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Author(s):
Drechsel, Dirk; Mikosch, Heiner; Sarferaz, Samad; Bannert, Matthias

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What Do Firm Managers Tell Us About the Transmission Channels of Oil Price Shocks?

Dirk Drechsel, Heiner Mikosch, Samad Sarferaz, and Matthias Bannert*

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Abstract

In this paper, we investigate the transmission channels of oil price shocks using a factorial survey. We confront CEOs and CFOs of a representative sample of firms with a hypothetical vignette in which the oil price rises exogenously above managers' baseline expectations. The managers then estimate the short- and medium-term cost, price, and output effects of the shock on their firms. We find that the managers expect the shock to have very different effects on their firms: the cross-sectional distributions of the responses are large, skewed, and have fat tails. Higher firm-specific energy input costs lead managers to expect greater output losses and sales price increases. Higher market power accelerates this input cost effect. Another important determinant is managers' pre-shock uncertainty about business prospects. The importance of the three channels varies considerably across industries.

JEL classifications: C83, D22, D84, E31, E32
Keywords: Oil price shocks, transmission channels, firms, expectations, surveys, vignettes

*All authors: KOF Swiss Economic Institute, ETH Zurich, Leonhardstrasse 21 LEE, 8092 Zurich, Switzerland. Authors' e-mails: dirk.drechsel@daimler.com, mikosch@kof.ethz.ch, sarferaz@kof.ethz.ch, and bannert@kof.ethz.ch. We are grateful to Klaus Abberger, Andreas Dibiasi, Steve Heinke, Marius Ley, Hashem Pesaran, Alexander Rathke, Frank Schorfheide, Jan-Egbert Sturm, and Johannes Wohlfart for helpful comments and discussions. We further thank Florian Eckert, Enes Poyraz, and Theo Süllow for valuable research assistance.

1 Introduction

The 2022 Russian invasion of Ukraine has again highlighted the strategic and economic importance of oil price fluctuations. Despite important progress on the transmission channels of oil shocks during the past years (e.g., Kilian, 2008; Hamilton, 2008; Kilian, 2014; Baumeister and Kilian, 2016; Herrera, Karaki, and Rangaraju, 2019 for overviews) several open questions remain. For one, theoretical models posit that the impact of an oil price shock on prices and output varies with the degree of competitive pressure (Rotemberg and Woodford, 1996).[1] However, this market power channel has never been confirmed or rejected empirically so far. The energy input cost channel poses another challenge: albeit theoretically straightforward, this channel has rarely been identified empirically in previous research (see, e.g., the ambiguous finding in Lee and Ni, 2002). A further case is the uncertainty channel, according to which uncertainty amplifies the negative effects of adverse macroeconomic shocks on economic activity (e.g., Bernanke, 1983; Bloom, 2009; Bloom et al., 2018). This, however, has been rarely studied for the case of oil price shocks so far (Lee, Kang, and Ratti, 2011).

In this paper, we study the aforementioned channels by means of a factorial survey, which we conduct among leading managers (mostly CEOs and CFOs) of Swiss firms. The response sample includes over 1000 firms and is representative for the Swiss economy. The questionnaire confronts the managers with a shock scenario ("hypothetical vignette"): the oil price surges by 30% despite unchanged economic circumstances and then remains 30% above each manager's previous price expectation path. The managers are then asked to assess the 6-month and 18-month effects of the shock on output, prices, and costs

[1] See Finn (2000) and Leduc and Sill (2004) for further discussion.

of their respective firm. We pair the hypothetical vignette with a collection of firm-specific data and study, based on the assessment of the managers, the relevance of the shock transmission channels. We do this at different levels of (dis)aggregation.

Our paper is part of a fast growing literature that uses information treatments or hypothetical vignettes in surveys to study the expectation and decision formation of households or firms (e.g., Jappelli and Pistaferri, 2014, Drechsel et al., 2015, Armantier et al., 2016, Cavallo, Cruces, and Perez-Truglia, 2017, Armona, Fuster, and Zafar, 2018, Binder and Rodrigue, 2018, Coibion, Gorodnichenko, and Kumar, 2018, Andre et al., 2021b, Christelis et al., 2019, Coibion, Gorodnichenko, and Weber, 2019, Coibion et al., 2019, Coibion, Gorodnichenko, and Ropele, 2020, Jappelli and Pistaferri, 2020, Roth and Wohlfart, 2020, Andre et al., 2021a, Christelis et al., 2021, Coibion et al., 2021b, Coibion et al., 2021a, Fuster, Kaplan, and Zafar, 2021, Link et al., 2021, Mikosch et al., 2021, Dibiasi, Mikosch, and Sarferaz, 2021, Fuster et al., 2022, and the recent overview article of Fuster and Zafar, 2022). Our focus on the role of transmission mechanisms of oil price shocks is novel in this literature.[2]

We find a large heterogeneity within firm managers' responses to the oil price shock scenario. While the majority of firms expect only small losses in real turnover, a significant share expects losses of 5% and more. Moreover, most firms plan only moderate increases in their sales prices. However, a non-negligible share of the firms responds with relatively strong price increases. Another non-negligible share plans to cut prices in response to the shock.

[2]Andre et al. (2021b) confront households and experts with an oil price shock scenario and other shock scenarios and elicit their beliefs about the effects of the shock on unemployment and inflation in the economy.

These firms apparently want to cushion the expected decline in demand for their products resulting from the projected general economic downturn due to the shock. We regress the managers' responses on various firm-specific variables. The pre-shock oil intensity of production, the pre-shock profit margin as well as the managers' subjective level of uncertainty about the future turnover outlook turn out to be significant determinants of how strongly the managers expect their respective firm's output and producer prices to respond to the shock scenario. This confirms the relevance of the aforementioned channels at the micro level. Further, we find evidence that market power channel serves as an accelerator to the input cost channel: The negative marginal effect of the oil intensity of production on the real turnover response to the shock gets amplified (muted) if the profit margin is high (low). Equally, the positive effect of the oil intensity on the producer price shock response gets amplified (muted) if the profit margin is high (low).

Previous research has argued that the relevance of different transmission channels varies across industries. However, the empirical evidence on this is still scarce (e.g., Lee and Ni, 2002; Edelstein and Kilian, 2009; Herrera, 2018).[3] We contribute to this literature by studying what the survey responses tell us about the perceived relevance of the channels for the different industries of the economy. The input cost channel turns out to play a comparatively important role for the firms in the transport & logistics industry and in the chemical & pharmaceutical industry. Demand channels are relatively important for the following industries: hotels & hospitality, computer & electronics and, to a lesser extend, automotives, telecommunication & IT. Especially the former

[3]Linn (2009) shows that inter-industry linkages amplify the macroeconomic effect of energy price shocks. Jiménez-Rodríguez (2008) and Jiménez-Rodríguez (2011) provides evidence on cross-industry heterogeneity in industry-level oil shock effects and for the role of the macroeconomic structure therein.

two industries offer services or goods whose demand is relatively elastic to discretionary income (discretionary income channel). The automotive industry is additionally affected by households and firms substituting away from goods whose operation requires high energy input (e.g., Hamilton, 1988 for the operating cost channel). The market power channel is relatively important for the food industry, which enjoys a fair amount of domestic market protection and whose demand is rather inelastic. In contrast, the market power channel takes no effect for the machinery & automotive industry, which is exposed to high international competitive pressure. The uncertainty channel is comparatively relevant for the hotels & hospitality industry and for the transport & logistics industry. This reflects the fact that orders can be canceled at short notice, but investments are not easily reversible in these industries.

Further, we compute value added weighted averages of the firm managers' expected output and price effects to the shock. According to these aggregated responses, the one-standard deviation oil price shock triggers economically significant price increases and output losses in the economy. 18 months after the shock domestic producer prices and foreign sales prices are expected to be 0.6% or 0.3% higher as compared to the no-shock scenario and real turnover is projected to fall by 0.6%. Input costs are expected to be 0.9% higher, hence, the cost increases due to the oil price shock are only partially passed on according to the managers' expectations. The overall majority of the price increases is expected to occur within the first 6 months. In contrast, the expected drop in production is more protracted: two thirds of the drop occur with the first 6 months, the rest thereafter. It is noteworthy that the calculated overall effects and their time path are in line with SVAR impulse responses for Switzer-

land (e.g., Peersman and Van Robays, 2012).[4] In addition, we study what the managers' firm-specific responses imply for the relevance of the different transmission channels to the production and price effects of the oil price shock scenario at the aggregated level. The uncertainty channel explains around 50% to the overall drop in real turnover, while the other two channels are somewhat less important. As regards the effect of the shock on producer prices, the input cost channel turns to be relatively important: it explains around 40% of the overall increase.

The remainder of the paper is structured as follows. Section 2 presents the firm survey and the hypothetical oil price shock vignette therein. Section 3 discusses the firm-level distributions of the managers' responses to the shock scenario and the value added weighted average responses. Section 4 then analyzes the relevance of the different shock transmission channels. Section 5 concludes.

2 The Firm Survey

2.1 Representative Sample and Survey Procedure

Our data stem from an questionnaire attached to the semi-annual KOF Swiss Economic Institute Investment Survey during the summer 2012 wave. The KOF Investment Survey is conducted since 1967; it collects realized and projected investment figures and other financial figures from Swiss firms. Firms' responses come mostly from CEOs and CFOs most of which are taking part in the survey on a regular basis (e.g., Abberger, Bannert, and Dibiasi, 2014). Anonymity of responses is guaranteed. Although not being conducted by the

[4]See, e.g., Hamilton (1983), Kilian (2009), Kilian and Murphy (2012), Baumeister and Hamilton (2019) on time series evidence on oil price shocks for the US and the overview in Kilian (2014).

Swiss Federal Statistical Office itself, the survey is subject to Swiss statistics law and is part of Switzerland's reporting requirement in its statistical cooperation with the European Union. The average answering time for the survey of the summer 2012 wave was 6.5 minutes.

The KOF Investment Survey employs the KOF enterprise panel which has been set up and is maintained according to the standards of the Swiss Federal Statistical Office. The survey has been sampled from the population of around registered 60300 Swiss firms (as taken from the Business Register of the Swiss Federal Statistical Office) and included around 5600 Swiss firms at the time of the survey. The usual procedures for prevention of sampling errors are applied (e.g., Cochrane, 1977). Stratified random sampling following, e.g., Dalenius and Gurney (1951) ensures that the KOF enterprise panel is a representative sample of the Swiss economy.

1037 Swiss firms completed the additional questionnaire. The participating firms received an invitation letter and had the option to fill out the questionnaire either online or on paper and send back the paper questionnaire by mail. Questionnaires were in German, French or Italian according to the respective respondent's language preference. The average answering time for the additional questionnaire was 8.75 minutes. There are no repetitive questions throughout the questionnaire, which limits the problem of survey fatigue. If addressed participants did not respond within 18 days they received a reminder. Firms that did not participate after being reminded were reminded via phone after an additional two weeks.

2.2 Hypothetical Vignette

This section explains the factorial survey part whose core is a hypothetical vignette. First, the managers stated the key financial figures of their respective firm such as turnover and costs for the recent past (2010, 2011) as well as the present period (1st half of 2012). The managers further indicated projections for these key firm-specific figures (2nd half of 2012, 2013). This task is helpful in setting the benchmark for the next step.

Thereafter, the questionnaire confronted the managers with the counterfactual situation ("hypothetical vignette") of an oil price shock and asked them to re-evaluate their answers under the new scenario:

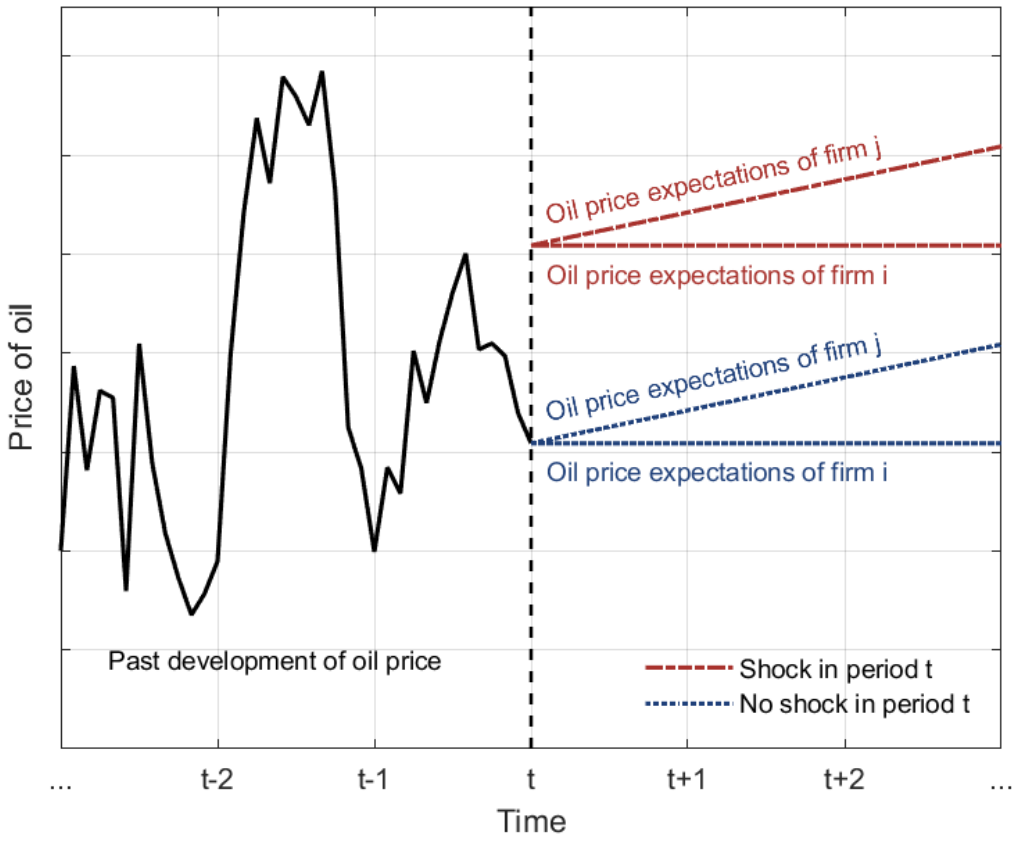
> Suppose that the oil price increases by 30% within the next month despite unchanged economic circumstances. Thereafter, the oil price remains 30% above your previous expectations regarding the oil price development. Please indicate how your financial figures change compared to your previous expectations regarding these figures.

The scenario formulation results from a evaluation of several vignette versions during the pre-test phase (see Appendix A). According to the pre-tests, the firm managers interpret the shock scenario as a permanent global cost-push shock that has been induced by a negative oil supply shock. The pre-tested managers considered a decline in their clients' demand, a deterioration in consumer and business sentiment, and various other changes as consequences of the shock.[5] Importantly, all pre-tested firm managers understood the concept

[5]Ultimately, we decided to refrain from any real-world scenario, because the pre-tested firm managers tended to connect these scenarios with other shocks in addition to the global cost-push shock. For instance, several managers associated the scenario "several Arabian

of structural shocks, i.e. that structural shocks are unexpected, exogenous and uncorrelated with other structural shocks. Further, all pre-tested managers clearly distinguished oil supply shocks from demand shocks (Kilian, 2009).

Figure 1: Oil Price Shock Scenario



The shock constitutes a level shift to firms' expectations on the future oil price path. The jump in the oil price is set to roughly one standard deviation of the monthly price series (Swiss francs per barrel crude oil Brent). The base level for the oil price shock is around CHF 91, the price of oil shortly before sending out the survey. Figure 1 provides a graphical illustration: firm i expects the oil price to remain unchanged, whereas firm j expects an upward drift. The

countries decide to sharply cut oil production ..." with a global uncertainty shock. In contrast, when we completely omitted any kind of accompanying storytelling from the scenario, we found that the managers focused their attention on the global cost-push shock as well as on the macroeconomic and firm-specific consequences resulting from this shock.

shock shifts both projected paths upwards. Further, the shock is specified as a permanent shock by stating that "the oil price remains 30% above your previous expectations".

As an excerpt of the questionnaire, the answer options for total turnover are:

Importantly, the above scenario question is designed such that the answers equal the firm-specific dynamic causal effect of the hypothetical oil price shock ("treatment effect"). These hypothetical responses can be specified as

$$\psi_{i,s} = E_{i,t}[y_{i,t+s}|\eta_t = 1] - E_{i,t}[y_{i,t+s}|\eta_t = 0], \tag{1}$$

where $s = \{6 \text{ months}, 18 \text{ months}\}$, $E_{i,t}[y_{i,t+s}|\eta_t = 1]$ represents, e.g., the expected turnover of firm i at horizon s given the oil price shock happened at time t, and $E_{i,t}[y_{i,t+s}|\eta_t = 0]$ represents firm i's expected turnover at horizon s given the oil price shock did not occur all else being equal. The differencing cancels out constant individual expectation biases on the future business development and addresses the issue of "coherent arbitrareness", according to which statements about differences are more reliable than statements about levels (Ariely, Loewenstein, and Prelec, 2003).[6]

[6]All respondents received the same vignette wording and shock size. An advantage over a design with multiple treatment arms is that the representative sample of respondents is not split into multiple parts and the expected effects can be compared and aggregated across all respondents without proportionality assumptions. A limitation compared to

In the same manner the questionnaire asked the managers to evaluate the effect of the oil price shock on their respective firm's average producer price for goods and services destined for the domestic market ("domestic sales producer price"), the average producer price for goods and services destined for foreign markets if the firm exports ("foreign sales producer price"), the average price for input goods and total expenditure. The questionnaire further asked for firms' (pre-shock) expenses for oil products (e.g., fuel, gasoline, diesel, oils, grease, plastics, chemical products) as a share of total expenses ("oil intensity of production"), exports in terms of total turnover ("export share"), and imports in terms of total costs ("import share"). The figures allow to derive the expected effect on total real turnover. Table 1 provides a comprehensive list of the survey responses and other variables used throughout this study. Appendix B displays the complete questionnaire. Appendix A reports evidence for the validity of the survey.

a design with multiple treatment arms is that no (within subject-)difference-in-(between subject-)difference design is possible. Thus, constant biases in the shock responses across all respondents cannot be removed. Importantly, however, the marginal effects in the regressions in Section 4.2 are not biased by possible individual-constant biases in the responses. Accordingly the analysis based on the marginal effects in Section 4.3 is also not affected. Assuming that possible individual-constant biases in the shock responses occur equally across industries, the analysis in Section 4.1 is also unaffected. The fact that the aggregated firm responses to the one standard deviation oil price shock scenario have a similar magnitude than impulse responses resulting from a similar shock in a SVAR is an indication that there is no general bias in the responses (see Section 3.2). Note also that the aggregated responses in Section 3.2 come with uncertainty bands which account for the projection inaccuracies of respondents.

Table 1: Data

Variable	Description
	Survey Data: Responses
Input price response	Average percentage change in input prices for goods and services in response to the 30% oil price shock as expected by the firm manager
Total costs response	Percentage change in total costs including wages, intermediate goods, and other expenses, but excluding investments in response to the 30% oil price shock as expected by the firm manager
Domestic sales producer price response	Average percentage change in producer prices for domestic sales in response to the 30% oil price shock as expected by the firm manager
Foreign sales producer price response	Average percentage change in producer prices for sales to foreign countries in response to the 30% oil price shock as expected by the firm manager
Producer price response	Weighted average of domestic sales producer price response and foreign sales producer price response. Weights are derived from the export share variable.
Nominal turnover response	Percentage change in total nominal turnover in Swiss francs in response to the 30% oil price shock as expected by the firm manager. Nominal turnover includes sales to foreign countries and excludes value added tax.
Real turnover response	Nominal turnover reponse minus weighted mean of domestic and foreign sales producer price responses. Weights are derived from the export share variable.
All responses have two horizons: 6 months and 18 months (i.e. effect of shock at end of 2012 and at end of 2013, respectively, with survey conducted in June/July 2012). All responses are collected in categories from $\leq -7.5\%$ to $\geq +7.5\%$ and are transformed to continuous scale afterwards.	
	Survey Data: Pre-shock Variables
Oil intensity of production	Share of expenses for oil products (e.g. fuel, gasoline, diesel, oils, grease, plastics, chemical products) as a share of total expenditures
Profit-over-cost margin	Turnover minus total costs over total costs in 2011
Turnover	Nominal turnover in Swiss francs. This includes sales to foreign countries and excludes value added tax.
Total costs	Total costs in Swiss francs including wages, intermediate goods, and other expenses, but excluding investments
Uncertainty	Uncertainty about the 6-month turnover outlook as indicated by the firm manager in four categories: very certain, rather certain, rather uncertain, very uncertain. When aggregating the firm-level uncertainties to the industry level, the ordinal categories are converted into cardinal scale with values from 1 to 4.
Export share	Share of exports relative to total turnover in percent
Import share	Share of imports relative to total costs in percent
Employees	Number of employees (full time equivalents) in Switzerland in 2011
	Data from Official Statistics
Value added	Gross value added for 2011 for Swiss industries based on the international NACE classification scheme (Swiss Federal Statistical Office, 2011 Value Added Statistics)

3 Survey Responses

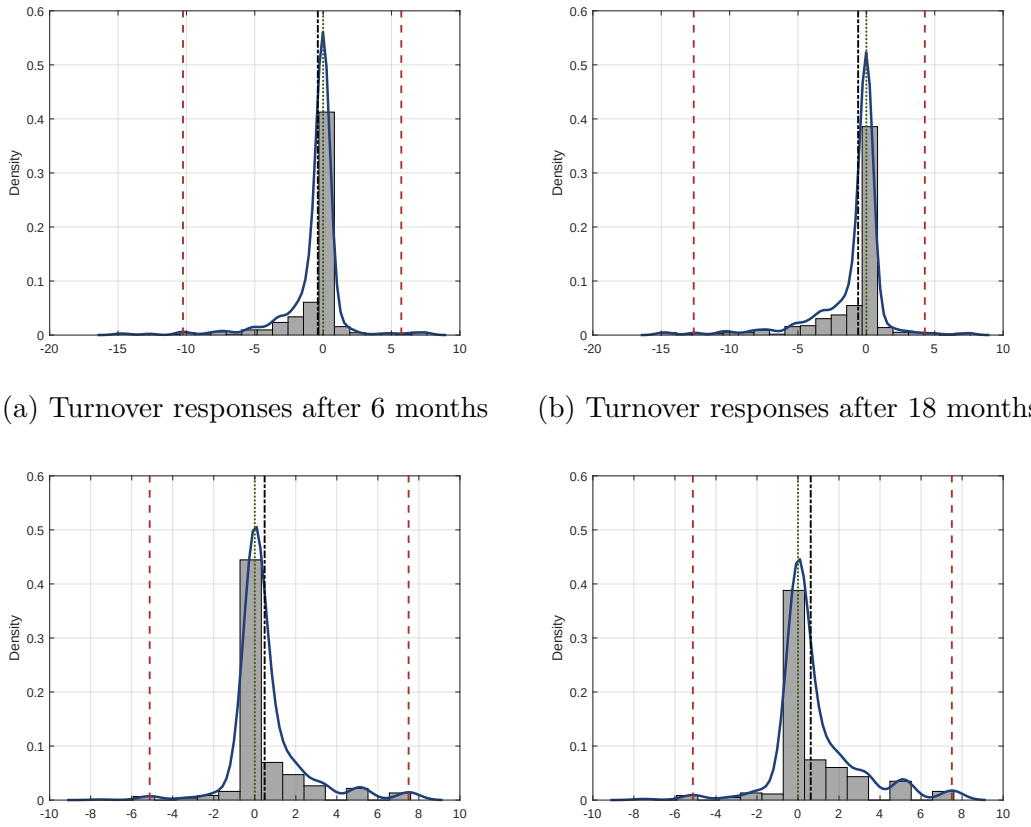
This section discusses what economic effects the firm managers expect from the oil price shock scenario. We first present the firm-level distribution of the managers' shock responses. Then, we aggregate the firm-level responses over the representative firm sample.

3.1 Firm-Level Distributions

Figure 2 shows the empirical distributions of the real turnover responses and of the domestic sales producer price responses to the 30% oil cost-push shock over all firms in the sample. Distributions are presented in form of empirical probability mass functions (pmf) and in form of smoothed kernel densities estimated from the pmf.

We observe a lot of heterogeneity in firms' responses to the hypothetical oil price shock. The overall weight of the real turnover distributions for both horizons lies in negative territory (first row of Figure 2). Both distributions have fat tails and are skewed to the left. The majority of firms expects no or only small reductions in output, yet a significant fraction expects output losses of 5% and more in response to the shock. Turning to domestic sales producer prices (second row of Figure 2), most firms expect positive changes in their sales prices compared to the no-shock case after 6 and 18 months. Both distributions are skewed to the right. While most of the firms exhibit only moderate price increases, there is a significant number of firms who expect price increases of 5% and more in response to the unexpected 30% surge in the oil price. Also, a non-negligible share of the firms reports to decrease their sales prices in response to the shock (see Section 4.1 on the rationale behind

Figure 2: Firm-Level Distribution of Survey Responses



(a) Turnover responses after 6 months

(b) Turnover responses after 18 months

(c) Price responses after 6 months

(d) Price responses after 18 months

Distributions of the real turnover and domestic sales producer price survey responses (in % relative to the no shock case) to a 30% oil cost-push shock for the 6 and 18 months horizons over all firms in the sample. The grey bars show the relative frequency of firms' responses in percentage points. The solid blue lines are smoothed kernel density estimates. The black dashed dotted lines depict the aggregated responses (see Section 3.2). The dashed red lines are the 1st and the 99th percentile, respectively. The green dotted lines represent the 50th percentile.

this behavior). Besides having more mass around zero the distributions of the foreign sales producer price response at the 6 and the 18 months horizon have a very similar shape as the corresponding distributions of the domestic sales producer price response shown in Figure 2. Section 4 will investigate which firm characteristics, such as oil dependency or market power, explain the variations in output and price responses across firms.

3.2 Aggregated Effects

We build overall survey responses by aggregating the sample of firm-level data from the survey experiment to the economy-wide level, the sector level (services, manufacturing, construction) or the industry-group level. For this, we employ standard procedures used in statistical agencies to build macroeconomic series from micro-level data such that the overall responses are representative at the aforementioned levels (European Commission, 2007). Formally, the aggregation can be expressed as

$$\psi_s = \sum_{i=1}^{n} \omega_i \ \psi_{i,s}, \tag{2}$$

where ψ_s is the aggregated effect of the shock according to the survey, ω_i is the aggregation weight of firm i with $\omega_i \geq 0$ and $\sum_{i=1}^{n} \omega_i = 1$, and $\psi_{i,s}$ was defined in Equation (1). Appendix C provides a detailed explanation of the aggregation procedure and addresses its robustness. It is important to note that we do not consider the overall survey responses as being general equilibrium responses.[7] Instead, the overall survey responses resulting from Equation (2) are, a priori, nothing more than the aggregates, i.e. the value added weighted averages, of the managers' firm-specific responses.[8]

Figure 3 shows the aggregated responses to the hypothetical 30% oil price shock over all firms in the sample (economy level). Input prices go up by 1.2% 6 months after the shock and by 1.5% 18 months after the shock according to the aggregated firm-specific expectations of the managers (not shown in the figure). Total input costs go up by 0.7% and 0.9% after 6 or 18 months,

[7] Some researchers equate the term "aggregate" with "general equilibrium", we do not do this.

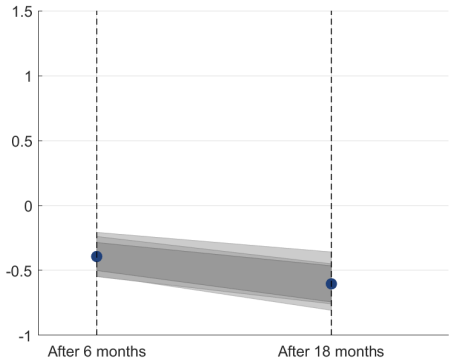
[8] The question, to which extent the managers' responses entail feedback loops and general equilibrium effects of the oil price shock, goes beyond the scope of this paper.

respectively. These numbers are reasonable viewing that the expenses for oil and oil-related products, such as fuel, gasoline, diesel, oils, grease, plastics, and chemical products, account for 2.2% of total expenditures in the economy (see Table 4 in Section 4.3). The managers expect that the input price increases are only partially channeled into higher producer prices: domestic sales producer prices increase by 0.5% 6 months after the shock and by 0.6% after 18 months at the aggregated level, while foreign sales producer prices increase by even less (0.2% and 0.3%). Further, the oil price shock has not only a significant effect on price expectations but also on expected real economic activity: real turnover falls by 0.4% 6 months after the shock and by 0.6% 18 months after the shock according to the aggregated firm-specific expectations of the managers. In sum, the firm managers expect that the oil price shock leads to a considerable increase in domestic producer prices and an economically significant drop in domestic economic activity. The overall majority of the price increases is expected to occur within the first 6 months. In contrast, the production drop is somewhat more protracted: the bigger share of the effects is expected to occur during the first six months, but the effects still grow afterwards. It is noteworthy that these findings are in line with results from SVAR analysis for the Swiss economy (e.g., Peersman and Van Robays, 2012).

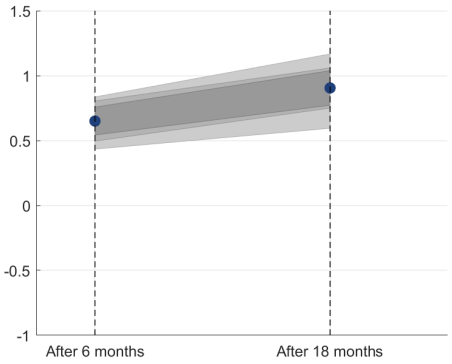
Figure 3 also provides uncertainty bands calculated in three alternative ways. A simple way is to calculate confidence bands based on the in-sample standard deviation of the respective aggregated survey based response. Second, in order to circumvent distributional assumptions we calculate empirical bootstrap confidence intervals around the aggregated responses by employing the standard non-parametric empirical bootstrap method originally popularized by Efron (1979). Third, we go beyond the in-sample variation of the data and calculate

Figure 3: Aggregated Survey Responses

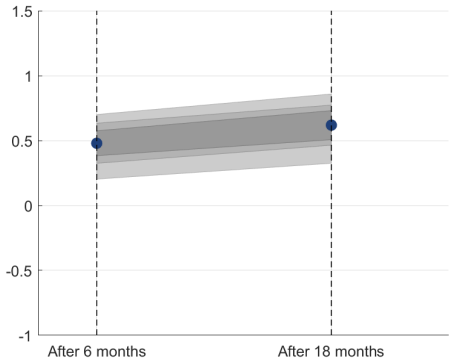
(a) Real turnover



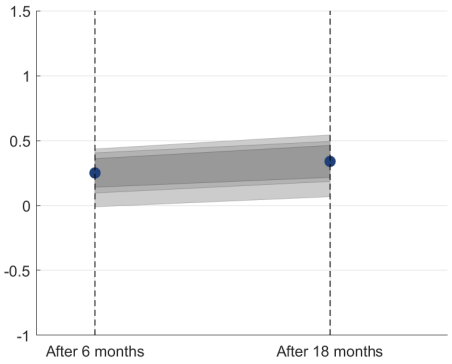
(b) Total input costs



(c) Producer prices (domestic sales)



(d) Producer prices (foreign sales)



Overall survey responses (in % relative to the no shock case) after 6 months and 18 months. The blue circles represent the aggregated values, the dark grey shaded area represents the 95% error band based on the cross-sectional standard deviation, the grey shaded area shows 95% empirical bootstrap confidence intervals, and the light grey shaded area depicts 95% prediction intervals based on past forecast errors. Note that the uncertainty bands are for the 6-month horizon and the 18-month horizon only.

prediction intervals based on firms' past projection errors. The conjecture behind this approach is that some firm managers are arguably better than others in projecting the effects of the shock on the outcomes of their respective firm. Hence, we want that the uncertainty bands account for differences in projection accuracy. Appendix D explains the three methods in detail. According to all methods, the responses of real turnover, total input costs, domestic sales producer prices and foreign sales producer prices at both horizons turn out to be different from zero at conventional levels of statistical uncertainty.

4 Transmission Channels

The following section studies three transmission channels of oil price shocks: the input cost channel, the market power channel, and the uncertainty channel. We first illustrate the channels at the industry level. Next, we analyze their significance at the firm level and their relevance at the aggregated level.

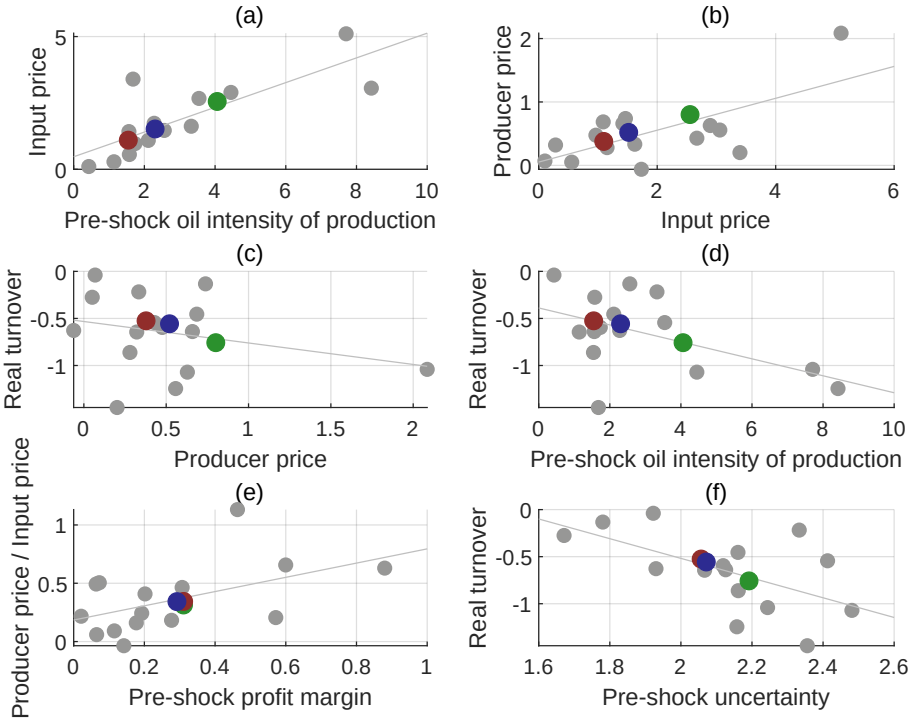
4.1 Industry-Level Evidence

We build industry-level survey responses and industry-level characteristics by aggregating the firm-level survey responses and characteristics in the same way as described in Section 3.2.[9] Figure 4 presents the patterns for the 18-month responses. The patterns for the 6-month responses are very similar and are available on request. Panel (a) shows a positive industry-level relation between the pre-shock oil intensity of production and the expected size of the response in input prices to the oil price shock. Likewise, panel (b) reveals a positive relation between the expected input price response and the expected response in producer prices (domestic and foreign sales). Further, panel (c) suggests a negative relation between the expected producer price response and the expected response in real turnover. Together, the three figures illustrate the *input cost channel*, according to which rising oil prices push up the cost of production and producer prices thereby depressing economic activity. Panel (d) summarizes the input cost channel by showing a negative relation between the pre-shock oil intensity of production and the expected response in real turnover. The finding stands in contrast to the ambiguous correlation between oil intensity and industry-level responses reported in Lee and Ni (2002). Notably, the input

[9]The industry-level responses are thus the industry-level value added weighted averages of the firm managers' expectations on the effect of the oil price shock on their respective *individual* firm, rather than on their respective industry as a whole.

cost channel does not matter equally for all industries. For instance, it plays a comparatively important role for the transport & logistics industry and for the chemical & pharmaceutical industry, which is the most important Swiss export industry in terms of value added. In contrast, the channel is basically irrelevant for banking & insurances being another major industry in the Swiss economy.

Figure 4: Industry-Level Survey Responses



Scatter plot of industry-level survey responses after 18 months. The green dots represent the aggregate for the manufacturing industries, the red dots denote the aggregate for all service industries and the blue dots are the economy-wide aggregates.

Panel (e) displays a positive relation between the pre-shock profit margin and the ratio of producer price response to input price response. Hence, according to the industry aggregates of the managers' firm-specific expectations, industries with comparatively high (low) markups shift a large (small) share of the

input price increases onto sales prices. The finding reveals the relevance of the *market power channel* developed by Rotemberg and Woodford (1996): an oil price shock induces a strong increase in producer prices and, in turn, a large drop in economic activity as firms do markup pricing and face inelastic demand due to imperfect competition.[10] It is noteworthy that the market power channel acts as an accelerator to the input cost channel (more on this in Section 4.2). The market power channel is comparatively important for the food industry, which enjoys a fair amount of domestic market protection and whose demand is rather inelastic. In contrast, the channel takes virtually no effect for hotel & hospitality services. This industry is part of the tourism industry which faces tough competition nationally and internationally. The machinery & automotive industry, which is both exposed to high international competitive pressure and very sensitive to the general cyclical situation, even expects to *lower* producer prices in response to the shock despite a rise in input prices. A probable reason for this reaction is that firms intend to contain turnover losses, which result from the general downturn in response to the shock, by giving price deductions. This finding suggests that the survey respondents factor in second-round effects, at least as far as they are relevant for their business.

Panel (d) reveals that, according to the industry aggregates of the managers' firm-specific expectations, some industries experience a comparatively strong drop in real turnover in response to the shock despite only low pre-shock oil intensities. This suggests that *demand channels* are at play in addition to the supply-side input cost channel (e.g., Edelstein and Kilian, 2009). The discretionary income argument is that higher oil prices reduce households' and firms' overall purchasing power or aggregate discretionary income. Additional

[10]Following, e.g., Boivin, Giannoni, and Mihov (2009) we proxy firms' degree of markup pricing power by their respective pre-shock profit margin.

demand-side arguments are that oil price hikes increase uncertainty or incentives for precautionary savings. In turn, households curtail consumption and firms reduce their input demand, especially for goods and services with a high income elasticity of demand. Another demand-side argument is that households and firms react to oil price increases by substituting away from goods whose operation requires high energy input such as automobiles (e.g., Hamilton, 1988). The following industries have a comparatively negative ratio between real turnover reaction and pre-shock oil intensity of production, hence, the demand channel seems to be relatively important: hotels & hospitality, computer & electronics and, less pronounced, the automotive industry, telecommunication & IT and wholesale & retail.[11] Especially the first two industries offer services or goods whose demand is presumably comparatively elastic to discretionary income.

Panel (f) shows a negative relation between the pre-shock uncertainty on the 6-month turnover outlook and the expected response in real turnover to the oil price shock. This pattern illustrates the *uncertainty channel*, according to which (pre-existing) microeconomic uncertainty amplifies the negative effects of adverse macroeconomic shocks on economic activity (e.g., Bernanke, 1983; Bloom et al., 2018). The figures suggests that the channel is comparatively relevant for, e.g., the hotel & hospitality industry and has comparatively low importance for, e.g., the construction industry. The comparatively low 6-month turnover outlook uncertainty of construction firms reflects the fact that construction projects have rather long planning horizons.

[11] Since the Swiss automotive industry is very small, we have merged it with the machinery industry for reasons of representativeness. The aforementioned finding arises when treating both industries separately.

4.2 Firm-Level Regressions

Using the survey experimental data we run the following regression model:

$$\psi_{i,s} = \boldsymbol{x}_i'\boldsymbol{\beta} + g\,\theta + \boldsymbol{d}_i'\boldsymbol{\gamma} + \xi_{i,s}. \tag{3}$$

$\psi_{i,s}$ is either the real turnover survey response (in %) or the producer price survey response (in %) of firm i at monthly horizon s to the 30% oil price shock with $i = 1, \ldots, n$ and $s = \{6 \text{ months}, 18 \text{ months}\}$. $\boldsymbol{x}_i$ is a column vector of firm-specific explanatory variables and $\boldsymbol{\beta}$ is the attached column vector of coefficients. $\boldsymbol{x}_i$ includes the following variables: the profit margin, the oil intensity of production, the firm manager's subjective uncertainty about the 6-month turnover outlook, the firm manager's expected turnover growth rate for the next six months, the turnover growth rate in the year before the shock, and the number of employees. All these variables are pre-shock variables, i.e. they are collected before confronting the firm managers with the shock scenario. g represents a dummy variable which takes value 1 for the horizon $s = 18$ months and zero otherwise. The attached coefficient θ captures the difference between the responses at the 18-month horizon and at the 6-month horizon. $\boldsymbol{d}_i$ is a column vector of K industry dummy variables where the k-th dummy takes value 1 if firm i is in industry k and zero otherwise with $k = 1, \ldots, K$. Accordingly, $\boldsymbol{\gamma}$ is a column vector of industry-specific fixed effects that control for unobserved heterogeneity between industries. In a baseline specification, we omit the industry dummies and simply include a constant intercept term. $\xi_{i,s}$ is the error term. The regression coefficients are estimated by ordinary least squares.

Column 1 of Table 2 shows the firm-level real turnover survey responses to the 30% oil price shock on average over all firms. Average real turnover drops by

0.64 percent 6 months after the shock according to the firm-specific expectations of the firm managers. 18 months after the shock average real turnover is expected to have dropped by an additional 0.33 percent. These average responses are roughly similar to the aggregated responses presented in Section 3.

Table 2: Firm-Level Determinants of Turnover Responses to an Oil Price Shock

	(1)	(2)	(3)	(4)
6-month (intercept) effect	-0.64^{***}	0.09		
	(0.09)	(0.23)		
18-month (intercept) effect	-0.33^{**}	-0.30^{**}	-0.30^{**}	-0.30^{**}
	(0.13)	(0.14)	(0.14)	(0.14)
Pre-shock oil intensity of production		-5.59^{***}	-3.30^{**}	-1.86
		(1.39)	(1.55)	(1.65)
Pre-shock profit margin		-0.16^{*}	-0.17^{**}	-0.003
		(0.08)	(0.09)	(0.11)
Oil intensity × profit margin				-6.04^{**}
				(2.39)
Pre-shock uncertainty: Rather certain		-0.43^{*}	-0.39^{*}	-0.38^{*}
		(0.22)	(0.22)	(0.22)
Pre-shock uncertainty: Rather uncertain		-1.01^{***}	-0.95^{***}	-0.90^{***}
		(0.26)	(0.26)	(0.26)
Pre-shock uncertainty: Very uncertain		-1.20^{**}	-1.00^{**}	-0.91^{*}
		(0.47)	(0.48)	(0.48)
Pre-shock 6-m expected turnover growth		-0.35	-0.53^{**}	-0.50^{**}
		(0.21)	(0.22)	(0.22)
Industry-specific fixed effects	No	No	Yes	Yes
Observations	1,381	1,148	1,148	1,148
Adjusted R^2	0.004	0.04	0.14	0.14

Dependent variable: Firm-level real turnover survey response, $\psi_{i,s}$, in percent. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Additional controls (never significant): "Pre-shock firm size", "turnover growth in the year before the shock", "pre-shock uncertainty: Not specified". "Pre-shock uncertainty: Very certain" dummy left out as baseline dummy.

Column 2 of Table 2 presents the firm-level regression results without inclusion of industry-specific fixed effects, whereas column 3 shows the results when

industry-specific fixed effects are included to control for a possible distortion of the variable coefficients by unobserved industry heterogeneity. While the inclusion of the fixed effects reduces most coefficients in terms of absolute size, the results remain generally robust. Note that the reduction of the coefficients is not surprising: Section 4.1 revealed that the importance of the transmission channels differs across industries, and the industry fixed effects now suck up this industry heterogeneity (and possibly additional confounding industry heterogeneity.)

According to column 3 of Table 2, a one standard deviation (0.05) higher oil cost share amplifies the expected drop of real turnover in response to the oil price shock by $3.30 \cdot 0.05 = 0.17$ percentage points. We thus find that firms' responsiveness of real turnover to an oil price shock depends on their oil intensity of production, after controlling for unobserved industry effects and covariates that also might influence firms' responsiveness. This finding provides firm-level evidence for the relevance of the *input cost channel*.

Column 3 of the regression table further reveals the relevance of the *market power channel* at the firm level. A one standard deviation (0.85) higher profit margin intensifies the reduction of real turnover in response to the oil price shock by $0.17 \cdot 0.85 = 0.14$ percentage points. The next subsection shows that this figure is quite significant at the macroeconomic level. According to Rotemberg and Woodford (1996), the market power channel acts as an accelerator to the input cost channel. Column 4 reveals that this is indeed the case: the interaction effect between the oil cost share and the profit margin is highly negative. Hence, the negative effect of the oil intensity of production on the real turnover survey response to the shock gets amplified (muted) if the profit

margin is high (low). Note also that the marginal effect of the oil intensity on the real turnover response is significantly negative, according to conventional levels of significance, across the whole profit margin range.

Further, column 3 of Table 2 indicates that, according to our survey data, the *uncertainty channel* plays a significant role for the propagation of oil price shocks on economic activity. When the firm management is rather certain (rather uncertain, very uncertain) about its pre-shock 6-month turnover outlook, the expected reduction of real turnover in response to the shock amplifies by 0.39 (0.95, 1.00) percentage points as compared to the case where the firm management is very certain about its outlook. The finding provides empirical micro-data based support for the heterogeneous firms DSGE model results in Bloom et al. (2018).

Turning to price effects, column 1 of Table 3 displays the firm-level domestic sales producer price response to the 30% oil price shock. On average over all firms, the firm managers expect producer prices to increase by 0.57 percentage points 6 months after the shock and by an additional 0.23 percentage points 18 months after the shock. As for real turnover, these average responses are roughly similar to the aggregated responses presented in Section 3.

Columns 2 and 3 of Table 3 show the regression results for the producer price responses without and with inclusion of industry-specific fixed effects, respectively. The fixed effects absorb part of the variation in the dependant variable and they also affect the coefficients of the covariates. Still, our findings are qualitatively robust to the inclusion of the fixed effects.

Table 3: Firm-Level Determinants of Producer Price Response to an Oil Price Shock

	(1)	(2)	(3)	(4)
6-month (intercept) effect	0.57***	0.02		
	(0.07)	(0.17)		
18-month (intercept) effect	0.23**	0.21**	0.21**	0.21**
	(0.10)	(0.11)	(0.10)	(0.10)
Pre-shock oil intensity of production		9.47***	7.51***	6.52***
		(1.09)	(1.19)	(1.27)
Pre-shock profit margin		0.16***	0.12*	0.01
		(0.06)	(0.06)	(0.08)
Oil intensity × profit margin				3.92**
				(1.79)
Pre-shock uncertainty: Rather certain		0.15	0.12	0.11
		(0.17)	(0.17)	(0.17)
Pre-shock uncertainty: Rather uncertain		0.46**	0.38*	0.34*
		(0.20)	(0.20)	(0.20)
Pre-shock uncertainty: Very uncertain		0.05	−0.09	−0.14
		(0.35)	(0.36)	(0.36)
Pre-shock 6-m expected turnover growth		0.37**	0.51***	0.50***
		(0.16)	(0.16)	(0.16)
Industry-specific fixed effects	No	No	Yes	Yes
Observations	1,394	1,144	1,144	1,144
Adjusted R^2	0.003	0.08	0.20	0.21

Dependent variable: Firm-level (domestic sales) producer price survey response, $\psi_{i,s}$, in percent. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Additional controls (never significant): "Pre-shock firm size", "turnover growth in the year before the shock", "pre-shock uncertainty: Not specified". "Pre-shock uncertainty: Very certain" dummy left out as baseline dummy.

According to column 3, a one standard deviation (0.05) higher oil cost share magnifies the expected increase in producer prices in response to the shock by $7.51 \cdot 0.05 = 0.38$ percentage points. This confirms the relevance of the *input cost channel*. Further, a one standard deviation (0.85) higher profit margin amplifies the price increase in response to the oil price shock by $0.12 \cdot 0.85 = 0.10$ percentage points. This finding supports the *market power channel* of Rotemberg and Woodford (1996). These authors argue that firms, which face relatively low competitive pressure and, thus, have relatively high profit margins, raise prices by more in response to an oil price shock than firms with high

competitive pressure. Column 4 confirms that the market power channel is an accelerator to the input cost channel, as the interaction effect between the oil cost share and the profit margin is strongly positive. Thus, the positive effect of the oil intensity of production on the expected price response to the shock gets amplified (muted) if the profit margin is high (low). Notably, the marginal effect of the oil intensity on the price response is significantly positive, according to conventional levels of significance, across the whole profit margin range. The effect of uncertainty on the price responses turns out to be ambiguous. When the firm management is rather certain (rather uncertain) about its pre-shock 6-month turnover outlook, the expected increase in producer prices in response to the shock amplifies, according to column 3, by 0.12 (0.39) percentage points as compared to the baseline case where the firm management is very certain about its outlook. In contrast, when the firm management is very uncertain about its outlook, the expected producer price increase is, according to conventional levels of significance, not different from the expected producer price increase in the baseline case.

4.3 Channel Contributions

In this section, we study what the firm-level responses of the managers imply for the relevance of the input cost, the market power and the uncertainty channel at the aggregated level. In order to derive the economy-wide aggregated response as a function of the aggregated characteristics of the economy, we insert Equation (3) into Equation (2) to get

$$\psi_s = \sum_{i=1}^{n} \omega_i \boldsymbol{x}_i' \boldsymbol{\beta} + g\,\theta + \sum_{i=1}^{n} \omega_i \boldsymbol{d}_i' \boldsymbol{\gamma} + \sum_{i=1}^{n} \omega_i \xi_{i,s}. \tag{4}$$

Let $x_{i,j}$ be the j-th element of the variable vector $\boldsymbol{x}_i$, let β_j be the j-th element of the coefficient vector $\boldsymbol{\beta}$, let $d_{i,k}$ be the k-th element of the industry dummy variable vector $\boldsymbol{d}_i$, and let γ_k be the k-th element of the industry-specific fixed effects vector $\boldsymbol{\gamma}$. The previous equation can then be rewritten as

$$\psi_s = \sum_{j=1}^{J} \beta_j x_j + \theta\, g + \gamma + \xi_s. \tag{5}$$

where $x_j = \sum_{i=1}^{n} \omega_i x_{i,j}$, $\gamma = \sum_{k=1}^{K} \gamma_k \sum_{i=1}^{n} \omega_i d_{i,k}$, and $\xi_s = \sum_{i=1}^{n} \omega_i \xi_{i,s}$. x_j is the aggregated characteristic of variable j in the economy. γ is the aggregated industry-specific fixed effect (which is constructed by aggregating the industry-specific fixed effects of all individual firms). Taking expectations on both sides of Equation (5) and replacing the unknown parameters $\beta_1, \ldots, \beta_J$, θ, and $\gamma_1, \ldots, \gamma_K$ by the respective estimated parameters gives the predicted aggregated response

$$\hat{\psi}_s = \sum_{j=1}^{J} \hat{\beta}_j x_j + \hat{\theta}\, g + \hat{\gamma}. \tag{6}$$

According to Equation (6), the predicted aggregated response, $\hat{\psi}_s$, depends on the aggregated variable characteristics $x_1, \ldots, x_J$, on the response horizon s, and on the estimated aggregated industry-specific fixed effect $\hat{\gamma}$. The aggregated variable characteristics in the economy are calculated in the same way as the aggregated shock responses (see Appendix C) and are displayed in Table 4. The parameter estimates are taken from column 2 of Table 2 (real turnover response) or column 2 of Table 3 (producer price response).[12] Inserting Equation

[12] Our findings remain qualitatively unchanged, when using the parameter estimates from columns 3 or 4 of the aforementioned regression tables instead.

(6) into Equation (5) yields

$$\psi_s = \sum_{j=1}^{J} \hat{\beta}_j x_j + \hat{\theta}\, g + \hat{\gamma} + \xi_s. \tag{7}$$

Equation (7) dissects the overall response ψ_s into the contribution of the different channels and determinants, $\hat{\beta}_1 x_1, \ldots, \hat{\beta}_J x_J$, an unidentified part, $\hat{\theta}\, g + \hat{\gamma}$, and the prediction error, ξ_s.

Table 4: Aggregate Variable Characteristics in the Representative Firm Sample

Variable	Value
Pre-shock profit-over-cost margin	0.295
Pre-shock oil intensity of production	0.022
Pre-shock uncertainty of 6-month turnover outlook: Rather certain	0.573
Pre-shock uncertainty of 6-month turnover outlook: Rather uncertain	0.114
Pre-shock uncertainty of 6-month turnover outlook: Very uncertain	0.016
Pre-shock uncertainty of 6-month turnover outlook: Not specified	0.190
Pre-shock 6-month ahead expected turnover growth	−0.005
Turnover growth in year before shock	0.066
Pre-shock firm size (as measured by number of employees)	565

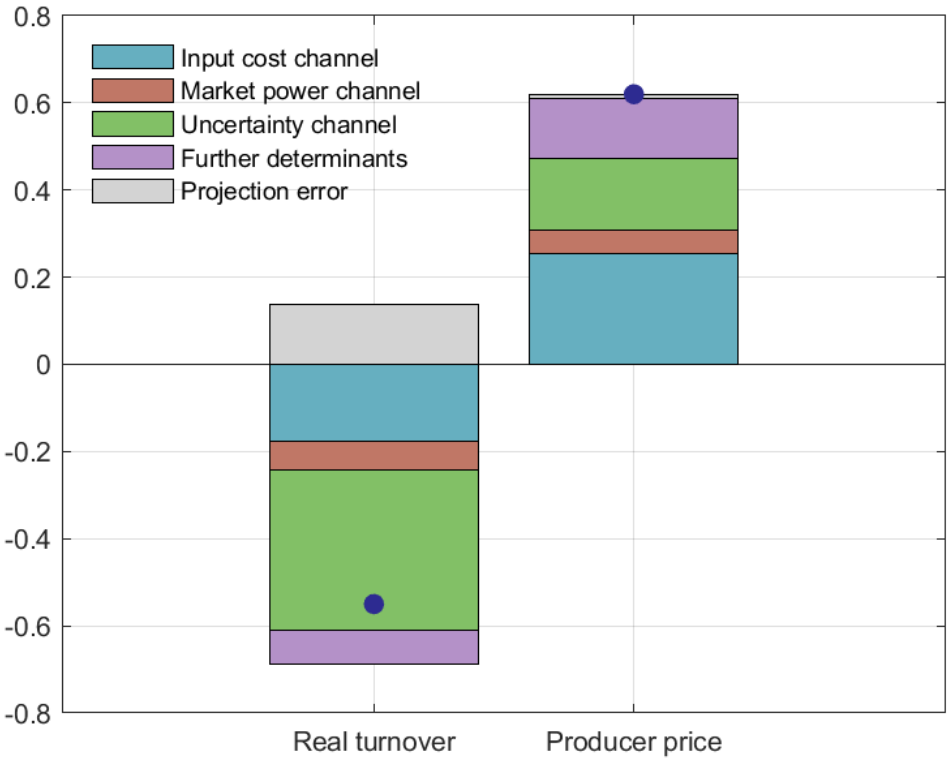
"Uncertainty of 6-month turnover outlook: Very certain" dummy variable left out as baseline dummy variable.

Building on Equation (7), we analyze what the managers' firm-specific responses imply for the contribution of the different transmission channels to the expected effect of the oil price shock scenario on economic activity and prices at the aggregated level. Figure 5 reveals that the uncertainty channel is relatively important for the real turnover response to the oil price shock according to the aggregated firm-level expectations.[13] It contributes −0.37 percentage points to the overall real turnover drop of −0.55% 18 months after the shock. Further, the input cost channel contributes −0.18 percentage

[13]In this section, we focus on the 18-month responses. The results for the 6-month responses are similar and are available on request.

points and the market power channel contributes another -0.07 percentage points. As regards the price response, the input cost channel turns out to be rather important according to the aggregated expectations of the managers. The channel contributes 0.25 percentage points to the increase in producer produce of 0.62% in response to the shock after 18 months. The market power channel contributes 0.05 percentage points and the uncertainty channel contributes 0.17 percentage points.

Figure 5: Channel Contributions



The figure applies Equation (7) and shows the contributions of the input cost, the market power and the uncertainty channel to the blue dotted 18-month aggregated survey responses (in % relative to the no shock case) of real turnover and domestic sales producer prices to a one standard deviation macroeconomic oil price shock scenario.

Further, singling out some variable $l \in \{1, \ldots, J\}$ (e.g., the profit-over-cost margin) from the set all variables $1, \ldots, J$ in Equation (6) gives the predicted

aggregated response as a function of variable l:

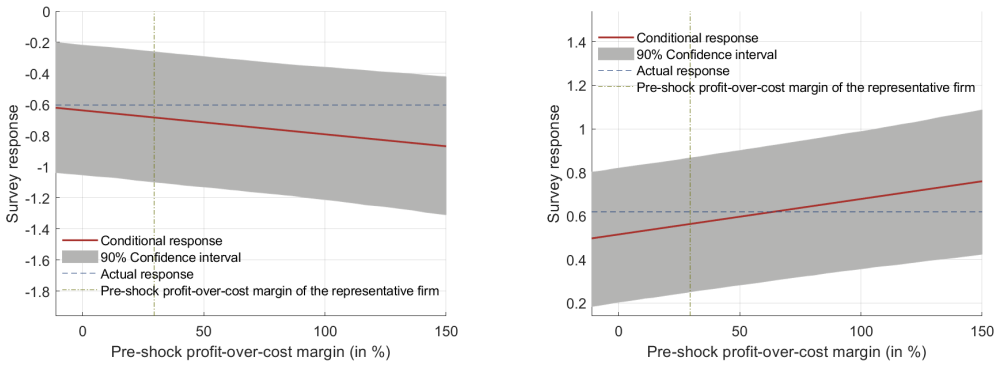
$$\hat{\psi}_s(x_l) = \hat{\beta}_l x_l + \sum_{j \in \{1,\ldots,J | j \neq l\}} \hat{\beta}_j x_j + \hat{\theta}\, g + \hat{\gamma}. \tag{8}$$

We choose x_l to take any value on the interval $[x_l^{lb}, x_l^{ub}]$ with x_l^{lb} and x_l^{ub} denoting the lower bound and the upper bound of the interval. Equation (8) allows to study the following *counterfactual question*: What would be, based on the survey experimental data, the predicted aggregated response if the aggregated variable characteristic x_l in the economy was different from its actual value, while all other observed and unobserved characteristics in the economy $(x_1, \ldots, x_J, g)$ and all estimated parametric relationships $(\hat{\beta}_l, \hat{\beta}_1, \ldots, \hat{\beta}_J, \hat{\theta}, \hat{\gamma})$ are unchanged? This question is all the more relevant as the economy characteristics are not necessarily stable (see, e.g., De Loecker and Eeckhout, 2018, and Weche and Wambach, 2018, who find that the degree of competition among firms varies substantially across time, countries, and sectors).

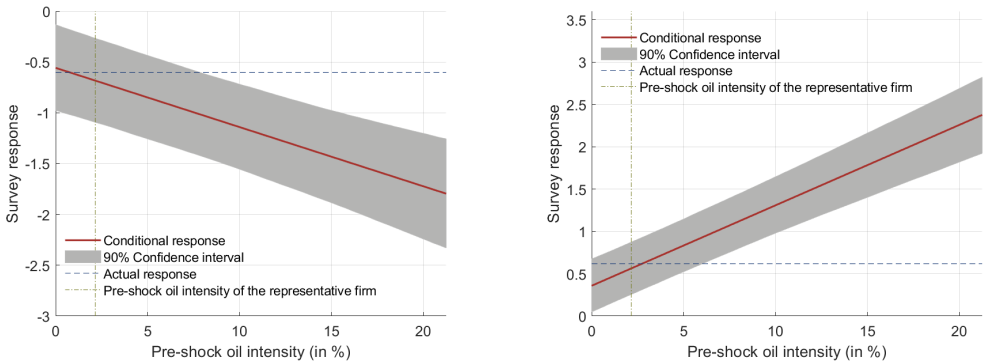
As shown in panels (a) and (b) of Figure 6, the managers' firm-levels responses imply that the overall response in economic activity and prices to the oil price shock scenario changes with the degree of competition in the economy ceteris paribus. If competitive pressure on the firms in the economy was comparatively high and, as a consequence, the aggregated pre-shock profit-over-cost margin was only 5%, then aggregated real turnover would fall by 0.64% and aggregated producer prices would increase by 0.52% 18 months after the 30% oil price shock according to the predicted aggregated response in Equation (8). In contrast, in case of comparatively low competitive pressure with the pre-shock profit-over-cost margin being as high as 100%, real turnover would drop by

Figure 6: Counterfactual Evaluation

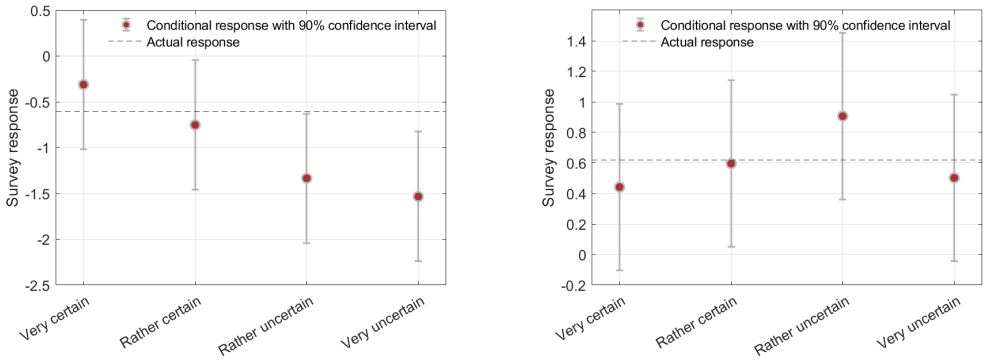
(a) Real turnover response and profit margin (b) Producer price response and profit margin



(c) Real turnover response and oil intensity (d) Producer price response and oil intensity



(e) Real turnover response and uncertainty (f) Producer price response and uncertainty



The figure applies Equation (8) and shows the predicted 18-month aggregated survey responses (in % relative to the no shock case) of real turnover and domestic sales producer prices to a one standard deviation macroeconomic oil price shock scenario as a function of either the aggregate profit-over-cost margin (as measured by turnover minus total costs as a share of total costs on aggregate over all firms in the economy), the aggregate oil intensity of production (as measured by the economy's expenses for oil products as a share of total expenses) or the aggregate level of uncertainty (about the 6-month turnover outlook) in the economy with all other variable values being equal to the aggregate variable characteristics displayed in Table 4. The 90% confidence intervals have been bootstrapped using the wild bootstrap procedure with Rademacher distribution for heteroskedastic errors as outlined in, e.g., Davidson and MacKinnon (2006). The unconditional (= actual) responses are the 18-month aggregated responses as presented in Section 3.2.

0.79% and producer prices would rise by 0.68% ceteris paribus. Our findings confirm Rotemberg and Woodford (1996) who argue that if firms face low competitive pressure and thus have high profit-over-cost margins, an oil price shock will trigger a relatively strong increase in producer prices and, in turn, a relatively big drop in output as compared to the case where firms face high competitive pressures.

Panels (c) and (d) of Figure 6 reveal that, according the survey data, the oil price shock responses heavily depend on the oil intensity of production in the economy. For instance, if the oil cost share was 0.5% (a low level in international comparison), aggregated real turnover would decrease by 0.59% and producer prices would grow by 0.41% 18 months after the one standard deviation oil price shock. However, if the oil cost share was 15% (a high level internationally) ceteris paribus, the decrease in real turnover would be more than two times as strong, namely 1.43%. Producer prices would increase by 1.78%, and, hence, more than four times stronger as compared to the low oil cost share economy. The findings support the input cost channel argument: rising oil prices push up the cost of production and thereby depress output (e.g., Kilian, 2008).

According to the managers' expectations, the level of uncertainty in the economy also exerts an important influence on how strongly economic activity reacts to an oil price shock (see panel (e) of Figure 6). If the aggregated subjective pre-shock uncertainty in the economy about the 6-month business outlook was very low, aggregated real turnover would drop by only 0.31% 18 months after the shock. In contrast, the fall in real turnover would be nearly five times stronger (1.53%) if the uncertainty was very high. This result confirms

the DSGE model results of Bloom et al. (2018) who find that microeconomic uncertainty amplifies the negative effects of adverse macroeconomic shocks on economic activity. As reported in panel (f) our findings are less clear for the producer price responses.

5 Conclusion

We conducted a factorial survey among a representative sample of over 1000 Swiss firms and studied managers' expectations about the cost, price and output effects of an exogenous oil price shock. To our best knowledge, our paper is the first to provide empirical evidence on the effects firm leaders expect from an oil price shock and the transmission channels involved. Also, we are the first to study which factors determine the differences in the expected effects across firms and industries.

Our empirical findings suggest that many firm managers expect the shock to have only small effects on the costs, input prices, sales prices, and/or output of their respective firm. Yet, a significant fraction of the managers expect strong cost increases, price increases, and/or output losses. Also, a non-negligible share reports that they will decrease their sales prices in response to the shock. These are firms that are exposed to high competitive pressure and intend to limit demand losses by reducing prices. The empirical distributions of the expected firm-level effects have fat tails and are heavily skewed, so they do not resemble a normal distribution at all. Aggregated over all firms, input prices are expected to increase by 1.2% 6 months after the 30% exogenous oil price shock and by 1.5% 18 months after the shock.

We focused on three transmission channels of oil price shocks which are theoretically well established, but whose empirical relevance is still unclear. First, rising oil prices increase the cost of production and producer prices and, thereby, depress economic activity. The empirical relevance of this input cost channel depends on the actual oil-intensity of production. Second, as shown theoretically by Rotemberg and Woodford (1996), an oil price shock induces strong price increases and, in turn, large declines in economic activity when firms do markup pricing and face imperfect competition. The empirical relevance of this market power channel depends on the actual degree of competition. Third, pre-existing uncertainty amplifies the negative effects of adverse shocks on economic activity (e.g., Bernanke, 1983; Bloom, 2009; Bloom et al., 2018). We regressed the firm managers' individual price and real turnover responses to the oil price shock on a set of firm characteristics and found that all three channels matter at the firm level. Firms with a comparatively high oil intensity of production expect, ceteris paribus, comparatively strong price increases and comparatively strong turnover decreases in response to the shock. Firms with comparatively high pre-shock profit margins (being a proxy for market power) also expect, ceteris paribus, comparatively strong price increases and comparatively strong turnover decreases. Further, we found that the market power channel acts as an accelerator of the input cost channel: The negative marginal effect of oil intensity on the real turnover response to the shock is amplified (dampened) when the profit margin is high (low). Likewise, the positive marginal effect of oil intensity on the price response is amplified (dampened) when the profit margin is high (low). Also, firm managers, who are comparatively uncertain about their pre-shock turnover outlook, expect comparatively strong real turnover losses in response to the oil price shock.

In addition to the firm regressions, we aggregated the survey data to the industry level to see if the channels have, according to the managers' expectations, different importance for different industries. This is indeed the case. For instance, the market power channel is important for the food industry, which enjoys strong market protection in Switzerland and whose demand is rather inelastic. In contrast, the market power channel is basically irrelevant for the machinery & automotive industry as well as for the hotel & hospitality service industry. Both industries are exposed to tough competition nationally and internationally and are very sensitive to the general cyclical situation. Furthermore, we aggregated the survey data to the economy level and determined the contribution of each channel to the overall expected effects of the oil price shock. The uncertainty channel turned out to be comparatively important for the economy-wide output loss resulting from the shock. In contrast, the input cost channel is comparatively important for the economy-wide price increase in response to the shock. Finally, through a counterfactual evaluation, we found that variations in the overall degree of competition, the overall oil intensity of production, or the overall degree of uncertainty in the economy dramatically alter the expected price and output effects of the oil price shock.

Two avenues for future research emerged from our investigation. First, some of our findings suggest that respondents' expectations about the effects of the oil price shock include second-round effects. However, further evidence is needed to which extent the managers' responses really take into account different kinds of general equilibrium effects (see Coibion et al., 2021a on higher order beliefs of firm managers). Second, although theory suggests that changes in expectations in response to a shock also result in changes in economic decisions, few studies have examined how and to what extent business managers actually

adjust their sales prices and output in response to changes in expectations (e.g., Enders, Hünnekes, and Müller, 2019).[14] Therefore, it seems worthwhile for future survey experimental research to bring together the expectations and actual decisions of firm managers.

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What Do Firm Managers Tell Us About the Transmission Channels of Oil Price Shocks? Online Appendix

Dirk Drechsel, Heiner Mikosch, Samad Sarferaz, and Matthias Bannert

A Survey Validity

The following section presents evidence for the validity of our firm survey.[1]

Preconditions

For a survey experiment to yield valid results the survey experimental scenario must be realistic, i.e. respondents have been confronted with similar real-world scenarios already in the past and/or they already considered the scenario and its effects before (e.g., Gaines, Kuklinski, and Quirk, 2006). Oil price shocks are well suited here as they are easily conceivable for survey respondents and have been prevalent in the past. Several features of the survey make us trust that firm respondents were indeed willing to participate carefully and correctly. The KOF Investment Survey, with occasionally attached special surveys, has a long history (since 1967), an official status and a strong reputation among Swiss firms. Further, the investment survey and the attached survey experiment are rather short which limits the cost of participation (average answering times of 6.5 minutes or 8.75 minutes, respectively). In addition, most of the survey respondents are the CEO or the CFO of their respective firm, and most of the

[1]The potential issue of coverage errors is addressed in Appendix C. Stantcheva (2022) provides a hands-on guide on setting up surveys and survey experiments.

respondents are taking part in the survey on a regular basis (e.g., Abberger, Bannert, and Dibiasi, 2014).

Pre-Tests

Previous to sending out the survey we conducted interviewer pre-tests among a group of randomly selected firm managers in order to check for the relevance and comprehensiveness of the survey experiment. In total, 30 firm managers in three consecutive waves were interviewed during the pre-test phase at their firm domiciles. At the start of each meeting, we handed out the survey to the firm manager without further comments. We then observed the manager filling out the survey questions and collected his/her feedback w.r.t. relevance and comprehensiveness. All 30 firm managers understood the questions and gave us the impression that they are able to evaluate the effects of a macroeconomic oil price shock on their respective firm. The managers indicated that unexpected oil price fluctuations occur recurrently and that a forward-looking management of the firm requires them to assess the effects of such events on their firm, their clients and suppliers. Indeed, the results of the survey experiment contain evidence that the firm managers included indirect or second-round effects of the oil price shock into their projections (see Section 3).

Testing for a Non-Response Bias

Potentially our results could be biased by self-selection into the sample. If our questionnaire was highly relevant to a particular group of firms, these firms may systematically select themselves into the response sample, while firms to which the questionnaire is less relevant might choose to drop out. Specifically, those managers whose firms have a relatively high oil share might perceive the

survey as especially relevant and, hence, participate more often than firms who depend little on oil. An over-representation of high oil share firms in the sample might lead to an over-estimation of the aggregated oil price shock effects.

To test whether the aforementioned selection bias exists in our sample, we apply the "surrogate" approach of Wallace and Mellor (1988). We compare the firms that responded on time, i.e. by July 9, 2012, with those that did not answer the survey until that date. Regarding the late respondents we enforced participation by pressuring them with phone calls. Hence, the late respondents can be interpreted as a sample from the non-response population. Following Wallace and Mellor (1988), we create two sub-samples by selecting the first 50 observations from the early respondents and the last 50 observations from late respondents. Given that subsample participants submitted in random order, both subsamples should be random draws from the total population and, thus, should not differ in their mean and distribution. We also perform a Kolmogorov-Smirnov test to check whether the distributions of both subsamples are equal. The following paragraphs present the results for an unweighted sample as well as for a weighted sample, which weighs firms as outlined in Appendix C.

Table 5 shows the results of a simple t-test on whether the means of the early respondents group and the late respondents groups are equal. The difference in mean oil shares turns out to be not significant at the 10 percent level. This result holds also when we multiply firms' oil shares by their weights used in the aggregation procedure. The sample mean helps to get a first idea of the oil share variable, but does obviously not fully represent differences in sampling distributions. Thus, we also compare the sampling distribution of the oil share

variable within the group of early respondents with the sampling distribution of the oil share variable within the group of late respondents. Figure 7 shows histograms for both groups. The Kolmogorov-Smirnov (KS) test fails to reject the hypothesis of equal distributions for both the weighted and the unweighted sample. Table 6 summarizes the results of the KS test.

Table 5: Mean Oil Shares of Early and Late Respondents

Sample	Mean oil share of early respondents	Mean oil share of late respondents	p-value (t-test)
Unweighted	4.4107	2.6941	0.1880
Weighted	0.0010	0.0043	0.1050

Figure 7: Oil Share Distributions of Early and Late Respondents

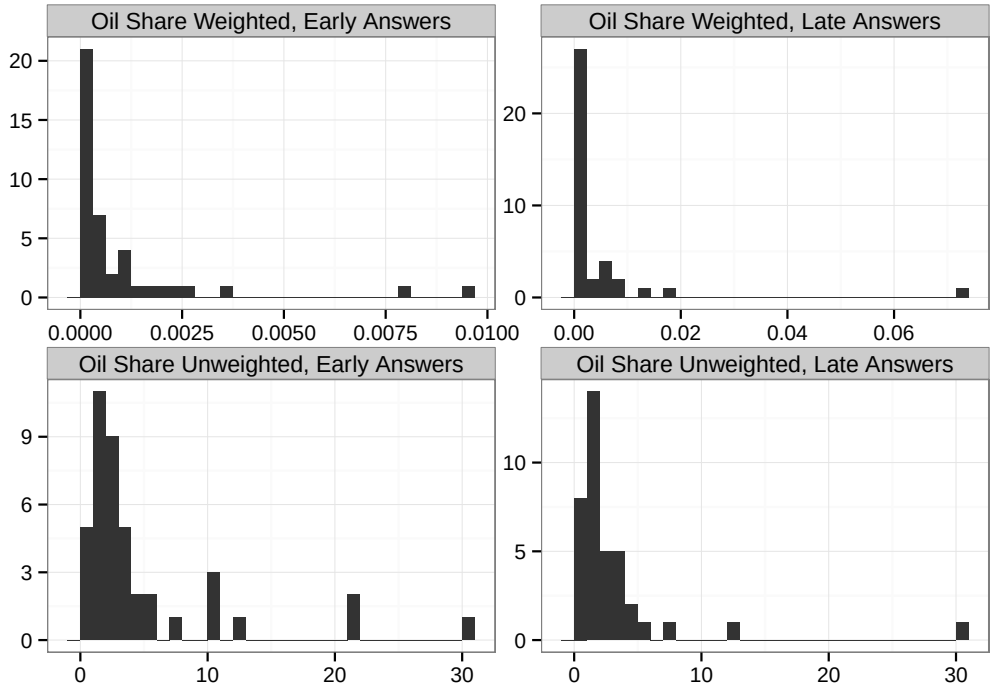


Table 6: Kolomogorov-Smirnov Test Results for Equality of Distributions

Sample	Test statistic D	p-value
Unweighted	0.1980	0.4147
Weighted	0.2544	0.1512

B Questionnaire

KOF Investment Survey

KOF Konjunkturforschungsstelle
ETH Zürich, WEC D 15, 8092 Zürich
www.kof.ethz.ch

Tel. 044 632 85 33
Fax 044 632 13 52
ivu@kof.ethz.ch

Please note

- Please tick relevant boxes or enter figures. Do not use a red pencil.
- Data applies to all production facilities in Switzerland.
- See explanatory information on the back side.
- Please return the questionnaire by: **29 June 2012**
- KOF is subordinated to the Federal Statistics Act (FStatA). All information will be treated strictly confidentially.

Spring Questionnaire

1. Total Investment Activity

a) Our gross fixed capital formation excluding VAT (construction, machinery, equipment and other investments) amounted to/is expected to amount to

2010 ’ ’ ’ .- CHF
2011 ’ ’ ’ .- CHF
2012 ’ ’ ’ .- CHF

b) In comparison to 2012, our gross fixed capital formation in 2013 is expected to

– –	–	=	+	++	NA
☐	☐	☐	☐	☐	☐

– – decrease strongly
– decrease slightly
= remain unchanged
+ increase slightly
++ increase strongly
NA no answer

2. Investment Activity by Kind

	Equipment and other Investments		Construction Investments	
2010	%	+	%	= 100%
2011	%	+	%	= 100%
2012	%	+	%	= 100%

3. Employees

Our number of employees in Switzerland (converted into full-time equivalent positions) at year end amounted to

2011 ’

4. Turnover

a) Our domestic and foreign sales (excluding VAT) originating from Switzerland amounted to/will amount to according to our expectations
Banks and insurances please refer to explanations on the back.

2010 ’ ’ ’ .- CHF
2011 ’ ’ ’ .- CHF
2012 ’ ’ ’ .- CHF

1st half of 2012
’ ’ ’ .- CHF

2nd half of 2012
’ ’ ’ .- CHF

b) We consider the realization of our sales forecast for **2012** to be

very certain	rather certain	rather uncertain	very uncertain	NA
☐	☐	☐	☐	☐

c) Compared to 2012, we expect our sales to change in **2013** as follows (approximately)

⩽-10%	-7.5%	-5%	-2.5%	0%	2.5%	5%	7.5%	10%	⩾20%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5. Expenditures

Our domestic total costs (including personnel expenditures, intermediate input, other expenses; excluding investments) amounted to/will amount to (according to our expectations)

2010 ’ ’ ’ .- CHF
2011 ’ ’ ’ .- CHF
2012 ’ ’ ’ .- CHF

1st half of 2012
’ ’ ’ .- CHF

2nd half of 2012
’ ’ ’ .- CHF

This questionnaire has been completed by:

Name: .....

Function: .....

Telephone: .....

In future we would like to answer the questionnaire via the internet. Our e-mail-address:

.....

Many thanks for your participation

Explanations

General remarks

The Investment Survey is an instrument for the early recording of planned investment trends.

Definition «Investment»

The investments addressed by this questionnaire mean inflows minus outflows of fixed capital assets. These assets should be recorded before depreciation on the basis of their purchase price (gross investment). It is irrelevant whether the equipment which is being used for the first time is new or second-hand, and whether it has been bought, hired or created in-house.

Fixed capital formation thus encompasses:

Construction

- New construction, conversion work and renovation of commercial premises.

Machinery and equipment

- Machinery, mechanical plants, conveying equipment and warehouse equipment, office machines incl. IT (hardware and software), furniture and equipment, vehicles used for business purposes, and (only) such services which are designed to preserve, to improve or to renovate plants.

This means that fixed capital formation does not include:

- Financial investment (e.g. equity holdings, securities)
- Investment in residential property
- Real estate costs
- Buildings and plants which are intended for hire by the lessor, where the lessor acts merely as a (third-party) financier
- Inventory investment (inventory increases)
- Intangible assets (e.g. expenditure on marketing concepts, for human capital, for research & development, for patents and licences)

Definition «Turnover»

The turnover addressed by this questionnaire conforms with the definition of the Swiss Federal Statistical Office:

«Turnover comprises the totals invoiced by the observation unit during the reference period, and this corresponds to market sales of goods or services supplied to third parties. Turnover includes all duties and taxes on the goods or services invoiced by the unit with the exception of the VAT invoiced by the unit vis-a-vis its customer and other similar deductible taxes directly linked to turnover. Turnover also includes all other charges (transport, packaging, etc.) passed on to the customer, even if these charges are listed separately in the invoice.

Reduction in prices, rebates and discounts as well as the value of returned packing must be deducted. Price reductions, rebates and bonuses conceded later to clients, for example at the end of the year, are not taken into account.»

Banks:
Earnings from interest revenue and trading, services and commission business.

Insurances:
Gross premiums minus gross payments for insurance claims plus net earnings from capital investments; gross fees for consulting services.

Definition «Expenditures»

Expenditures are defined as expenses for material, goods and services, wages and labor costs, social security contributions, other personnel and operating expenditures.

No expenditures are therefore:
Investments, financial expenses, depreciation, other writedowns, additional costs, nonoperating and extraordinary expenses, taxes.

Remarks

KOF Special Survey «Oil Price and Exchange Rate»

KOF Konjunkturforschungsstelle
ETH Zürich, WEC D 15, 8092 Zürich
www.kof.ethz.ch

Tel. 044 632 85 33
Fax 044 632 13 52
ivu@kof.ethz.ch

An approximate estimation based on experience is sufficient. Precise figures are not required.

6. Exchange Rate

a) The Swiss National Bank (SNB) announced to defend the lower limit of 1.20 CHF/EUR. The current exchange rate of euro to Swiss franc is 1.20 CHF/EUR. Which average exchange rate do you expect?

2nd half of 2012

⩽1.00	1.10	1.15	1.20	1.25	1.30	⩾1.40	NA
☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽1.00	1.10	1.15	1.20	1.25	1.30	⩾1.40	NA
☐	☐	☐	☐	☐	☐	☐	☐

b) How large are your current exports as a percentage of total turnover?

Exports to Euro Area

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Exports to Rest of the World

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

c) How large are your current imports as a percentage of total turnover?

Imports from Euro Area

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Imports from Rest of the World

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

7. Scenario «Exchange Rate»

Suppose the SNB reduces the lower limit of the exchange rate to 1.10 CHF/EUR under else constant economic circumstances. Suppose this leads to an exchange rate of 1.10 CHF/EUR, which corresponds to a revaluation of the Swiss franc. How do your financial figures change under these circumstances as compared to your previous expectations for these figures?

a) Total Turnover

2nd half of 2012

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

b) Total Expenditures (incl. staff, inputs, other expenses; excl. investments)

2nd half of 2012

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

8. Oil Share

How large are your expenses for oil (e.g. fuel, gasoline, diesel, oils, grease, plastics, chemical products) as a percentage of total expenditures?

0%	1%	2%	3%	4%	5%	7.5%	10%	12.5%	15%	20%	⩾30%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

9. Scenario «Oil Price»

Suppose that the oil price increases by 30% within the next month despite unchanged economic circumstances. Thereafter, the oil price remains 30% above your previous expectations regarding the oil price development. How do your financial figures change compared to your previous expectations regarding these figures?

a) Purchase Prices (average of all purchases of goods and services)

2nd half of 2012

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

b) Total Expenditures (incl. staff, inputs, other expenses; excl. investments)

2nd half of 2012

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

c) Domestic Sales Prices

2nd half of 2012

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

d) Foreign Sales Prices

2nd half of 2012

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

e) Total Turnover

2nd half of 2012

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2013

⩽-7.5%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	5%	⩾7.5%	NA
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

C Aggregation Scheme

1037 firms completed the additional survey questionaire (see Section 2.1). Of these, 85 firms are from the construction sector, 434 from manufacturing, and 518 from services. We aggregate the firm-level responses using a standard procedure for the aggregation of firm surveys (European Commission, 2007). The procedure ensures that the aggregated responses are representative at the economy-wide level and at the sector level (services, manufacturing, construction).[2] Specifically, we aggregate firms' individual responses by calculating the weighted mean

$$\psi_s = \sum_{i=1}^{n} \omega_i \ \psi_{i,s},$$

where $\psi_{i,s}$ is the response of firm $i = 1, \ldots, n$ for horizon s and ω_i is the weight attached to firm i. The weights ω_i are derived from a two-step weighting procedure:

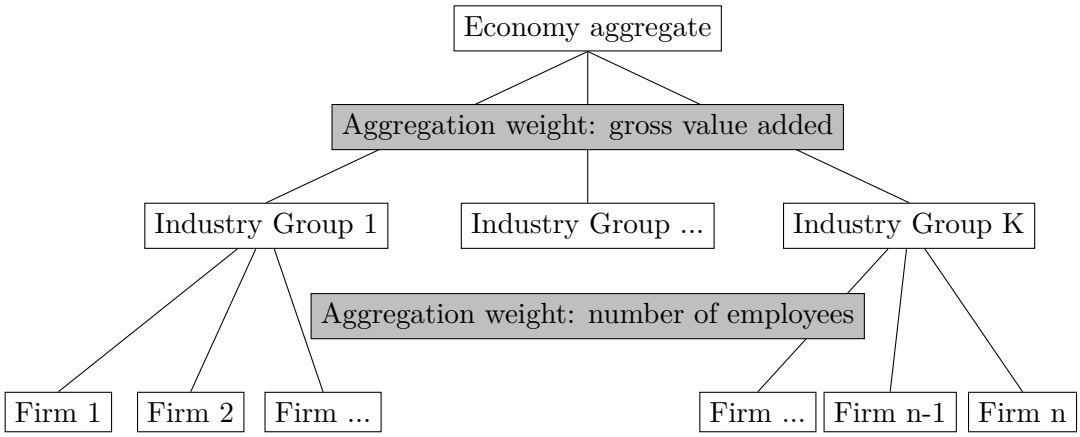
$$\omega_i = \omega_i^E * \omega_i^{VA},$$

where ω_i^E is the number of employees of firm i divided by the cumulated number of employees of all firms within firm i's industry group and where ω_i^{VA} is the gross value added of firm i's industry group divided by the cumulated gross value added of all industry groups in either the overall economy (economy aggregate), the service sector, the manufacturing sector, or the construction sector (sector aggregates). The number of employees of a firm serves as a proxy for the firm's value added. The industry-level value added data have been taken from the 2011 Value Added Statistics of the Swiss Federal Statistical Office.

[2] As outlined in Section 2.1, the enterprise panel underlying the survey is a representative sample of the Swiss economy.

Figure 8 depicts the aggregation scheme for the case of the economy aggregate.

Figure 8: Aggregation Scheme



Importantly, the employed two-step weighting procedure corrects for potential coverage errors which might stem from the omission of non-covered units (Weisberg, 2005). In our context this might be the case if we under-represent certain industry groups while over-representing others. For means of robustness we also investigated whether our results vary with the applied weighting scheme. Interestingly, we found that the results do not depend on the weighting scheme: unweighted results turned out to be only marginally different from weighted results.

D Measuring Uncertainty Around Survey Responses

In this section, we present three alternative ways to calculate uncertainty bands around the aggregated survey responses.

The first approach is to calculate confidence bands based on the in-sample standard deviations of the aggregated responses: The aggregated response

ψ_s is aggregated from the individual firm-level responses according to $\psi_s = \sum_{i=1}^{n} \omega_i \ \psi_{i,s}$, where $\psi_{i,s}$ is the response of firm $i = 1, \ldots, n$ for horizon s and ω_i is the specific aggregation weight attached to firm i (see Appendix C). The sample standard deviation corresponding to ψ_s then is

$$\tau_{\psi_s} = \frac{1}{\sqrt{n}} \sqrt{\sum_{i=1}^{n} (\psi_{i,s} - \psi_s)^2 \ \omega_i}.$$

Assuming that ψ_s follows a normal distribution, the in-sample confidence interval shown in Figure 3 of the main text is

$$\Big(\psi_s - z^* \tau_{\psi_s}, \psi_s + z^* \tau_{\psi_s}\Big),$$

where $z^* = 1.96$ for the 95% confidence level. The normality assumption may be considered as too restrictive. However, according to the central limit theorem ψ_s is, certain conditions provided, normally distributed irrespective of the distribution of the firm-level responses from which ψ_s is aggregated.

The second approach does neither rely on the aforementioned normality assumption nor on the estimation of a standard deviation based on in-sample information. Instead, we bootstrap confidence intervals according to the non-parametric empirical bootstrap method for construction of confidence intervals around population means as originally popularized by Efron (1979). To briefly describe the procedure: We resample with replacement from the full sample of firm-level responses which have been used to construct the aggregated response ψ_s. We choose the number of bootstrap samples to be $M = 1000$, where the size of each bootstrap sample equals the size of the original sample. Next, we apply the aggregation procedure outlined in Appendix C to each of the M bootstrap samples leaving us with M occurrences, $\psi_s^{b,1}, \ldots, \psi_s^{b,M}$, of the

bootstrapped response ψ_s^b. Note that each firm-level response always keeps its original aggregation weight when applying the aggregation procedure to each bootstrap sample. The aggregation weights are not random variables, but they are fixed by the mechanical aggregation procedure outlined in Appendix C. We would like to know the distribution of

$$\delta = \psi_s - \psi_s^*,$$

where $\psi_s^* = \sum_{i=1}^n \omega_i^* \psi_{i,s}^*$ is the true aggregated response. The bootstrap principle suggests to estimate ψ_s^* by ψ_s and to approximate the distribution of δ by the distribution of

$$\delta^b = \psi_s^b - \psi_s^*.$$

As we have M occurrences of the bootstrapped response ψ_s^b, by the law of large numbers, we can estimate the distribution of δ^b very precisely. We compute δ^b for each of the M occurrences of the bootstrapped response and sort them according to their size. The bootstrap principal further suggests to approximate the quantiles of the distribution of δ by the quantiles of the empirical distribution of δ^b. Finally we compute for Figure 3 the 95% bootstrap confidence interval

$$\Big(\psi_s - \delta_{lb}^b, \psi_s + \delta_{ub}^b\Big),$$

where δ_{lb}^b is the 2.5% quantile and δ_{ub}^b is the 97.5% quantile of the δ^b-distribution.

A third approach to measure the uncertainty around the aggregated responses is to construct prediction intervals based on firm managers' forecast errors:

We use the firm managers' 6-months ahead and 18-months ahead projections of their firm-specific investments as indicated in the summer 2012 wave of the KOF Investment Survey (the same wave in which the survey experiment has been conducted). Firm-level forecast errors are built by subtracting these projections from the respective firm-specific investment realizations as collected in the summer 2014 wave of the survey. Assuming that the relative forecast error, i.e. realization minus forecast error divided by forecast error, of a manager's projection of his/her firm's future investment equals the relative errors of the manager's projection $\psi_{i,s}$ for the oil price shock scenario, the firm-specific squared forecast error writes

$$e_{i,s}^2 = \left(\psi_{i,s} \frac{y_{i,s}^{inv} - E_{i,t}[y_{i,s}^{inv}]}{E_{i,t}[y_{i,s}^{inv}]}\right)^2,$$

where $E_{i,t}[y_{i,s}^{inv}]$ is the manager's projection at time t on the firm-specific investment at horizon s and $y_{i,s}^{inv}$ is the corresponding investment realization. Under the assumption that firms' forecast errors are independent of each other, the aggregated root square forecast error (RSFE) can be calculated as

$$e_s = \sqrt{\sum_{i=1}^{n} \omega_i^2 e_{i,s}^2}.$$

The central limit theorem implies that, if certain conditions are fulfilled, the aggregated response ψ_s follows a normal distribution. The RSFE based prediction interval, which is shown in Figure 3, is then given by

$$\Big(\psi_s - z^* e_s, \psi_s + z^* e_s\Big),$$

where again $z^* = 1.96$ for the 95% confidence level.