer.

The solution to the static problem for each point in the domestic productivity and asset grid gives the export policy function, optimal level of output, market-specific prices, markups, profits, marginal costs, levels of capital and labor, and the effective price of capital for each domestic producer, exporter, and importer. After that, we proceed with solving the dynamic problem of the entrepreneur:

1. We make the initial guess of the value function, $\hat{g}(a_d, z_d)$

2. For any point on the domestic productivity and asset grid, given profits from the static problem, computed above $(\pi(z_d, a_d))$, we numerically solve for the policy function of domestic entrepreneurs $a'(a_d, z_d)$ as a solution to:

$$a'(a_d, z_d) = \arg\max_{a' \in G_a} \mathbf{O}(a'; a_d, z_d)$$

   where

$$\mathbf{O}(a'; a_d, z_d) = \frac{1}{1+\nu}\left[W_d + \pi(z_d, a_d) + a_d(1+R_d) - a'\right]^{1+\nu} + \beta \mathbb{E}_{z'}[\hat{g}(a_d, z_d)]$$

3. Given the optimal net-worth policy $(a'(a_d, z_d))$, for each point of the domestic productivity and asset grid, the optimal consumption policy can be determined as:

$$c(a_d, z_d) = W_d + \pi(z_d, a_d) + a_d(1+R_d) - a'(a_d, z_d)$$

4. Under the policies we derived above, $c(a_d, z_d)$ and $a'(a_d, z_d)$, we derive the value function:

$$g(a_d, z_d) = \frac{1}{1+\nu} c(a_d, z_d)^{1+\nu} + \beta \mathbb{E}_{z'}[g(a_d, z_d)]$$

5. If the difference between $g(a_d, z_d)$ and $\hat{g}(a_d, z_d)$ is small enough, we treat $c(a_d, z_d)$ and $a'(a_d, z_d)$ as solutions to the dynamic problem of the domestic entrepreneur. In another case, we set $\hat{g}(a_d, z_d) = g(a_d, z_d)$ and iterate through 1-4 again.

3.5.2 Static problem of a domestic non-exporting firm

We start describing the solution procedure by writing down the static problem of a non-exporting firm:

$$\pi(a_{dt}(\omega), z_{dt}(\omega)) = \max_{y_{ddt}(\omega), p_{ddt}(\omega), k_{dt}(\omega), l_{dt}(\omega)} p_{ddt}(\omega) y_{ddt}(\omega) - W_{dt} l_{dt}(\omega) - (R_{dt} + \delta) k_{dt}(\omega)$$

$$\text{s.t.}$$

$$\begin{aligned} y_{ddt}(\omega) &= \left[1 - \varepsilon \ln\left(\frac{\sigma}{\sigma - 1} p_{ddt}(\omega) \frac{D_{dt}}{P_{dt}}\right)\right]^{\frac{\sigma}{\varepsilon}} Y_{dt} \\ y_{ddt}(\omega) &= z_{dt}(\omega) k_{dt}^{\alpha}(\omega) l_{dt}^{1-\alpha}(\omega) \\ k_{dt}(\omega) &\leq \frac{1 + R_{dt}}{1 + R_{dt} - \theta} a_{dt}(\omega) \end{aligned}$$

The system of first-order conditions for the domestic producer is given by:

$$\begin{aligned} &\frac{\sigma - 1}{\sigma} \exp\left(\frac{1 - q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right) \frac{P_{dt}}{D_{dt}} = \frac{\sigma}{\sigma - q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)} MC_{ddt}(\omega) \\ &W_{dt} = (1 - \alpha) MC_{ddt}(\omega) z_{dt}(\omega) k_{dt}^{\alpha}(\omega) l_{dt}^{-\alpha}(\omega) \\ &R_{dt} + \delta + \lambda_{dt}(\omega) = \alpha MC_{ddt}(\omega) z_{dt}(\omega) k_{dt}^{\alpha - 1}(\omega) l_{dt}^{1-\alpha}(\omega) \end{aligned}$$

Similarly to Kohn et al. (2020) and Edmond et al. (2023), we define three associated complementary slackness conditions:

$$\begin{aligned} &MC_{ddt}(\omega)(z_{dt}(\omega) k_{dt}^{\alpha}(\omega) l_{dt}^{1-\alpha}(\omega) - y_{ddt}(\omega)) = 0 \\ &q_{ddt}(\omega) \left(\frac{\sigma - 1}{\sigma} \exp\left(\frac{1 - q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right) \frac{P_{dt}}{D_{dt}} - \frac{\sigma}{\sigma - q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)} MC_{ddt}(\omega)\right) = 0 \\ &\lambda_{dt}(\omega) \left(\frac{1 + R_{dt}}{1 + R_{dt} - \theta} a_{dt}(\omega) - k_{dt}(\omega)\right) = 0 \end{aligned}$$

Since it is ex-ante ambiguous whether the entrepreneur is constrained, given the level of assets and productivity, the first step in solving the problem is to determine the effective cost of capital, at which the firm would serve profit-maximizing output. This value is equal to $\max(R_{dt} + \delta, \overline{CC}(\omega))$, where $\overline{CC}_{dt}(\omega)$ is implicitly defined as a solution to the following equation

$$\frac{\sigma - q(\overline{CC}_{dt}(\omega))^{\frac{\varepsilon}{\sigma}}}{\sigma} \frac{\sigma - 1}{\sigma} \exp\left(\frac{1 - q(\overline{CC}_{dt}(\omega))^{\frac{\varepsilon}{\sigma}}}{\varepsilon}\right) \frac{P_{dt}}{D_{dt}} = \left(\frac{\overline{CC}_{dt}(\omega)}{\alpha}\right)^{\alpha} \left(\frac{W_{dt}}{1 - \alpha}\right)^{1-\alpha} \frac{1}{z_{dt}(\omega)}$$

where

$$q(\overline{CC}_{dt}(\omega)) = \left[\frac{\overline{CC}_{dt}(\omega)}{\phi_{dt}(\omega)}\right]^{1-\alpha},$$

$$\phi_{dt}(\omega) = W_{dt}\frac{\alpha}{1-\alpha}\left[\frac{Y_{dt}}{z_{dt}(\omega)k(a_{dt}(\omega))}\right]^{\frac{1}{1-\alpha}}$$

$$k(a_{dt}(\omega)) = a_{dt}(\omega)\frac{1+R_{dt}}{1+R_{dt}-\theta}$$

with $\overline{CC}_{dt}(\omega) \in [R_{dt}+\delta, +\infty)$ In essence, $\overline{CC}_{dt}(\omega)$ provides the level of the effective cost of capital used by the entrepreneur, facing binding borrowing constraint. The fraction of the level of assets provides an upper bound for the capital such an entrepreneur can acquire; knowing this, such an entrepreneur solves the profit maximization problem with marginal costs, increasing in the output of the firm. An increase in output decreases marginal revenue and, at the same time, increases the effective cost of capital. The unique solution to the equation defines the level of marginal costs and optimal profit-maximizing output. For the sake of computational tractability, we use a bijective relationship between relative output and effective cost of capital to write the problem not as determining the optimal level of output, solving the profit-maximization problem of the firm, but by determining the effective cost of capital, a constrained firm pays to produce profit-maximizing output when its borrowing constraint binds. If the firm is constrained, the solution to this equation lies within $(R_{dt}+\delta; +\infty)$. If the firm is unconstrained, the solution to the equation is weakly less than $R_{dt}+\delta$; in this case, we set the effective cost of capital equal to $R_{dt}+\delta$.

When $\overline{CC}_{dt}(\omega)$ is determined, we are able to compute $MC_{ddt}(\omega) = \frac{1}{z_{dt}(\omega)}\frac{W_{dt}^{1-\alpha}\overline{CC}_{dt}^{\alpha}(\omega)}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}$. Then, similarly to Edmond et al. (2023), we solve for the optimal level of output, implicitly defined as a non-zero root of the following equation if $q_{ddt}(\omega) > 0$ or 0 if non-zero solution does not exist:

$$q_{ddt}(\omega)\left(\frac{\sigma-1}{\sigma}\exp\left(\frac{1-q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right)\frac{P_{dt}}{D_{dt}} - \frac{\sigma}{\sigma-q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)}\frac{1}{z_{dt}(\omega)}\frac{W_{dt}^{1-\alpha}\overline{CC}_{dt}^{\alpha}(\omega)}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}\right) = 0$$

Monotonicity of the term in brackets implies that if a positive solution to the term in the brackets exists, it is unique, given $z_{dt}(\omega)$ and $\overline{CC}_{dt}(\omega)$. Knowing $q_{ddt}(\omega)$ is sufficient to calculate $\mu_{ddt}(\omega) = \frac{\sigma}{\sigma-q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)}$ and $p_{ddt}(\omega) = \frac{\sigma}{\sigma-q_{ddt}^{\frac{\varepsilon}{\sigma}}(\omega)}MC_{ddt}(\omega)$. Using Y_{dt}, we are able to recover $y_{ddt}(\omega)$, this allows us to calculate $k_{dt}(\omega) = \frac{\alpha y_{ddt}(\omega)MC_{ddt}(\omega)}{R_{dt}+\delta}$ and $l_{dt}(\omega) = \frac{(1-\alpha)y_{ddt}(\omega)MC_{ddt}(\omega)}{W_{dt}}$ for an unconstrained firm and $l_{dt}(\omega)$ for a constrained firm (recall, that binding borrowing constraint for a constrained firm implies, that constrained firm exhausts her borrowing limits, which uniquely determines its level of capital). Profits are calculated as $\pi_{ddt}(\omega) = y_{ddt}(\omega)(p_{ddt}(\omega) - MC_{ddt}(\omega))$

3.5.3 Static problem of a domestic exporter

We start describing the solution procedure by writing down the static problem of exporting firm:

$$\begin{aligned}
\pi(a_{dt}(\omega), z_{dt}(\omega)) = & \max_{\substack{y_{edt}(\omega), p_{edt}(\omega), y_{eft}(\omega),\\ p_{eft}(\omega), k_{dt}(\omega), l_{dt}(\omega)}} p_{edt}(\omega) y_{edt}(\omega) + p_{eft}(\omega) y_{eft}(\omega) \\
& - W_{dt} l_{et}(\omega) - (R_{dt} + \delta) k_{et}(\omega) - W_{dt} F \\
\text{s.t.} & \\
& y_{edt}(\omega) = \left[1 - \varepsilon \ln\left(\frac{\sigma}{\sigma - 1} p_{edt}(\omega) \frac{D_{dt}}{P_{dt}}\right)\right]^{\frac{\sigma}{\varepsilon}} Y_{dt} \\
& y_{eft}(\omega) = p_{eft}^{-\sigma}(\omega) \frac{A_{ft}}{P_{ft}^{-\sigma}} \\
& \tau_{dft} y_{eft}(\omega) + y_{edt}(\omega) = z_{dt}(\omega) k_{et}^{\alpha}(\omega) l_{et}^{1-\alpha}(\omega) \\
& k_{et}(\omega) \leq \frac{1 + R_{dt}}{1 + R_{dt} - \theta} a_{dt}(\omega)
\end{aligned}$$

The system of first-order conditions is given by:

$$\begin{aligned}
& \frac{\sigma - 1}{\sigma} \exp\left(\frac{1 - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right) \frac{P_{dt}}{D_{dt}} = \frac{\sigma}{\sigma - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)} MC_{edt}(\omega) \\
& P_{ft} A_{ft}^{\frac{1}{\sigma}} y_{eft}^{-\frac{1}{\sigma}}(\omega) = \frac{\sigma}{\sigma - 1} MC_{eft}(\omega) \\
& W_{dt} = (1 - \alpha) MC_{edt}(\omega) z_{dt}(\omega) k_{et}^{\alpha}(\omega) l_{et}^{-\alpha}(\omega) \\
& R_{dt} + \delta + \lambda_{et}(\omega) = \alpha MC_{edt}(\omega) z_{dt}(\omega) k_{et}^{\alpha - 1}(\omega) l_{et}^{1-\alpha}(\omega)
\end{aligned}$$

The associated complementary slackness conditions share similarities with the ones for the domestic producer:

$$\begin{aligned}
& MC_{edt}(\omega)(z_{dt}(\omega) k_{et}^{\alpha}(\omega) l_{et}^{1-\alpha}(\omega) - \tau_{dft} y_{eft}(\omega) - y_{edt}(\omega)) = 0 \\
& q_{edt}(\omega) \left(\frac{\sigma - 1}{\sigma} \exp\left(\frac{1 - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right) \frac{P_{dt}}{D_{dt}} - \frac{\sigma}{\sigma - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)} MC_{edt}(\omega)\right) = 0 \\
& \lambda_{et}(\omega) \left(\frac{1 + R_{dt}}{1 + R_{dt} - \theta} a_{dt}(\omega) - k_{et}(\omega)\right) = 0
\end{aligned}$$

Similarly to the previous section of the Appendix, we start solving the problem by determining the effective cost of capital, consistent with profit maximization by a constrained firm. We denote its value by $\max(R_{dt} + \delta, \overline{CC}_{et}(\omega))$. If the effective cost of capital is $\overline{CC}_{et}(\omega)$, the total output it produces after exhausting its borrowing constraint is

$$\tau_{dft} y_{eft}(\omega) + y_{edt}(\omega) = z_{dt}(\omega) k(a_{dt}(\omega)) \left[\frac{k(a_{dt}(\omega))}{l_{et}(\omega)}\right]^{\alpha - 1} = z_{dt}(\omega) k(a_{dt}(\omega)) \left[\frac{\overline{CC}_{et}(\omega)(1 - \alpha)}{W_{dt} \alpha}\right]^{1-\alpha}$$

CES demand on the foreign market enables exporter to calculate the exact value of profit-maximizing exported output:

$$y_{eft}(\omega) = \frac{A_{ft}}{P_{ft}^{-\sigma}} \left[\frac{\sigma}{\sigma-1} \frac{W_{dt}^{1-\alpha}\overline{CC}_{et}^{\alpha}(\omega)}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} \frac{\tau_{dft}}{z_{dt}(\omega)} \right]^{-\sigma}$$

This enables us to express the residual relative output of exporter on the domestic market as

$$q(\overline{CC}_{et}(\omega)) = \frac{z_{dt}(\omega)k(a_{dt}(\omega))}{Y_{dt}} \left[\frac{\overline{CC}_{et}(\omega)(1-\alpha)}{W_{dt}\alpha} \right]^{1-\alpha} - \frac{A_{ft}\tau_{dft}^{1-\sigma}}{P_{ft}^{-\sigma}Y_{dt}} \left[\frac{\sigma}{\sigma-1} \frac{W_{dt}^{1-\alpha}\overline{CC}_{et}^{\alpha}(\omega)}{(1-\alpha)^{1-\alpha}\alpha^{\alpha} z_{dt}(\omega)} \right]^{-\sigma}$$

With this in mind, we are able to implicitly define $\overline{CC}_{et}(\omega)$ as a solution to the following equation:

$$\frac{\sigma - q(\overline{CC}_{et}(\omega))^{\frac{\varepsilon}{\sigma}}}{\sigma} \frac{\sigma-1}{\sigma} \exp\left(\frac{1 - q(\overline{CC}_{et}(\omega))^{\frac{\varepsilon}{\sigma}}}{\varepsilon} \right) \frac{P_{dt}}{D_{dt}} = \left(\frac{\overline{CC}_{et}(\omega)}{\alpha} \right)^{\alpha} \left(\frac{W_{dt}}{1-\alpha} \right)^{1-\alpha} \frac{1}{z_{dt}(\omega)}$$

where again $\overline{CC}_{et}(\omega) \in [R_{dt} + \delta; \infty)$. The logic behind determining the effective cost of capital for a constrained producer is similar to a domestic producer - a constrained firm has its $\overline{CC}_{et}(\omega) \in (R_{dt} + \delta; \infty)$, while unconstrained firm pays $R_{dt} + \delta$ for capital. Knowing the effective cost of capital, we are able to compute the marginal cost of the firm on the domestic market

$$MC_{edt}(\omega) = \frac{1}{z_{dt}(\omega)} \frac{W_{dt}^{1-\alpha}\overline{CC}_{et}^{\alpha}(\omega)}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}$$

and on the exporting market

$$MC_{eft}(\omega) = \tau_{dft} MC_{edt}(\omega)$$

This information is sufficient to compute

$$y_{eft}(\omega) = \frac{A_{ft}}{P_{ft}^{-\sigma}} \left[\frac{\sigma}{\sigma-1} \frac{W_{dt}^{1-\alpha}\overline{CC}_{et}^{\alpha}(\omega)}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} \frac{\tau_{dft}}{z_{dt}(\omega)} \right]^{-\sigma},$$

however, $y_{edt}(\omega)$ has no closed-form expression. We compute it as a product of Y_{dt} and $q_{edt}(\omega)$, giving a non-zero solution to (provided that such solution exists):

$$q_{edt}(\omega) \left(\frac{\sigma-1}{\sigma} \exp\left(\frac{1 - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon} \right) \frac{P_{dt}}{D_{dt}} - \frac{\sigma}{\sigma - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)} \frac{1}{z_{dt}(\omega)} \frac{W_{dt}^{1-\alpha}\overline{CC}_{dt}^{\alpha}(\omega)}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} \right) = 0$$

Knowledge of $y_{edt}(\omega)$ enables us to calculate relative domestic output $q_{edt}(\omega)$, domestic markup $\mu_{edt}(\omega) = \frac{\sigma}{\sigma - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)}$ and price $p_{edt}(\omega) = \frac{\sigma}{\sigma - q_{edt}^{\frac{\varepsilon}{\sigma}}(\omega)} MC_{edt}(\omega)$. Foreign markup is constant and equal to $\frac{\sigma}{\sigma-1}$, foreign price is just $p_{eft}(\omega) = \frac{\sigma}{\sigma-1}\tau_{dft}MC_{edt}(\omega)$. Knowing both outputs, we are able to calculate total output as $\tau_{dft}y_{eft}(\omega) + y_{edt}(\omega)$. In its turn, total output enables calculating the total value of labor and capital stock for the unconstrained firm ($k_{et}(\omega) = \frac{\alpha(\tau_{dft}y_{eft}(\omega)+y_{edt}(\omega))MC_{edt}(\omega)}{R_{dt}+\delta}$, $l_{et}(\omega) = \frac{(1-\alpha)(\tau_{dft}y_{eft}(\omega)+y_{edt}(\omega))MC_{edt}(\omega)}{W_{dt}}$). For a constrained firm the level of labor is determined similarly, while capital stock is determined by the level of capital, binding borrowing constraint. The profit exporter obtains on the domestic market is equal to $\pi_{edt}(\omega) = y_{edt}(\omega)(p_{edt}(\omega) - MC_{edt}(\omega))$, the profits from exporting market are equal to $\pi_{eft}(\omega) = y_{eft}(\omega)(p_{eft}(\omega) - MC_{eft}(\omega)) - FW_{dt}$.

3.5.4 Static problem of the foreign importer, selling to domestic consumers

Assuming out financial frictions in the foreign market allows determining foreign importer's policy function by just comparing the total profits earned at the domestic market with $W_{ft}F$ [11]. The problem in the domestic market thus takes the following form:

$$\begin{aligned}
\pi(z_{ft}(\omega)) = & \max_{\substack{y_{mdt}(\omega),p_{mdt}(\omega),y_{mft}(\omega),\\ p_{mft}(\omega),k_{mt}(\omega),l_{mt}(\omega)}} p_{mdt}(\omega)y_{mdt}(\omega) + p_{mft}(\omega)y_{mft}(\omega) - \\
& - W_{ft}l_{mt}(\omega) - (R_{ft}+\delta)k_{mt}(\omega) - W_{ft}F \\
\text{s.t.} & \\
& y_{mdt}(\omega) = \left[1 - \varepsilon \ln\left(\frac{\sigma}{\sigma-1}p_{mdt}(\omega)\frac{D_{dt}}{P_{dt}}\right)\right]^{\frac{\sigma}{\varepsilon}} Y_{dt} \\
& y_{mft}(\omega) = p_{mft}^{-\sigma}(\omega)\frac{A_{ft}}{P_{ft}^{-\sigma}} \\
& \tau_{fdt}y_{mdt}(\omega) + y_{mft}(\omega) = z_{ft}(\omega)k_{mt}^{\alpha}(\omega)l_{mt}^{1-\alpha}(\omega)
\end{aligned}$$

The first-order conditions for profit maximization relevant to the decisions on the domestic market are:

$$\begin{aligned}
& \frac{\sigma-1}{\sigma}\exp\left(\frac{1-q_{mdt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right)\frac{P_{dt}}{D_{dt}} = \frac{\sigma}{\sigma - q_{mdt}^{\frac{\varepsilon}{\sigma}}(\omega)}MC_{mdt}(\omega) \\
& W_{ft} = (1-\alpha)MC_{mdt}(\omega)z_{ft}(\omega)k_{mt}^{\alpha}(\omega)l_{mt}^{-\alpha}(\omega) \\
& R_{ft}+\delta = \alpha MC_{mdt}(\omega)z_{ft}(\omega)k_{mt}^{\alpha-1}(\omega)l_{mt}^{1-\alpha}(\omega)
\end{aligned}$$

[11] In the following, we still call the domestic market from the perspective of domestic consumers, from the standpoint of importers who are at the focus of the subsequent analysis, this will be exporting market

The associated complementary slackness conditions are given by:

$$MC_{mft}(\omega)(z_{ft}(\omega)k_{mt}^{\alpha}(\omega)l_{mt}^{1-\alpha}(\omega) - \tau_{fdt}y_{mdt}(\omega) - y_{mft}(\omega)) = 0$$

$$q_{mdt}(\omega)\left(\frac{\sigma-1}{\sigma}\exp\left(\frac{1-q_{mdt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right)\frac{P_{dt}}{D_{dt}} - \frac{\sigma}{\sigma - q_{mdt}^{\frac{\varepsilon}{\sigma}}(\omega)}MC_{mdt}(\omega)\right) = 0$$

The latter two equations enable us to compute the marginal cost of importer in the domestic market

$$MC_{mdt}(\omega) = \frac{\tau_{fdt}}{z_{ft}(\omega)}\frac{W_{ft}^{1-\alpha}(R_{ft}+\delta)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}.$$

After that, for each point of the importer's productivity grid, we can calculate the output level consistent with profit maximization. Then, dividing by Y_{dt}, we get $q_{mdt}(\omega)$ and we determine it as a non-zero root of the following equation (if such root exists):

$$q_{mdt}(\omega)\left(\frac{\sigma-1}{\sigma}\exp\left(\frac{1-q_{mdt}^{\frac{\varepsilon}{\sigma}}(\omega)}{\varepsilon}\right)\frac{P_{dt}}{D_{dt}} - \frac{\sigma}{\sigma - q_{mdt}^{\frac{\varepsilon}{\sigma}}(\omega)}\frac{\tau_{fdt}}{z_{ft}(\omega)}\frac{W_{ft}^{1-\alpha}(R_{ft}+\delta)^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}\right) = 0 \tag{3.5.1}$$

We use the resulting value of $q_{mdt}(\omega)$, we compute the markup on the domestic market $\left(\mu_{mdt}(\omega) = \frac{\sigma}{\sigma - q_{mdt}^{\frac{\varepsilon}{\sigma}}(\omega)}\right)$ price of importer set on the domestic market, $p_{mdt}(\omega) = \mu_{mdt}(\omega)MC_{mdt}(\omega)$. Using this information, we compute domestic profits of the importer $\pi_{mdt}(\omega) = q_{mdt}(\omega)Y_{dt}(p_{mdt}(\omega) - MC_{mdt}(\omega))$. If $\pi_{mdt}(\omega)$ is weakly greater than $W_{ft}F$, we set the exporting decision of the importer as 1; if not, we set it equal to 0.

3.5.5 Solving the aggregate problem

The solution to the problem in sections 3.1-3.2 hinges on our knowledge of D_d, Y_d, and W_d and other variables, determined in general equilibrium ($P_d, |\Omega_d|, \xi$ etc.). We simplify the problem by dividing general equilibrium variables into 3 groups:

1. Variables we use to solve for the general equilibrium: W_d, Y_d, D_d;

2. Variables we normalize and keep fixed by Small Open Economy assumption: $W_f = 1, P_d = 1, P_f = \xi P_d$;

3. Variables we get from the data: $A_f, R_d, R_f, |\Omega_{dd}|, |\Omega_{dm}|, \xi$.

We solve for the general equilibrium by determining W_d, Y_d, D_d, for which solutions to the static and dynamic problems of entrepreneurs result in allocations, satisfying Final

Good market clearing, Labor Market clearing, and equalization of Kimball Aggregator:

$$\begin{aligned}
&\int_{s\in G_a\times G_z}[n(s)+e(s)F]\phi(s)ds = 1\\
&\int_{s\in G_a\times G_z}[c(s)+x(s)]\phi(s)ds = Y_h\\
&\frac{1}{|\Omega_{dd}|}\int_{\Omega_{dd}}\Upsilon\left(\frac{|\Omega_{dd}|y_d(\omega)}{Y_d}\right)d\omega + \frac{1}{|\Omega_{dm}|}\int_{\Omega_{dm}}\Upsilon\left(\frac{|\Omega_{dm}|y_{md}(\omega)}{Y_d}\right)d\omega = 1
\end{aligned} \tag{3.5.2}$$

Note, that in the last equation, we used $y_d = (1-e)y_{dd} + ey_{ed}$. We achieve equality by minimizing the distance between the left- and right-hand sides of these equations. More specifically, we start with some guesses of these variables; given these guesses, we solve static and dynamic problems of entrepreneurs, solve for a stationary distribution as in Kohn et al. (2020), and check whether the resulting allocations satisfy the system of three equations above. If the difference between the left and right sides is under some convergence criteria, we stop and treat W_d, Y_d, D_d as consistent with the steady state of the model. If the above does not happen, we update guesses and proceed with the next iteration.

3.5.6 Numerical Algorithm for solving the Extension in a constant markup environment

The numerical algorithm for solving the CES version of the model is very similar to the one we use to solve the benchmark model. However, a substantial benefit of this case is that we can derive closed-form expressions for many of these terms. Here we list some important differences between solving the benchmark problem and its CES variant:

1. D_{dt} is not solved for in equilibrium; in the CES version, it is held fixed at $\frac{\sigma-1}{\sigma}$;
2. $\mu_{ddt} = \mu_{edt} = \mu_{eft} = \mu_{mdt} = \frac{\sigma}{\sigma-1}$

3.5.7 Static problem of a domestic firm in a constant markup environment

We start describing the solution procedure by writing down the static problem of a non-exporting firm:

$$\pi(a_{dt}(\omega), z_{dt}(\omega)) = \max_{y_{ddt}(\omega), p_{ddt}(\omega), k_{dt}(\omega), l_{dt}(\omega)} p_{ddt}(\omega)y_{ddt}(\omega) - W_{dt}l_{dt}(\omega) - (R_{dt}+\delta)k_{dt}(\omega)$$

$$\begin{aligned} \text{s.t.} \\ & y_{ddt}(\omega) = p_{ddt}(\omega)^{-\sigma}\frac{Y_{dt}}{P_{dt}^{-\sigma}} \\ & y_{ddt}(\omega) = z_{dt}(\omega)k_{dt}^{\alpha}(\omega)l_{dt}^{1-\alpha}(\omega) \\ & k_{dt}(\omega) \leq \frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega) \end{aligned}$$

The system of first-order conditions and complementary slackness conditions are similar to Kohn et al. (2020):

$$\begin{aligned} & p_{ddt}(\omega) = \frac{\sigma}{\sigma-1}MC_{ddt}(\omega) \\ & W_{dt} = (1-\alpha)MC_{ddt}(\omega)z_{dt}(\omega)k_{dt}^{\alpha}(\omega)l_{dt}^{-\alpha}(\omega) \\ & R_{dt}+\delta+\lambda_{dt}(\omega) = \alpha MC_{ddt}(\omega)z_{dt}(\omega)k_{dt}^{\alpha-1}(\omega)l_{dt}^{1-\alpha}(\omega) \\ & MC_{ddt}(\omega)(z_{dt}(\omega)k_{dt}^{\alpha}(\omega)l_{dt}^{1-\alpha}(\omega) - y_{ddt}(\omega)) = 0 \\ & \lambda_{dt}(\omega)\left(\frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega) - k_{dt}(\omega)\right) = 0 \end{aligned}$$

For an unconstrained firm, $\lambda_{dt}(\omega) = 0$, values of output, profits, capital, and labor are:

$$MC_{ddt}(\omega) = \frac{1}{z_{dt}(\omega)}\frac{(R_{dt}+\delta)^{\alpha}W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}$$

$$y_{ddt}(\omega) = \left[\frac{\sigma}{\sigma-1}\frac{1}{z_{dt}(\omega)}\frac{(R_{dt}+\delta)^{\alpha}W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right]^{-\sigma}\frac{Y_{dt}}{P_{dt}^{-\sigma}}$$

$$\pi_{ddt}(\omega) = \frac{1}{\sigma}\left[\frac{\sigma}{\sigma-1}\frac{1}{z_{dt}(\omega)}\frac{(R_{dt}+\delta)^{\alpha}W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right]^{1-\sigma}\frac{Y_{dt}}{P_{dt}^{-\sigma}}$$

$$l_{dt}(\omega) = \left[\frac{\sigma}{\sigma-1}\right]^{-\sigma}\left[\frac{1}{z_{dt}(\omega)}\frac{(R_{dt}+\delta)^{\alpha}}{\alpha^{\alpha}}\right]^{1-\sigma}\left[\frac{W_{dt}}{1-\alpha}\right]^{\sigma\alpha-\alpha-\sigma}\frac{Y_{dt}}{P_{dt}^{-\sigma}}$$

$$k_{dt}(\omega) = \left[\frac{\sigma}{\sigma-1}\right]^{-\sigma}\left[\frac{1}{z_{dt}(\omega)}\frac{W_{dt}^{1-\alpha}}{(1-\alpha)^{1-\alpha}}\right]^{1-\sigma}\left[\frac{R_{dt}+\delta}{\alpha}\right]^{\alpha-\sigma\alpha-1}\frac{Y_{dt}}{P_{dt}^{-\sigma}}$$

When the firm is constrained, it cannot afford to use the unconstrained amount of capital; the maximum it can acquire is $\frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega)$. If $k_{dt}(\omega) \leq \frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega)$, we categorize firm as unconstrained, in another case, we categorize it as constrained, use $k_{dt}(\omega) = k(a_{dt}(\omega)) = \frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega)$ and determine the effective cost of capital, needed to produce profit-maximizing output. We do this by solving the equation:

$$y_{ddt}(\omega) = \left[\frac{\sigma}{\sigma-1}\frac{1}{z_{dt}(\omega)}\frac{(R_{dt}+\delta+\lambda_{dt}(\omega))^{\alpha}W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right]^{-\sigma}\frac{Y_{dt}}{P_{dt}^{-\sigma}} = z_{dt}(\omega)k(a_{dt}(\omega))^{\alpha}l_{dt}^{1-\alpha}(\omega)$$

The unique solution to this equation allows computing values of marginal costs, price, output, and labor of the constrained firm:

$$R_{dt}+\delta+\lambda_{dt}(\omega) = \alpha\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma}{\alpha\sigma+1-\alpha}}\left(\frac{1-\alpha}{W_{dt}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}}\left(\frac{Y_{dt}}{P_{dt}^{-\sigma}k(a_{dt}(\omega))}\right)^{\frac{1}{\alpha\sigma+1-\alpha}}$$

$$MC_{dt}(\omega) = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma}{\alpha\sigma+1-\alpha}}\left(\frac{W_{dt}}{1-\alpha}\right)^{\frac{1-\alpha}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{-\frac{1}{\alpha\sigma+1-\alpha}}\left(\frac{Y_{dt}}{P_{dt}^{-\sigma}k(a_{dt}(\omega))}\right)^{\frac{\alpha}{\alpha\sigma+1-\alpha}}$$

$$y_{ddt}(\omega) = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma(1-\alpha)}{\alpha\sigma+1-\alpha}}\left(\frac{1-\alpha}{W_{dt}}\right)^{\frac{\sigma(1-\alpha)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma}{\alpha\sigma+1-\alpha}}\left(\frac{Y_{dt}}{P_{dt}^{-\sigma}}\right)^{\frac{1-\alpha}{\alpha\sigma+1-\alpha}} k(a_{dt}(\omega))^{\frac{\alpha\sigma}{\alpha\sigma+1-\alpha}}$$

$$\pi_{ddt}(\omega) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{W_{dt}}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}}\left(\frac{Y_{dt}}{P_{dt}^{-\sigma}}\right)^{\frac{1}{\alpha\sigma+1-\alpha}} k(a_{dt}(\omega))^{\frac{\alpha(\sigma-1)}{\alpha\sigma+1-\alpha}}$$

$$l_{dt}(\omega) = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma}{\alpha\sigma+1-\alpha}}\left(\frac{1-\alpha}{W_{dt}}\right)^{\frac{\sigma}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}}\left(\frac{Y_{dt}}{P_{dt}^{-\sigma}}\right)^{\frac{1}{\alpha\sigma+1-\alpha}} k(a_{dt}(\omega))^{\frac{\alpha(\sigma-1)}{\alpha\sigma+1-\alpha}}$$

3.5.8 Static problem of an exporter in a constant markup environment

$$\pi(a_{dt}(\omega), z_{dt}(\omega)) = \max_{\substack{y_{edt}(\omega), p_{edt}(\omega), y_{eft}(\omega), \\ p_{eft}(\omega), k_{dt}(\omega), l_{dt}(\omega)}} p_{edt}(\omega) y_{edt}(\omega) + p_{eft}(\omega) y_{eft}(\omega) -$$

$$- W_{dt} l_{dt}(\omega) - (R_{dt} + \delta) k_{dt}(\omega) - W_{dt} F$$

s.t.

$$y_{edt}(\omega) = p_{edt}^{-\sigma}(\omega) \frac{Y_{dt}}{P_{dt}^{-\sigma}}$$

$$y_{eft}(\omega) = p_{eft}^{-\sigma}(\omega) \frac{A_{ft}}{P_{ft}^{-\sigma}}$$

$$\tau_{dft} y_{eft}(\omega) + y_{edt}(\omega) = z_{dt}(\omega) k_{et}^{\alpha}(\omega) l_{et}^{1-\alpha}(\omega)$$

$$k_{et}(\omega) \leq \frac{1 + R_{dt}}{1 + R_{dt} - \theta} a_{dt}(\omega)$$

The system of first-order conditions and the associated complementary slackness conditions is given by:

$$p_{edt}(\omega) = \frac{\sigma}{\sigma - 1} MC_{edt}(\omega)$$

$$p_{eft}(\omega) = \frac{\sigma}{\sigma - 1} MC_{eft}(\omega)$$

$$W_{dt} = (1 - \alpha) MC_{edt}(\omega) z_{dt}(\omega) k_{et}^{\alpha}(\omega) l_{et}^{-\alpha}(\omega)$$

$$R_{dt} + \delta + \lambda_{et}(\omega) = \alpha MC_{edt}(\omega) z_{dt}(\omega) k_{et}^{\alpha - 1}(\omega) l_{et}^{1-\alpha}(\omega)$$

$$MC_{edt}(\omega)(z_{dt}(\omega) k_{et}^{\alpha}(\omega) l_{et}^{1-\alpha}(\omega) - \tau_{dft} y_{eft}(\omega) - y_{edt}(\omega)) = 0$$

$$\lambda_{et}(\omega) \left(\frac{1 + R_{dt}}{1 + R_{dt} - \theta} a_{dt}(\omega) - k_{et}(\omega) \right) = 0$$

For an unconstrained firm, $MC_{edt}(\omega) = MC_{ddt}(\omega)$, $y_{edt}(\omega) = y_{ddt}(\omega)$, $\pi_{edt}(\omega) = \pi_{ddt}(\omega)$. Values of marginal costs, outputs, and profits of an unconstrained firm on the foreign market are:

$$MC_{eft}(\omega) = \frac{\tau_{dft}}{z_{dt}(\omega)} \frac{(R_{dt} + \delta)^{\alpha} W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1 - \alpha)^{1-\alpha}}$$

$$y_{eft}(\omega) = \left[\frac{\sigma}{\sigma - 1} \frac{\tau_{dft}}{z_{dt}(\omega)} \frac{(R_{dt} + \delta)^{\alpha} W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1 - \alpha)^{1-\alpha}} \right]^{-\sigma} \frac{Y_{ft}}{P_{ft}^{-\sigma}}$$

$$\pi_{eft}(\omega) = \frac{1}{\sigma} \left[\frac{\sigma}{\sigma - 1} \frac{\tau_{dft}}{z_{dt}(\omega)} \frac{(R_{dt} + \delta)^{\alpha} W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1 - \alpha)^{1-\alpha}} \right]^{1-\sigma} \frac{Y_{ft}}{P_{ft}^{-\sigma}}$$

$$\pi_{et}(\omega) = \frac{1}{\sigma} \left[\frac{\sigma}{\sigma - 1} \frac{1}{z_{dt}(\omega)} \frac{(R_{dt} + \delta)^{\alpha} W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1 - \alpha)^{1-\alpha}} \right]^{1-\sigma} \left[\frac{Y_{dt}}{P_{dt}^{-\sigma}} + \tau_{dft}^{1-\sigma} \frac{Y_{ft}}{P_{ft}^{-\sigma}} \right] - FW_{dt}$$

The total amount of labor and capital used can be calculated as follows:

$$l_{dt}(\omega) = \left[\frac{\sigma}{\sigma-1}\right]^{-\sigma}\left[\frac{1}{z_{dt}(\omega)}\frac{(R_{dt}+\delta)^{\alpha}}{\alpha^{\alpha}}\right]^{1-\sigma}\left[\frac{W_{dt}}{1-\alpha}\right]^{\sigma\alpha-\alpha-\sigma}\left[\frac{Y_{dt}}{P_{dt}^{-\sigma}}+\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]$$

$$k_{dt}(\omega) = \left[\frac{\sigma}{\sigma-1}\right]^{-\sigma}\left[\frac{1}{z_{dt}(\omega)}\frac{W_{dt}^{1-\alpha}}{(1-\alpha)^{1-\alpha}}\right]^{1-\sigma}\left[\frac{R_{dt}+\delta}{\alpha}\right]^{\alpha-\sigma\alpha-1}\left[\frac{Y_{dt}}{P_{dt}^{-\sigma}}+\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]$$

Again, constrained firm can only employ at most $\frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega)$. If $k_{dt}(\omega) \leq \frac{1+R_{dt}}{1+R_{dt}-\theta}a_{dt}(\omega)$ units of capital, we again categorize firm as unconstrained, in another case, we categorize it as constrained, use $k_{dt}(\omega) = k(a_{dt}(\omega))$ and determine the effective cost of capital the firm should pay to maximize profits on both markets. We do this by solving the equation:

$$y_{edt}(\omega) + \tau_{dft}y_{eft}(\omega) = \left[\frac{\sigma}{\sigma-1}\frac{1}{z_{dt}(\omega)}\frac{(R_{dt}+\delta+\lambda_{dt}(\omega))^{\alpha}W_{dt}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right]^{-\sigma}\left[\frac{Y_{dt}}{P_{dt}^{-\sigma}}+\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right] =$$
$$= z_{dt}(\omega)k(a_{dt}(\omega))^{\alpha}l_{dt}^{1-\alpha}(\omega)$$

The unique solution to this equation allows computing values of marginal costs, price, and output on both markets, as well as the employment level of the constrained exporter:

$$R_{dt}+\delta+\lambda_{et}(\omega) = \alpha\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma}{\alpha\sigma+1-\alpha}}\left(\frac{1-\alpha}{W_{dt}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}}\left(\frac{\frac{Y_{dt}}{P_{dt}^{-\sigma}}+\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}}{k(a_{dt}(\omega))}\right)^{\frac{1}{\alpha\sigma+1-\alpha}}$$

$$MC_{edt}(\omega) = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma}{\alpha\sigma+1-\alpha}}\left(\frac{W_{dt}}{1-\alpha}\right)^{\frac{1-\alpha}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{-\frac{1}{\alpha\sigma+1-\alpha}}\left(\frac{\frac{Y_{dt}}{P_{dt}^{-\sigma}}+\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}}{k(a_{dt}(\omega))}\right)^{\frac{\alpha}{\alpha\sigma+1-\alpha}}$$

$$MC_{eft}(\omega) = \tau_{dft}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha\sigma}{\alpha\sigma+1-\alpha}}\left(\frac{W_{dt}}{1-\alpha}\right)^{\frac{1-\alpha}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{-\frac{1}{\alpha\sigma+1-\alpha}}\left(\frac{\frac{Y_{dt}}{P_{dt}^{-\sigma}}+\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}}{k(a_{dt}(\omega))}\right)^{\frac{\alpha}{\alpha\sigma+1-\alpha}}$$

$$y_{edt}(\omega) = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma(1-\alpha)}{\alpha\sigma+1-\alpha}}\left(\frac{1-\alpha}{W_{dt}}\right)^{\frac{\sigma(1-\alpha)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma}{\alpha\sigma+1-\alpha}}\frac{\frac{Y_{dt}}{P_{dt}^{-\sigma}}k(a_{dt}(\omega))^{\frac{\alpha\sigma}{\alpha\sigma+1-\alpha}}}{\left[\frac{Y_{dt}}{P_{dt}^{-\sigma}}+\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]^{\frac{\sigma\alpha}{\alpha\sigma+1-\alpha}}}$$

$$y_{eft}(\omega) = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma(1-\alpha)}{\alpha\sigma+1-\alpha}} \left(\frac{1-\alpha}{W_{dt}}\right)^{\frac{\sigma(1-\alpha)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma}{\alpha\sigma+1-\alpha}} \frac{\tau_{dft}^{-\sigma}\frac{Y_{ft}}{P_{ft}^{-\sigma}} k(a_{dt}(\omega))^{\frac{\alpha\sigma}{\alpha\sigma+1-\alpha}}}{\left[\frac{Y_{dt}}{P_{dt}^{-\sigma}} + \frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]^{\frac{\sigma\alpha}{\alpha\sigma+1-\alpha}}}$$

$$y_{edt}(\omega) + \tau_{dft}y_{eft}(\omega) = \left(\frac{\sigma-1}{\sigma}\frac{1-\alpha}{W_{dt}}\right)^{\frac{\sigma(1-\alpha)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma}{\alpha\sigma+1-\alpha}} \left[\frac{Y_{dt}}{P_{dt}^{-\sigma}} + \frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]^{\frac{1-\alpha}{\alpha\sigma+1-\alpha}} k(a_{dt}(\omega))^{\frac{\alpha\sigma}{\alpha\sigma+1-\alpha}}$$

$$l_{et}(\omega) = \left(\frac{\sigma-1}{\sigma}\frac{1-\alpha}{W_{dt}}\right)^{\frac{\sigma}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}} \left[\frac{Y_{dt}}{P_{dt}^{-\sigma}} + \frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]^{\frac{1}{\alpha\sigma+1-\alpha}} k(a_{dt}(\omega))^{\frac{\alpha(\sigma-1)}{\alpha\sigma+1-\alpha}}$$

$$\pi_{edt}(\omega) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{W_{dt}}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}} \frac{\frac{Y_{dt}}{P_{dt}^{-\sigma}} k(a_{dt}(\omega))^{\frac{\alpha(\sigma-1)}{\alpha\sigma+1-\alpha}}}{\left[\frac{Y_{dt}}{P_{dt}^{-\sigma}} + \frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]^{\frac{(\sigma-1)\alpha}{\alpha\sigma+1-\alpha}}}$$

$$\pi_{eft}(\omega) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{W_{dt}}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}} \frac{\frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}} k(a_{dt}(\omega))^{\frac{\alpha(\sigma-1)}{\alpha\sigma+1-\alpha}}}{\left[\frac{Y_{dt}}{P_{dt}^{-\sigma}} + \frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]^{\frac{(\sigma-1)\alpha}{\alpha\sigma+1-\alpha}}}$$

$$\pi_{et}(\omega) + FW_{dt} = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{W_{dt}}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha\sigma+1-\alpha}} z_{dt}(\omega)^{\frac{\sigma-1}{\alpha\sigma+1-\alpha}} \left[\frac{Y_{dt}}{P_{dt}^{-\sigma}} + \frac{\tau_{dft}^{1-\sigma}Y_{ft}}{P_{ft}^{-\sigma}}\right]^{\frac{1}{\alpha\sigma+1-\alpha}} k(a_{dt}(\omega))^{\frac{\alpha(\sigma-1)}{\alpha\sigma+1-\alpha}}$$

As in the benchmark case, the firm agrees to sell on two markets if $\pi_{et}(\omega) + FW_{dt} \geq \pi_{ddt}(\omega)$. Again, for the financially-unconstrained firm, it is sufficient to just compare $\pi_{eft}(\omega)$ with FW_{dt} but this comparison is no longer sufficient for the financially-constrained firm.

3.5.9 Static problem of an importer in a constant markup environment

Intuitively, the problem of the importer is a symmetric version of the problem of domestic exporter, with the main difference that we abstract from financial constraints abroad. This allows us to consider exporting decisions of importers independently from the decisions on their domestic market; thus the only first-order conditions and complementary slackness conditions relevant to this problem are:

$$
\begin{aligned}
&p_{mdt}(\omega) = \frac{\sigma}{\sigma-1} MC_{mdt}(\omega)\\
&W_{ft} = (1-\alpha) MC_{mft}(\omega) z_{ft}(\omega) k_{mt}^{\alpha}(\omega) l_{mt}^{-\alpha}(\omega)\\
&R_{ft} + \delta + \lambda_{mt}(\omega) = \alpha MC_{mft}(\omega) z_{ft}(\omega) k_{mt}^{\alpha-1}(\omega) l_{mt}^{1-\alpha}(\omega)\\
&MC_{mdt}(\omega)(z_{ft}(\omega) k_{mt}^{\alpha}(\omega) l_{mt}^{1-\alpha}(\omega) - \tau_{fdt} y_{mdt}(\omega) - y_{mft}(\omega)) = 0
\end{aligned}
$$

Values of marginal costs, outputs, and profits on the domestic market are similar to the expressions for the unconstrained firms we have derived before:

$$
\begin{aligned}
MC_{mdt}(\omega) &= \frac{\tau_{fdt}}{z_{ft}(\omega)} \frac{(R_{ft}+\delta)^{\alpha} W_{ft}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\\
y_{mdt}(\omega) &= \left[\frac{\sigma}{\sigma-1} \frac{\tau_{fdt}}{z_{ft}(\omega)} \frac{(R_{ft}+\delta)^{\alpha} W_{ft}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right]^{-\sigma} \frac{Y_{dt}}{P_{dt}^{-\sigma}}\\
\pi_{mdt}(\omega) &= \frac{1}{\sigma}\left[\frac{\sigma}{\sigma-1} \frac{\tau_{fdt}}{z_{ft}(\omega)} \frac{(R_{ft}+\delta)^{\alpha} W_{ft}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right]^{1-\sigma} \frac{Y_{dt}}{P_{dt}^{-\sigma}}
\end{aligned}
$$

Importer agrees to export to the domestic market if $\pi_{mdt}(\omega)$ is greater, than $W_{ft}F$

3.5.10 Solving the aggregate problem in a constant markup environment

When domestic markups are fixed, $D_{dt} = \frac{\sigma-1}{\sigma}$. This leaves us only with two variables to solve for, which makes it difficult to satisfy all three equilibrium conditions simultaneously. Kohn et al. (2020) resolve this problem by determining equilibrium ξ as well; we solve this problem by keeping P_f fixed but solving for P_d instead (in essence, both approaches are similar with the only difference that P_d changes the numeraire). Keeping the variable selection similar to the aggregate problem in the environment with variable markups, in the environment with constant markups, we solve for optimal P_d, W_d, and Y_d, which simultaneously satisfy the final good and labor market clearing and equalize Kimball, which we write in a slightly different form:

$$
\begin{aligned}
&\int_{s\in G_a\times G_z} [n(s) + e(s)F]\phi(s)ds = 1\\
&\int_{s\in G_a\times G_z} [c(s) + x(s)]\phi(s)ds = Y_d\\
&\int_{\Omega_{dd}} |\Omega_{dd}|^{-\frac{1}{\sigma}} y_d^{\frac{\sigma-1}{\sigma}}(\omega)d\omega + \int_{\Omega_{dm}} |\Omega_{dm}|^{-\frac{1}{\sigma}} y_{md}^{\frac{\sigma-1}{\sigma}}(\omega)d\omega = Y_d^{\frac{\sigma-1}{\sigma}}
\end{aligned} \tag{3.5.3}
$$

Again, note, that in the last equation, we used $y_d = (1-e)y_{dd} + ey_{ed}$. We find steady-state equilibrium prices using a procedure similar to the baseline model.

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Eidesstattliche Erklärung

Hiermit erkläre ich, die vorliegende Dissertation selbstständig angefertigt und mich keiner anderen als der in ihr angegebenen Hilfsmittel bedient zu haben. Insbesondere sind sämtliche Zitate aus anderen Quellen als solche gekennzeichnet und mit Quellenangaben versehen.

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