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The Macroeconomic Effects of Aerospace Shocks

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Abstract

As major future space explorations are firmly rooted in the US government agenda, research into the macroeconomic impact of a space mission is still scarce. This paper tries to fill the existing gap by building a narrative of the *aerospace structural shocks* to assess their macroeconomic effects. The main finding is that almost all the publicly funded space missions significantly and persistently raise real GDP, while this is not the case in the private narrative. We conclude that the latest events, while important from the perspective of private investors, do not reflect yet the milestone achievements carried out under government-driven space activity.

Keywords: Space Explorations, Narrative Events, Space Economy, VAR.
JEL: E0; C1; A1.

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1 Introduction

On May 30th 2020, after more than 50 years from the Apollo missions (NASA, 2020a), the Falcon 9 rocket launched a new space capsule, the Crew Dragon. Less than a day later the spacecraft crew joined the International Space Station (ISS).
Differently from the government sponsored military-industrial missions of the 1960s, the current mission is under the umbrella of SpaceX, a private company founded in 2002 by Elon Musk. This was America's first crewed spacecraft since the Space Shuttle, which first flew in 1981 and was retired in 2011, NASA (2020c).
What makes the SpaceX mission so relevant is that it opens the door to a range of new era of human space exploration with potentially enormous technological developments that can have large economic spillovers, see Economist (2020). These include spacecraft that deliver people to space for research, industry, and recreation, Rogers (2001); high-resolution Earth imaging for environmental monitoring; satellites for communications and data sharing on and off-planet Mann (2020); and mining the solar system for precious metals providing infinite access to resources whose supply is becoming limited on Earth, Krolikowski and Elvis (2019). This renaissance of space exploration that we are witnessing, will enable humans to settle in space in the future and enhance the sustainability of life on Earth.
All the major space missions from Mercury (1961), Gemini-Apollo (1966-1973) to the Space Shuttle (1981-2011) have been carried out by huge US government projects, since the large costs and risks involved made the sector generally inaccessible to private actors. American astronauts went from first Earth orbiting to landing on and returning from the moon in only eight years. The incredible array of innovative high technology needed to run the Apollo program was, therefore, mainly driven by demand in the aerospace sector: the world's biggest rocket, the world's smallest and fastest computer, the first worldwide, high-speed data network, spacesuits and space food, see Fishman (2020). Most of the technology for the Apollo program had to be invented from scratch with an estimated cost, adjusted for inflation, of about 152 Billion Dollars, Forbes (2020).
With decreasing costs of spacecraft development, as well as improved remote sensing and data analytic capabilities, more and more space exploration and investment activities have been undertaken by private space companies. Today, major technological advancements and a new entrepreneurial spirit are rapidly shaping a new space economy that sees unrivalled commercial opportunities in space exploration and exploitation.
Starting from the first successful mission in 2008 (SpaceX's Falcon 1) the private sector has stepped into the aerospace industry with other milestones missions such as Blue Origins (2016) funded by Jeff Bezos and SpaceX's Falcon 9 (2017). Com-

mercial space is a large and rapidly growing market that will be worth trillions of dollars over the next decade. These lucrative opportunities together with the falling costs of space exploration make space an attractive investment with start-ups that are growing at a rapid pace, see Weinzierl (2018).

At the same time, new space discoveries, create a variety of spillovers in the real economy and therefore on output. From physics to chemistry, from material sciences to engineering, the pursuit of space has produced revolutionary technologies that have been translated into the industrial sector. The potential spillovers from these new technologies may represent a pivotal extra stimulus for global economies, see Crawford (2017) for a thoughtful discussion. NASA prepares to return to the Moon to stay by 2024 with the Artemis missions NASA (2020b), and together with SpaceX and other investors are planning the next round of technological inventions needed for the future missions to Mars by 2028 and to harvest natural resources from the Moon and the Asteroids.

This huge and fast development of space exploration opens the way to study the consequences of past and future space exploration from a micro and macro perspective and to treat space economy as a field comparable to development economics, agricultural economics, information economics, resource economics, and political economics. Very few up-to-date studies have addressed this interesting new field. Weinzierl (2018) provides a thoughtful analysis of the development of the space economy. Beldavs and Sommers (2018) discuss why space economics is an important field of study, O'Neil et al. (2016) analyze the economic contribution that the Aerospace and defence industry make in terms of employment, value added (contribution to GDP), sales (output), labor income and taxes. Krolikowski and Elvis (2019) discuss different type of asteroid activities classifying them in scientific research (science), the human settlement of other parts of the solar system (settlement), planetary defence (security), and mining (sales).

This is the first paper, to our knowledge, that analyzes the macroeconomic effect of space exploration, what we call aerospace shocks, AS henceforth. The main questions we wish to address in this paper are (i) what is the macroeconomic impact of the space program and (ii) whether the spillovers in the real economy are larger under government-oriented or privately funded space programs. To identify the macroeconomic impact of the AS we impose narrative sign restrictions following Antolín-Díaz and Rubio-Ramírez (2018). The main advantage of this methodology is that it permits to augment standard sign restrictions with additional information coming from key historical missions. The historical events we select are the inaugural missions of each main space program and we then constraint the historical decomposition of the aerospace structural shocks around these episodes.

Following NASA (2020a) we distinguish between the publicly funded space missions: 1961Q1 for the Mercury program, *Event1*; 1962Q1 for the Gemini program, *Event2*; 1968Q4 for the Apollo program, *Event3*; and 1981 for the Space Shuttle program, *Event4*. For the two privately funded missions described above we consider 2008Q3 the first mission of SpaceX, *Event5*; and 2016Q2 the first mission by Amazon Company, *Event6*.

Our main finding is that in almost all the publicly funded space missions when we add our narrative sign restrictions, real GDP persistently and significantly goes upon impact by 0.5% and remains elevated for many quarters. We also find that these effects are generally enhanced when we impose additional restrictions on the aerospace shocks and assume that the related technological developments are driven by sectoral demand. In the private narrative, GDP is instead almost silent to aerospace shocks. While the latest events represent certainly major contributions to the aerospace industry, they do not reflect yet the milestone achievements carried out under government driven space activity.

The paper proceeds as follows. The dataset with the identification strategy is presented in Section 2. Section 3 presents the main empirical results. Finally Section 4 draws some conclusions.

2 Identification and Estimation of Aerospace Shocks

To investigate the macroeconomic effects of the AS we rely on a standard VAR model given by:

$$y_t = c + \sum_{k=1}^{p} \beta_k y_{t-k} + u_t, \qquad u_t \sim \mathrm{N}(0, \Sigma_u), \tag{1}$$

where c is a vector of constants, p is the lag length, y_t stands for the vector of endogenous variables and u_t is a Gaussian white noise with covariance matrix Σ_u. In order to transform the reduced-form errors, u_t, into fundamental innovations, $e_t = Au_t$, it is necessary to place theoretical sign restrictions on the matrix A. Following Rubio-Ramírez et al. (2010) and Antolín-Díaz and Rubio-Ramírez (2018), the procedure is to *i*) obtain the estimates of the reduced elements $vec(B) = (\beta_1 \ldots, \beta_k, c)$ and Σ_u; *ii*) orthogonalize the innovations using a Cholesky decomposition; *iii*) draw a matrix Q from a *QR-decomposition* of a random standard normal matrix such that $A = \tilde{A}Q$, where $\tilde{A}\tilde{A}' = \Sigma_u$; and *iv*) check if the signs are matched. If these are not satisfied, redraw Q until they are met.

In addition to pure sign restrictions, we impose narrative sign restrictions to identify AS following Antolín-Díaz and Rubio-Ramírez (2018). The main advantage of this methodology is that it permits to augment standard sign restrictions with additional information coming from key historical events. To choose these historical events, we select the first mission for each major space program and constraint the historical decomposition of AS around these episodes. As discussed before we distinguish between public and private narrative programs following the funding source. The private missions are present in the late 2000s where Aerospace companies such that Blue Origin or SpaceX became the focus of attention in the aerospace race. On the other hand, public missions are the ones fully financed by the USA government. A graphical description of these missions, which we call events, is depicted in Figure 1. One may wonder whether aerospace innovations are truly exogenous. We contemplate that exogeneity in AS is guaranteed given that the aerospace missions were carried out independently of the economic conditions at each time that we consider. For instance, in 2008Q3 SpaceX accomplished its first orbital launch Falcon 1 and, at the same time, the US economy was stuck in a profound downturn.

Table 1: *Data Overview*

Full name	Abbreviation	Frequency
Real Gross Domestic Product	GDP	Quarterly
GDP Implicit Price Deflator	Price Level	Quarterly
Capacity Utilization: Aerospace Durable Manufacturing	Aerospace CU	Quarterly
Price Index for Private Aerospace Fixed Investment	Aerospace Price	Annual

Note: Real GDP is obtained from BEA (retrieved from FRED): GDPC1. GDP deflator from OECD (retrieved from FRED): USAGDPDEFQISMEI. Capacity utilization in the aerospace industry from the Board of Governors of the Federal Reserve System (retrieved from FRED): CAPUTLG3364T9S. Aerospace price index from BEA (retrieved from FRED): Y015RG3A086NBEA.

The observable included in y_t are summarized in Table 1. We consider four time series over the period 1960Q1 through 2018Q1. All the variables are introduced in log-levels. The table reports for each series the abbreviation used in the paper, the full name of the series, and the frequency. Real GDP and its implicit price deflator are indicators commonly used in the VAR literature. However, aerospace capacity utilization and price level in the aerospace industry are not particularly employed. The former represents the extent to which aerospace capital is being used in aerospace durable manufacturing. One can observe in Figure 1 that the utilization rate is close to its maximum for the 1960s and before the Great Recession. Regarding aerospace prices, we refer to the price index for private fixed investment in aerospace products. Given that is only available at annual frequency, we apply cubic spline interpolation to convert it into quarterly figures and we take care of seasonality using US Census Bureau's X-12 ARIMA. We employ Bayesian techniques to estimate the reduced-form VAR model as in Antolín-Díaz and Rubio-Ramírez (2018). Specifically, we use a conjugate Normal-inverse Wishart prior, assuming that $vec(B)$ is normally distributed and that Σ_u has an inverse Wishart distribution.[1] Table 2 displays the signs imposed for the standard sign restriction approach. Besides the AS, we identify the other two shocks: an aggregate demand shock and an aggregate supply shock. The table imposes the minimum sign restrictions required to identify these three different shocks. We assume that an AS is the one that rises capacity utilization in the aerospace sector on impact. In this flexible case, we are agnostic about the variable of interest: real GDP. One can also notice that we are silent about the response to prices in the aerospace sector. This because we do not know if an aerospace shock is demand-driven or supply-driven in its own industry. Yet, we later investigate whether imposing a positive or a negative sign on the aerospace price index enhances or worsens the response on GDP.

Table 2: *Sign Restrictions*

	Aerospace Shock	Demand Shock	Supply Shock
Aerospace CU	+	?	?
Aerospace Price	?	?	?
GDP	?	+	+
Price Level	?	+	−

Note: Sign restrictions are imposed on impact. Symbols + and − refer to the direction of the response for the considered period of time. When being agnostic about the sign, the symbol ? is employed.

Next, to implement the narrative approach, it is also required that the identified contribution of AS is constrained on particular dates. Figure 1 reports the selected events, as described earlier, in the aerospace industry from 1960Q1 to 2018Q1 together with its historical capacity utilization. For these episodes, we impose narrative information on the historical decomposition of the estimated aerospace shocks as in Antolín-Díaz and Rubio-Ramírez (2018). Consequently, for the events outlined in Figure 1, we impose the following restriction:

> ***Narrative Restriction:*** For the periods specified in Figure 1, AS are the most important contributor to the observed changes in aerospace capacity utilization.

[1] For a detailed description of the Bayesian inference, see Section III in Antolín-Díaz and Rubio-Ramírez (2018).

The restriction above is imposed at each episode and one at a time. In this way, we can study the narrative contribution of each particular aerospace program.[2]

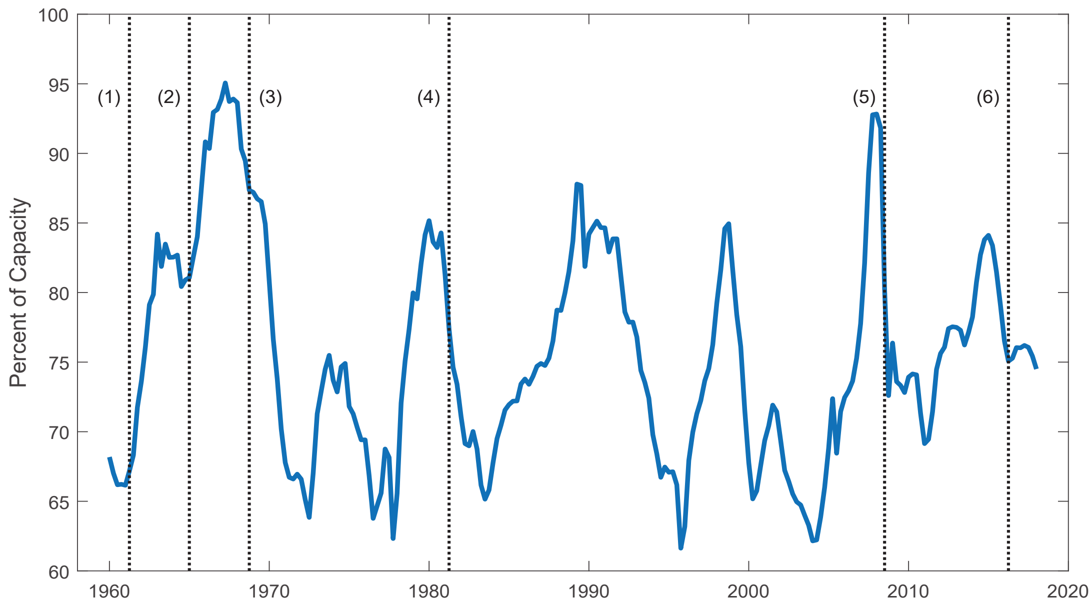


Figure 1: Aerospace Capacity Utilization and Inaugural Missions

Note: The blue-solid line displays quarterly capacity utilization in the aerospace industry. The vertical-dotted lines represent the following aerospace missions: (1) 1961Q2 – Mercury Redstone 3; (2) 1965Q1 – Gemini 3; (3) 1968Q4 – Apollo 7; (4) 1981Q2 – Space Shuttle; (5) 2008Q3 – SpaceX's Falcon 1; (6) 2016Q2 – Blue Origins (Amazon Company).

3 Results

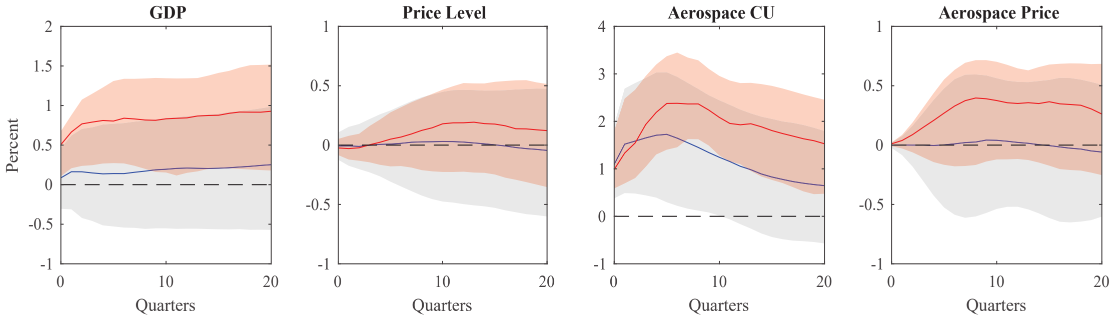
This section analyzes the macroeconomic effects of the selected public and private aerospace events.

3.1 *Public Narrative Events*

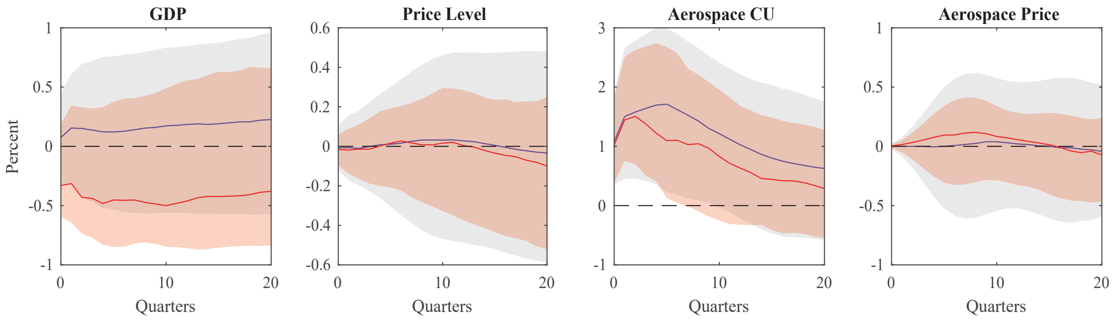
Figure 2 plots the impulse response functions (IRFs) to a one standard deviation AS.[3] The figure reports in blue (dotted) lines the IRFs only when the traditional sign restrictions of Table 2 is considered. The figure also reports in red (dashed) lines the results after adding the *Narrative Restriction* around the *Event 1*.

[2] In Appendix A.1 we also show the findings after taking into account all the public events at the same time. And the same applied to the private missions.

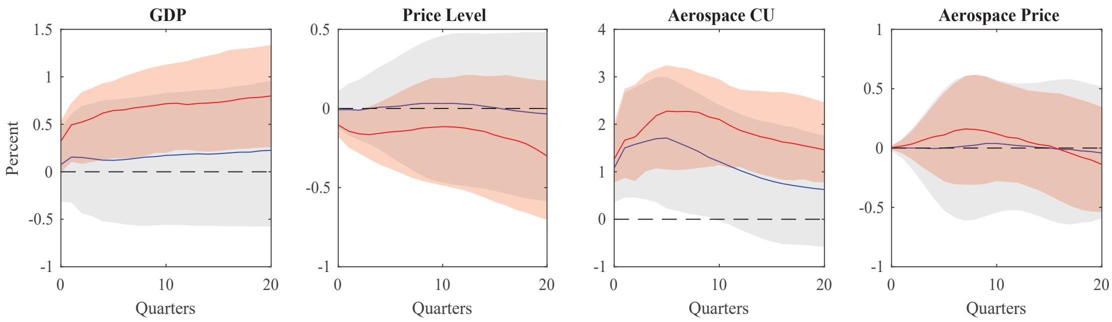
[3] We only report in the main text the IRFs to an aerospace shock. In Appendix A.2, we present the full set of IRFs where the three different structural shocks are identified.



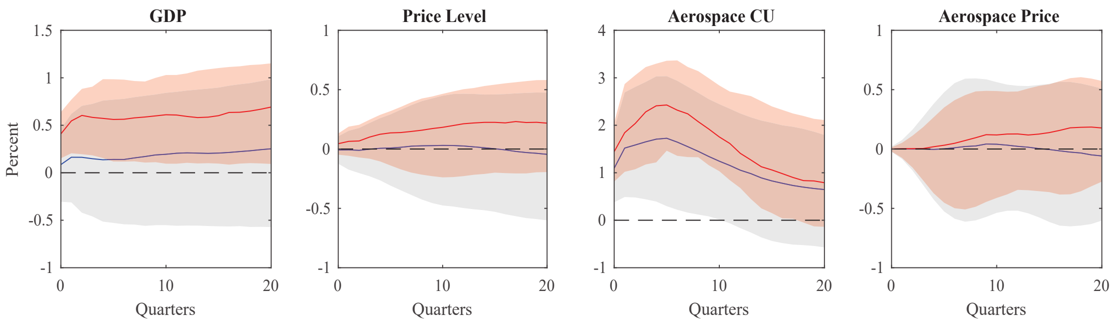
(a) *Event 1*



(b) *Event 2*



(c) *Event 3*



(d) *Event 4*

Figure 2: *IRFs to One Standard Deviation Aerospace Shock: Public Events*

Note: The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

We can observe the response of the observable in the VAR to an AS. Under the pure sign restrictions in Table 2, we note that aerospace capacity utilization rises on impact by 1% and the response on real GDP is not statistically different from zero. However, when we add our narrative sign restriction, that helps shrink the set of admissible structural parameters, the real GDP persistently and significantly goes upon impact by 0.5%, remaining elevated for many quarters. The effects on the other variables of interest, GDP deflator and aerospace price index, are ambiguous. Without imposing any prior beliefs on the responses of these two variables, it is not clear whether they significantly react as a consequence of an aerospace shock or not.

The sole inclusion of the *Narrative Restriction* in 1961Q2 is responsible for the positive effects of an AS to GDP. *Event 1* is crucial. It corresponds with the mission where the Mercury Redstone 3 was the first-ever crewed flight in the United States human spaceflight (its first astronaut was Alan Shepard). Moreover, it links to a presidential speech by John F. Kennedy where he proposed the ambitious goal of landing a man on the Moon before the end of that decade.

Let's turn now to *Event 2*. In this case, the IRFs are reported in Figure 2 Panel (b). We can notice here that once the *Narrative Restriction* is imposed around 1965Q1, the GDP response in the aftermath of an AS is not as significant as the one obtained around the *Event 1*. The dynamics concerning the other variables are also unclear if no further restrictions are introduced. The *Event 2* corresponds to the Gemini program that was mainly oriented to develop space travel techniques to support the Apollo mission. Contrarily to the Mercury and Apollo programs, where NASA did achieve the first earth and lunar orbiting and landing, the program did not achieve major exploration milestones. Indeed, while the inaugural Gemini mission flew three low Earth orbits without any extravehicular activity, on 18 March 1965, Alexei Leonov a Russian cosmonaut became the first person to conduct a spacewalk, exiting the capsule during the USSR Voskhod 2 orbital mission for 12 minutes and 9 seconds. The achievement was reported at the time as a shock to the Americans who had dreamed to be the first to send a man in space. Leonov's spacewalk also demonstrated the Soviets' superiority, casting doubts on the scope of the Gemini mission. This might be one of the possible reasons why the narrative of the Gemini program does not have any sizable effect in the US GDP, see BBC (2016).

The third event represents the first mission of the Apollo program that started on 11 October 1968 and ended on 7 December 1972 with the last lunar landing. Panel (c) in Figure 2 shows that adding our *Narrative Restriction* around *Event 3* does generate a significant development in real GDP.

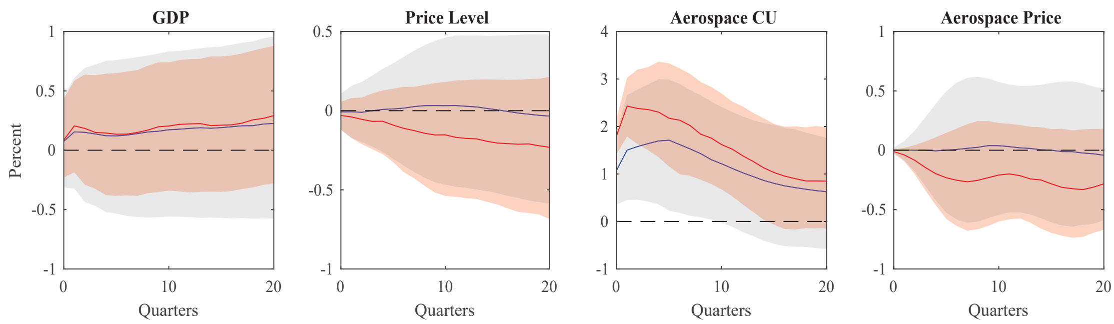
The last public aerospace episode occurred in 1981Q2 (*Event 4*). This coincides

with the first flight of the Space Shuttle program (the fourth human spaceflight program carried out by the NASA). The space shuttle was an important innovation because it marked the first flight of a human-rated, winged, reusable spacecraft, that could carry astronauts into space more frequently. The space shuttle established a constant human presence beyond Earth's atmosphere and allowed learning how to live in space and carry out scientific advancements only possible in microgravity. Again, we observe very similar effects on real GDP with an initial impact of 0.5% when the *Narrative Restriction* is implemented (Panel (d) Figure 2).
Finally, we investigate whether restricting the aerospace price response can attenuate or enlarge the measured impact of an AS on real activity. To this end, we first augment the standard sign restrictions in Table 2 by assuming that aerospace prices react positively on impact. In this way, we would be inferring that AS are demand-driven. On the contrary, we also assume next that the response of prices is negative upon impact, implying that the AS are supply-driven. Appendix A.3 indicates that when we impose a positive reaction on aerospace prices in *Event 1*, *Event 3* and *Event 4*, the effects on GDP are generally enhanced. This suggests that the data is prone to reflect a more demand-driven nature of the AS.

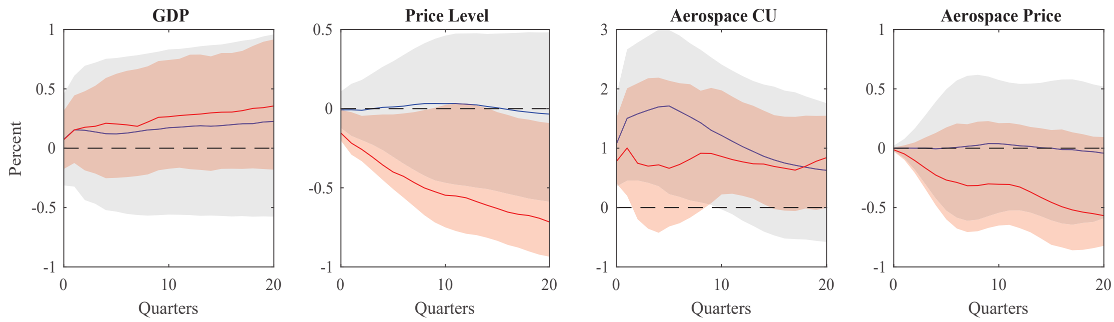
3.2 *Private Narrative Events*

A new space race era has just begun, in which private companies have entered the exploration domain and are driving the aerospace sector towards new ambitious exploration activities. Nowadays the space race is mainly driven by a competition for customers and the reduction of launch costs rather than the need to show political dominance. Private companies such as Blue Origins or SpaceX are at the forefront of space exploration and are pushing forward the aerospace sector faster than would be the case if left to government investments alone. But is the next era of space activities led by the new generation of entrepreneurs, including Bezos, Branson and Musk also affecting the real economy?
The red lines in Figure 3 exhibit the responses after including the *Narrative Restriction* around the following episodes: *i*) 2008Q3 – SpaceX Falcon 1's first successful orbital launch of any privately funded and developed rocket (Panel (a)); and *ii*) 2016Q2 – successful sub-orbital flight and landing of a reused booster (New Shepard 2) by Blue Origins (Panel (b)).
These events represent major contributions to the aerospace industry. However, they have not yet achieved new major exploration milestones as it was the case of the publicly funded space programs. For this reason, the reaction of real GDP after adding the narrative information is insignificant. We believe that this is going to change in the future as soon as new exploration milestones, i.e. further exploring

the moon and beyond, will be achieved, opening up a new chapter in the history of the space exploration which will spur innovation across related industries into the real economy.



(a) *Event 5*



(b) *Event 6*

Figure 3: *IRFs to One Standard Deviation Aerospace Shock: Private Events*

Note: The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

4 Conclusion

As major future space explorations are firmly rooted in the US government agenda, research into the macroeconomic impact of a space mission is still scarce. The paper takes the cue from the inaugural mission of major programs in the US aerospace history and constraints the historical decomposition of the aerospace structural shocks around these episodes to assess their macroeconomic impact. The main finding is that almost all the publicly funded space missions significantly and persistently raise real GDP. In the private narrative, GDP is, instead, almost silent to the aerospace shocks. Given the new ambitious plan by NASA who prepares to return to the Moon to stay by 2024 with Artemis missions and to Mars by 2028, we wonder whether many of the future new technologies will have a similar impact on the real economy and become part of day-to-day life on Earth, just as many Mercury, Gemini and Apollo inventions already have. As NASA plans upcoming Artemis missions, with new objectives and long-term exploration goals, it's clear that, once again, much of the necessary technology and infrastructure doesn't yet exist for sustainable missions. The mission architecture — rocket and capsule, surface modules, spacecraft that will ferry astronauts to and from the lunar surface, and all the technology that enables sustainable operations on the Moon - will probably represent a new demand-driven boost in the aerospace sector. Technology created for Artemis will certainly find secondary applications on Earth and it will enable a new economy in space.

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Supplementary Material for "The Macroeconomic Effects of Aerospace Shocks"

[For Online Publication]

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September 2020

A Appendix

A.1 Public vs Private Missions

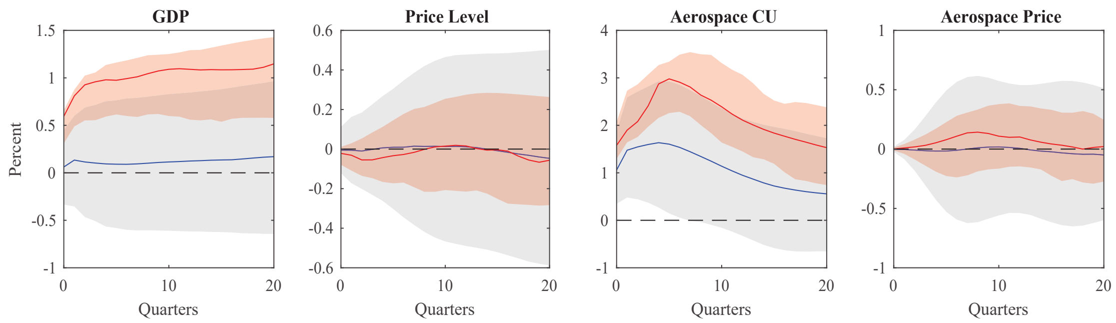

Figure 4: IRFs to One Standard Deviation Aerospace Shock: All Public Events

Note: The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

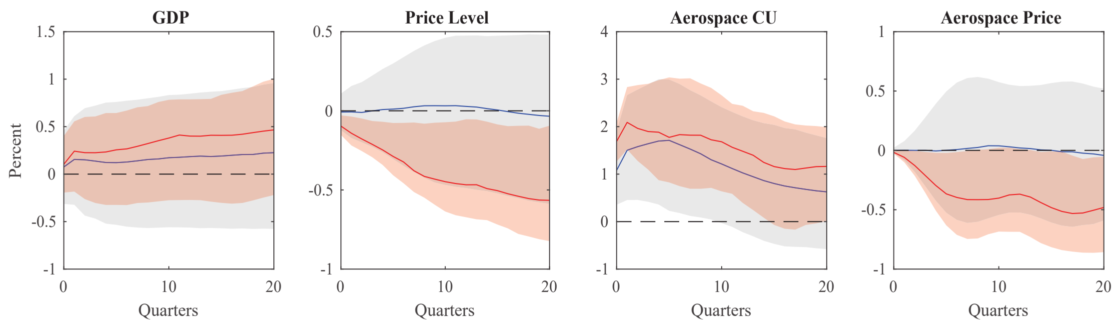

Figure 5: IRFs to One Standard Deviation Aerospace Shock: All Private Events

Note: The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

A.2 Full Set of Identified Shocks

A.2.1 Public Narrative Events

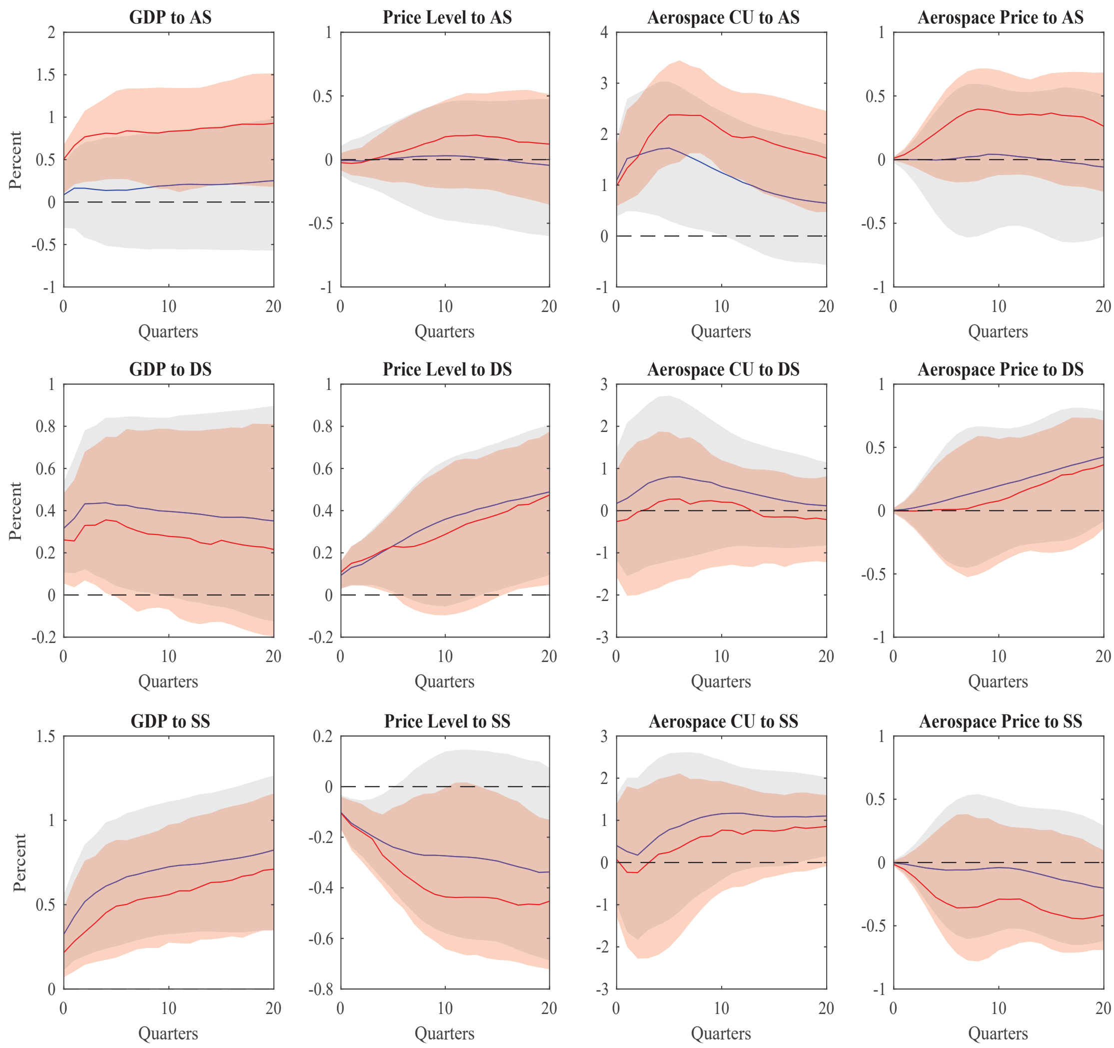

Figure 6: IRFs to One Standard Deviation Aerospace Shock: Event 1

Note: The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

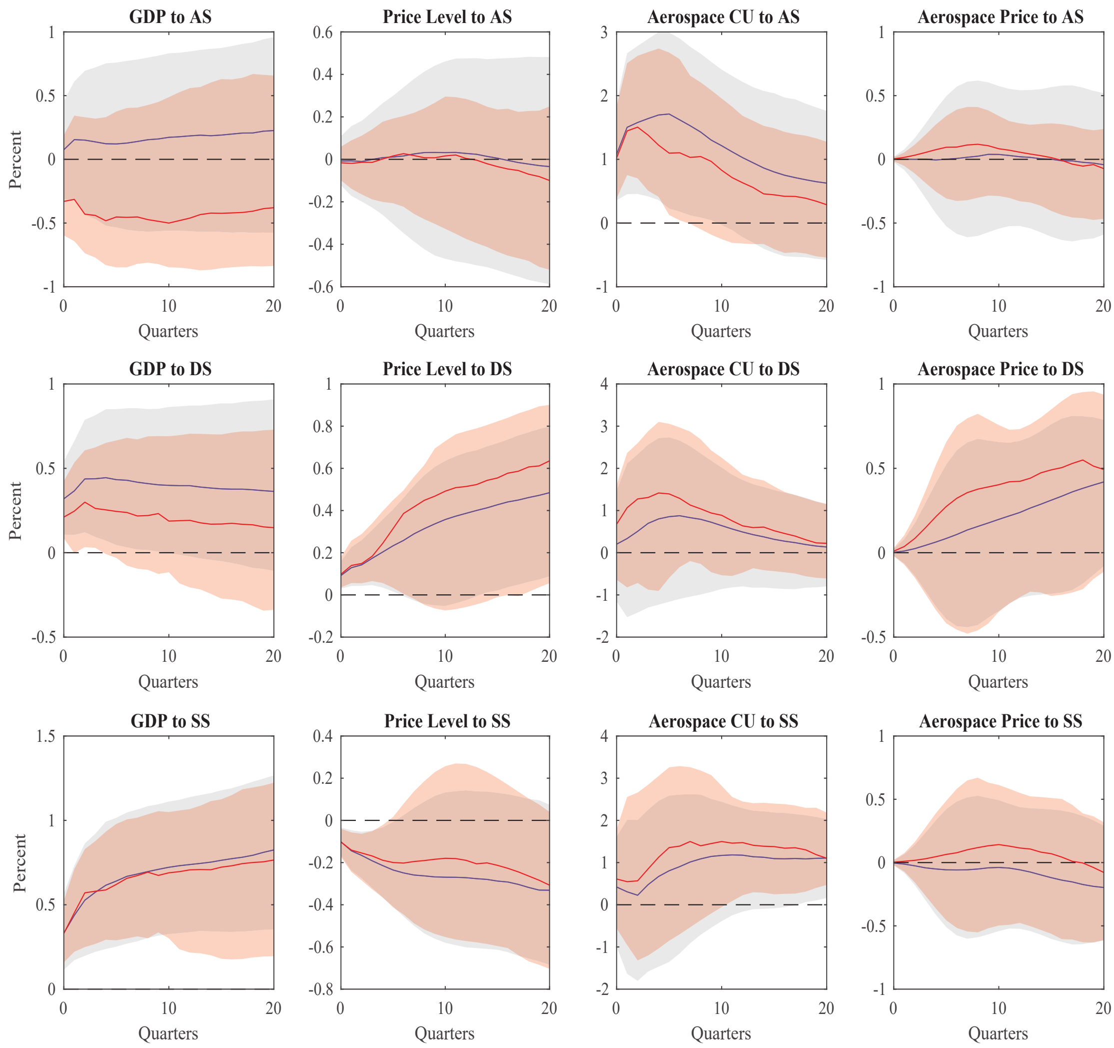

Figure 7: IRFs to One Standard Deviation Aerospace Shock: Event 2

Note: The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

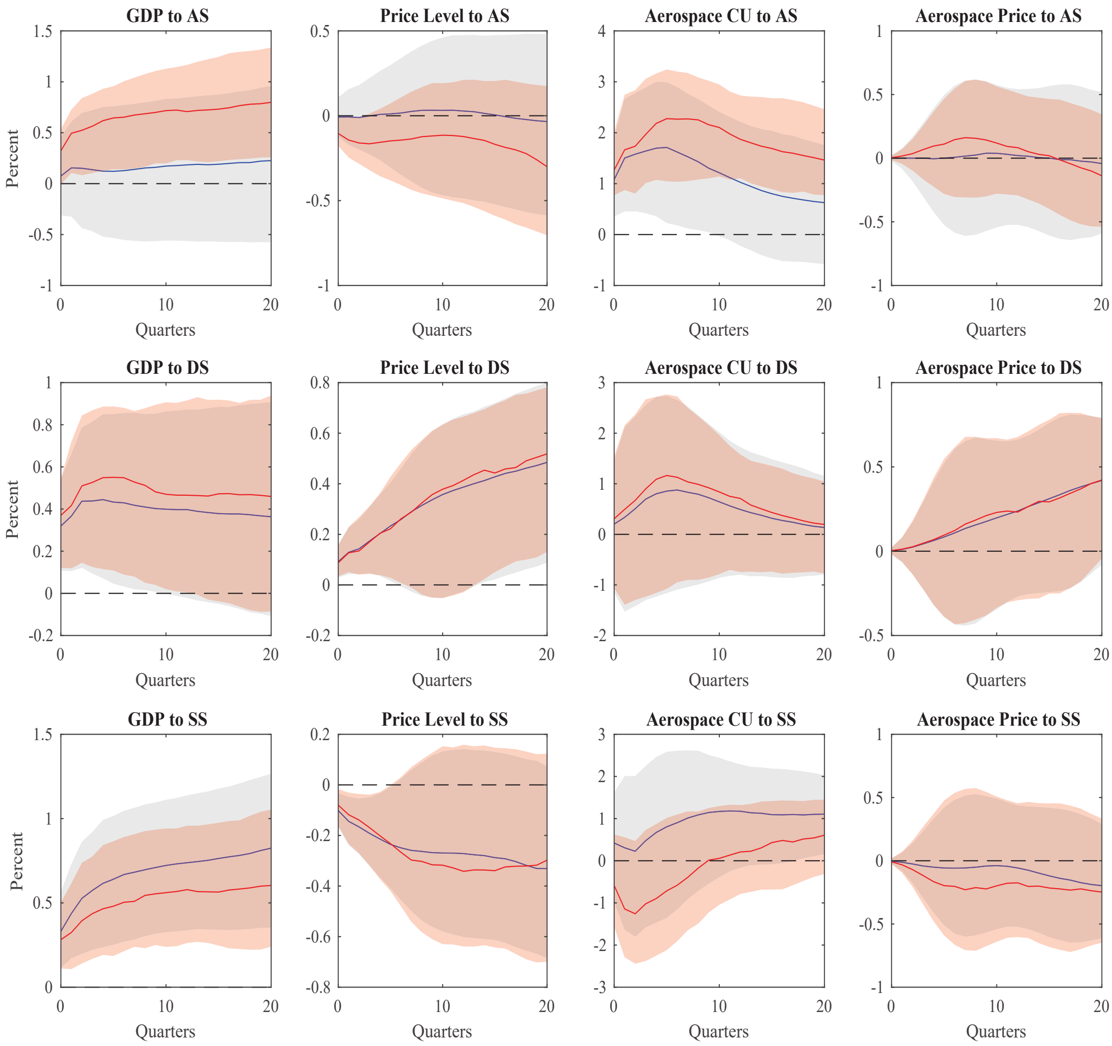

Figure 8: IRFs to One Standard Deviation Aerospace Shock: Event 3

Note: The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

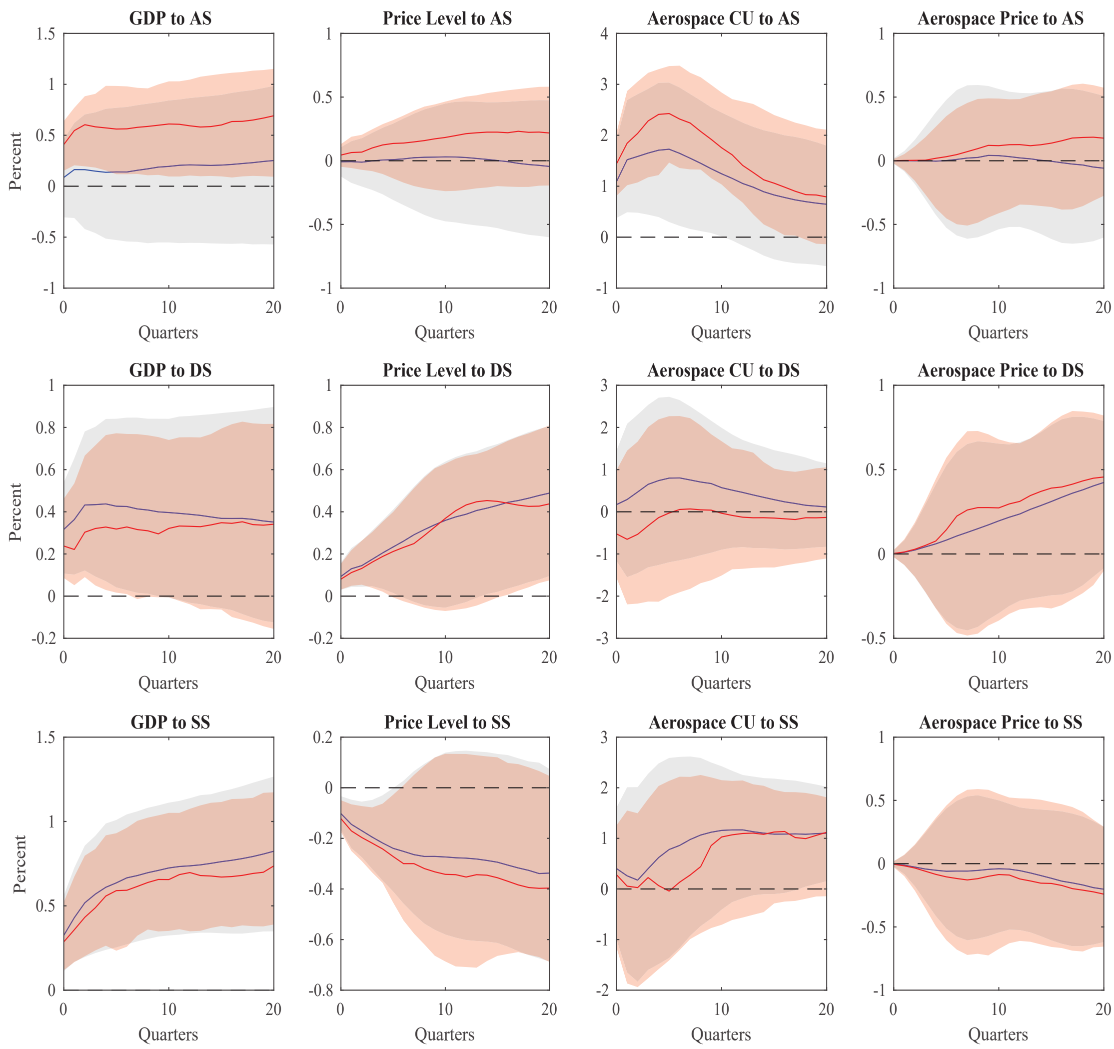

Figure 9: IRFs to One Standard Deviation Aerospace Shock: Event 4

Note: The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

A.2.2 Private Narrative Events

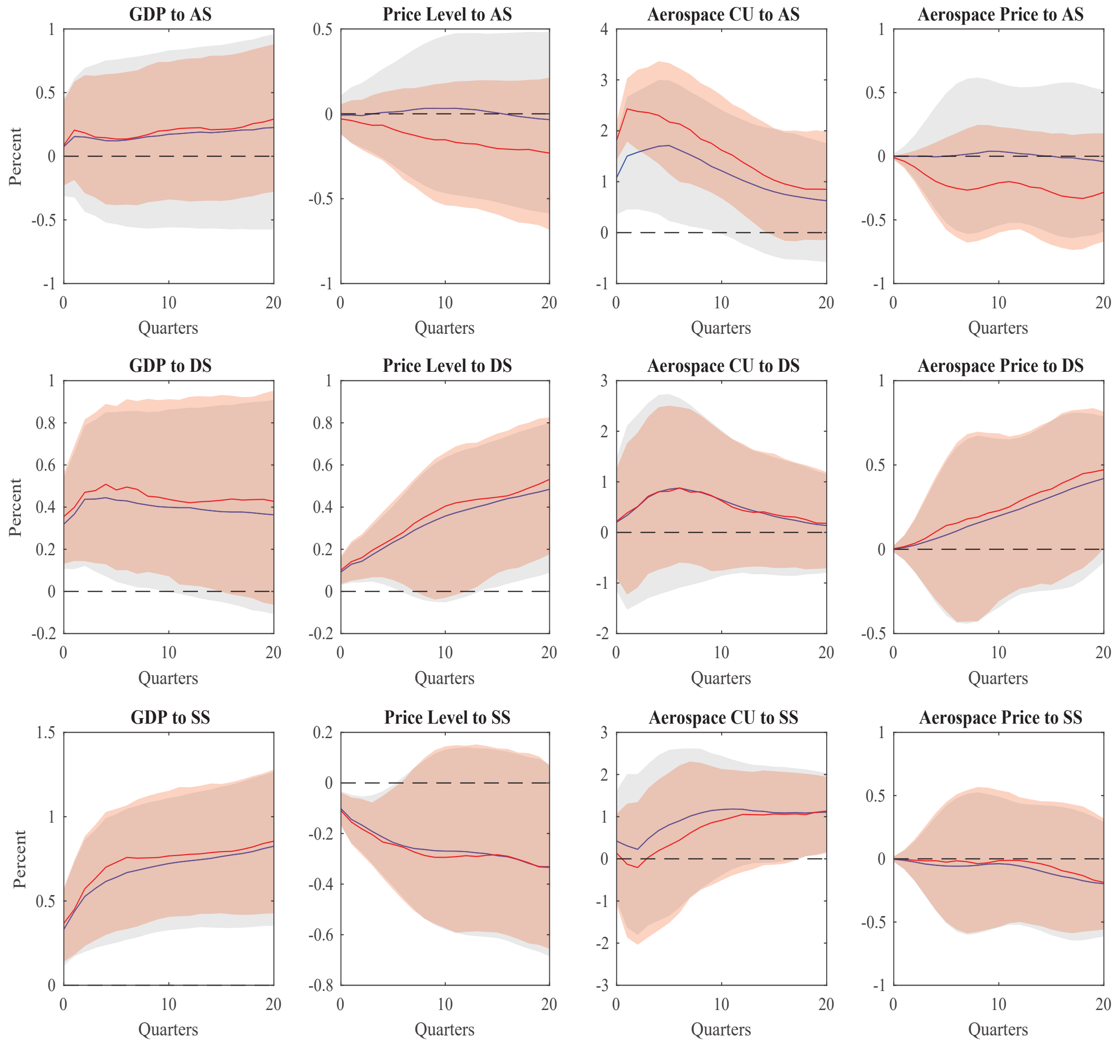

Figure 10: IRFs to One Standard Deviation Aerospace Shock: Event 5

Note: The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

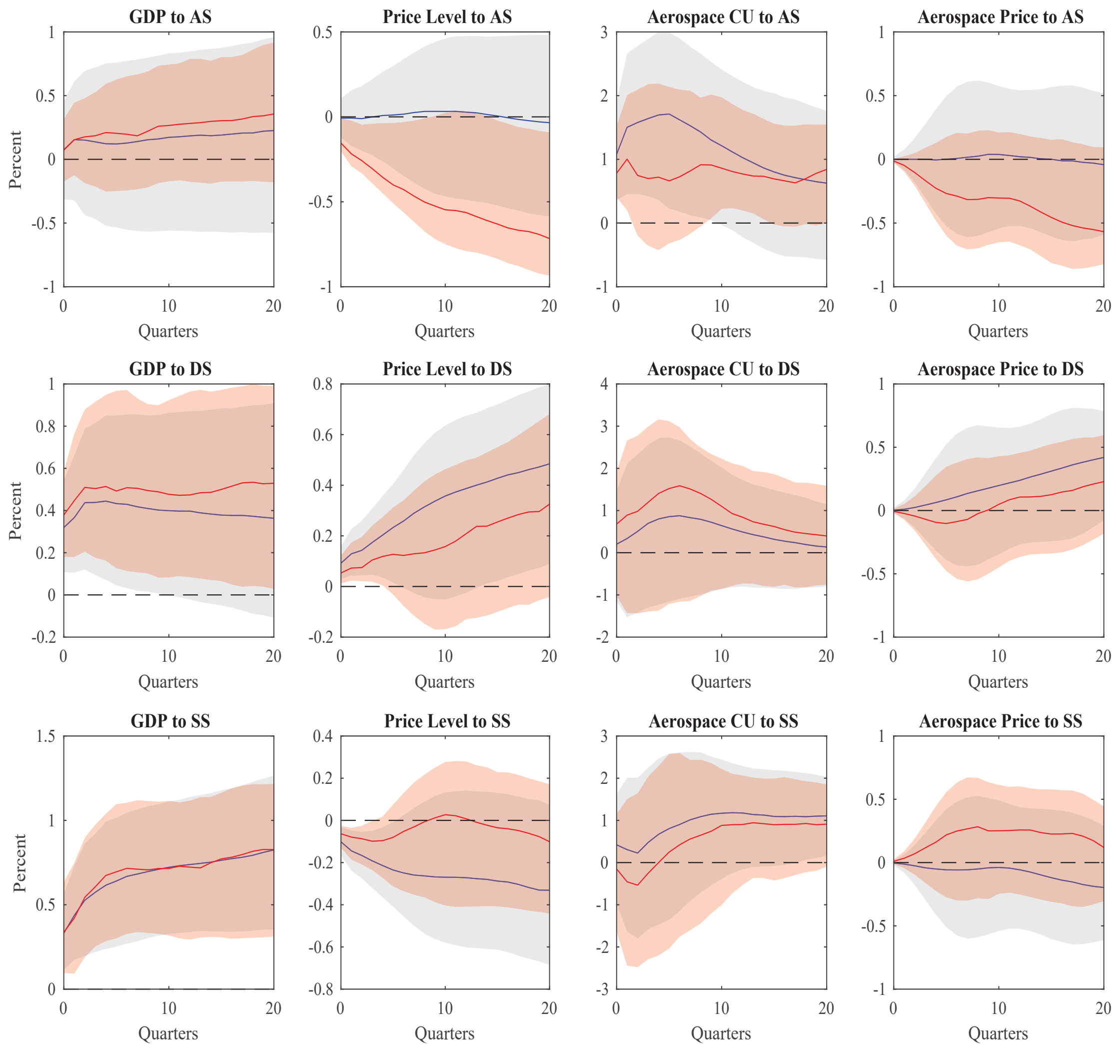

Figure 11: IRFs to One Standard Deviation Aerospace Shock: Event 6

Note: The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

A.3 Are Aerospace Shocks Demand or Supply Driven?

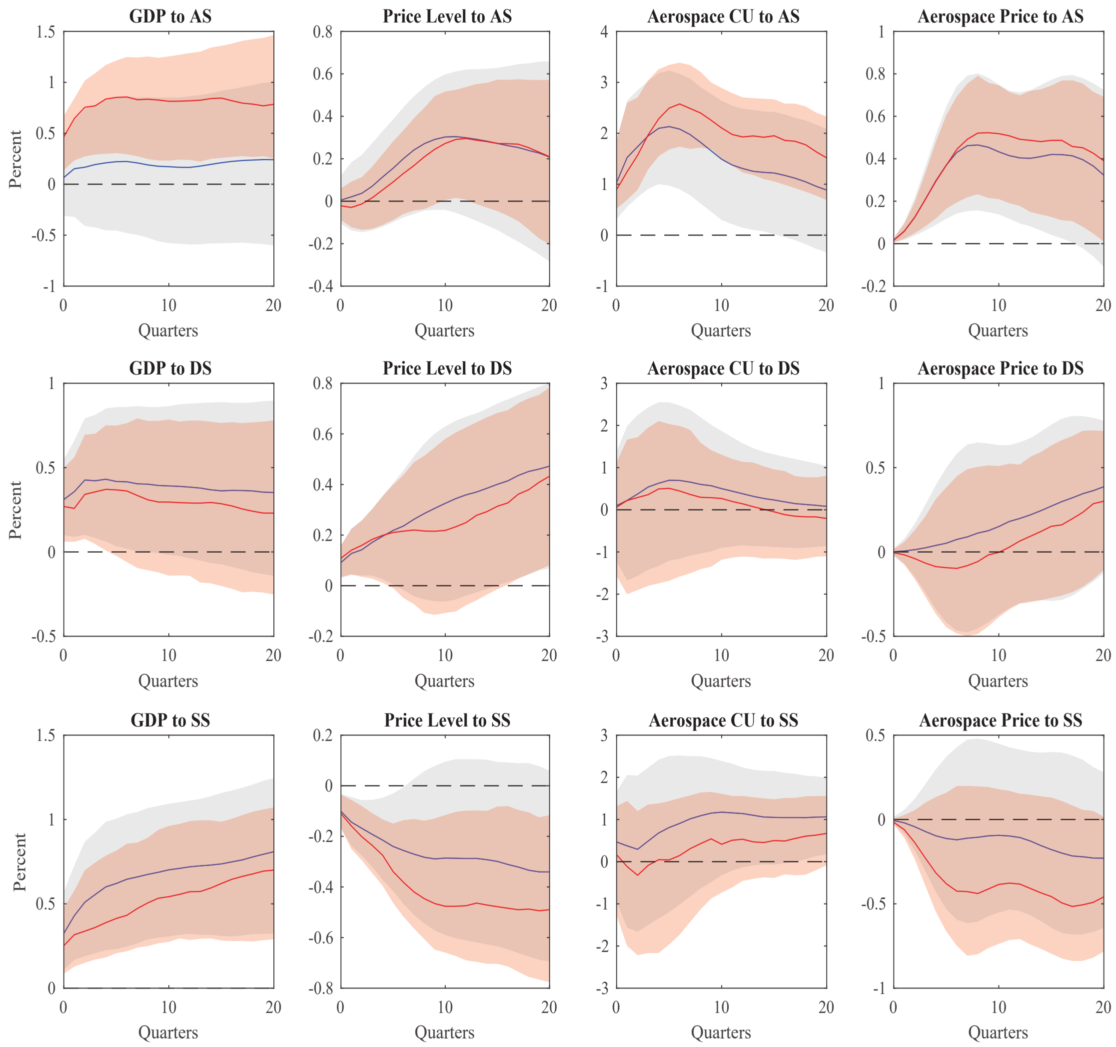

Figure 12: IRFs to One Standard Deviation Aerospace Shock: Event 1 and Positive Aerospace Prices

Note: Imposing a positive sign on aerospace prices upon impact. As if the aerospace shock was demand-driven. The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

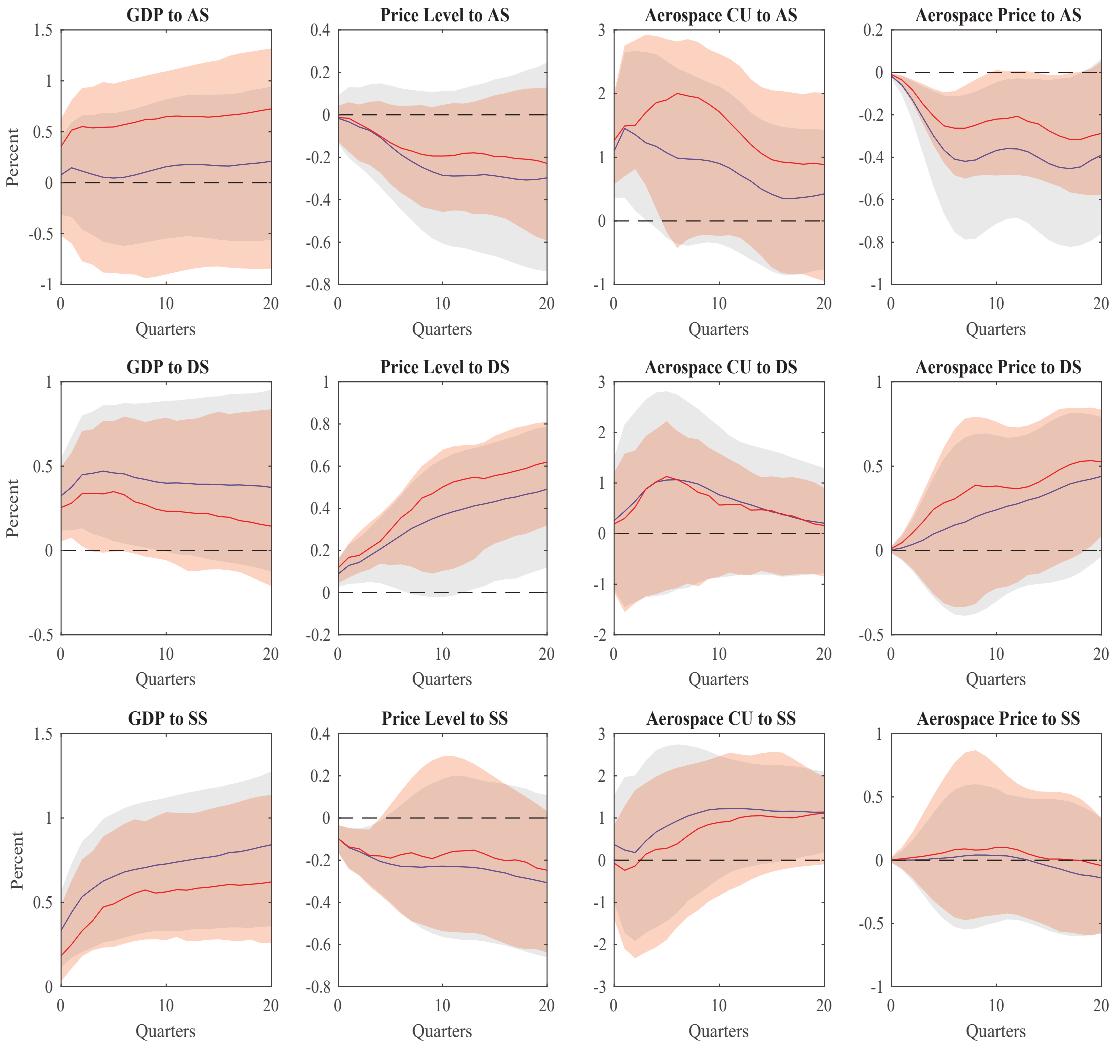

Figure 13: IRFs to One Standard Deviation Aerospace Shock: Event 1 and Negative Aerospace Prices

Note: Imposing a negative sign on aerospace prices upon impact. As if the aerospace shock was supply-driven. The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

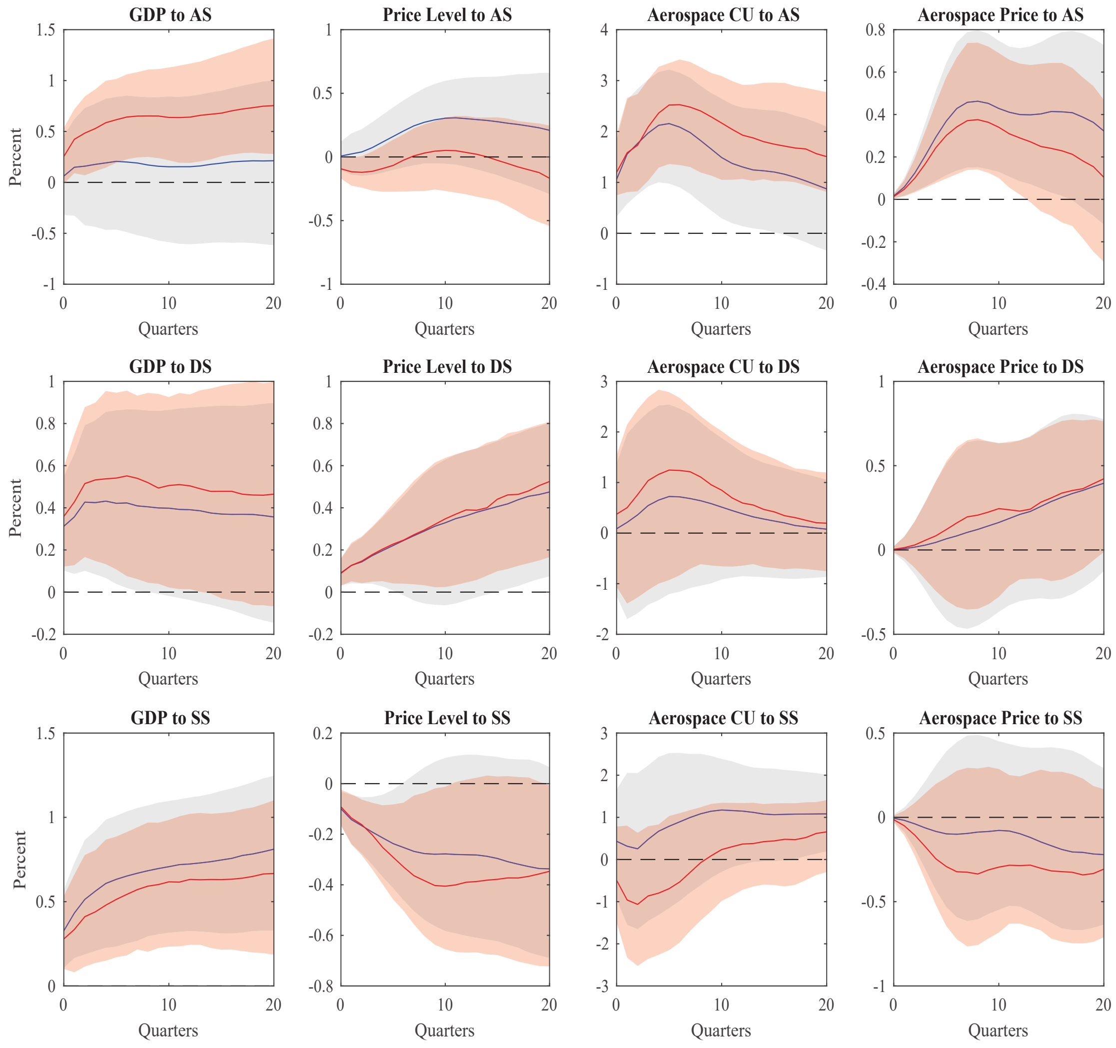

Figure 14: IRFs to One Standard Deviation Aerospace Shock: Event 3 and Positive Aerospace Prices

Note: Imposing a positive sign on aerospace prices upon impact. As if the aerospace shock was demand-driven. The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

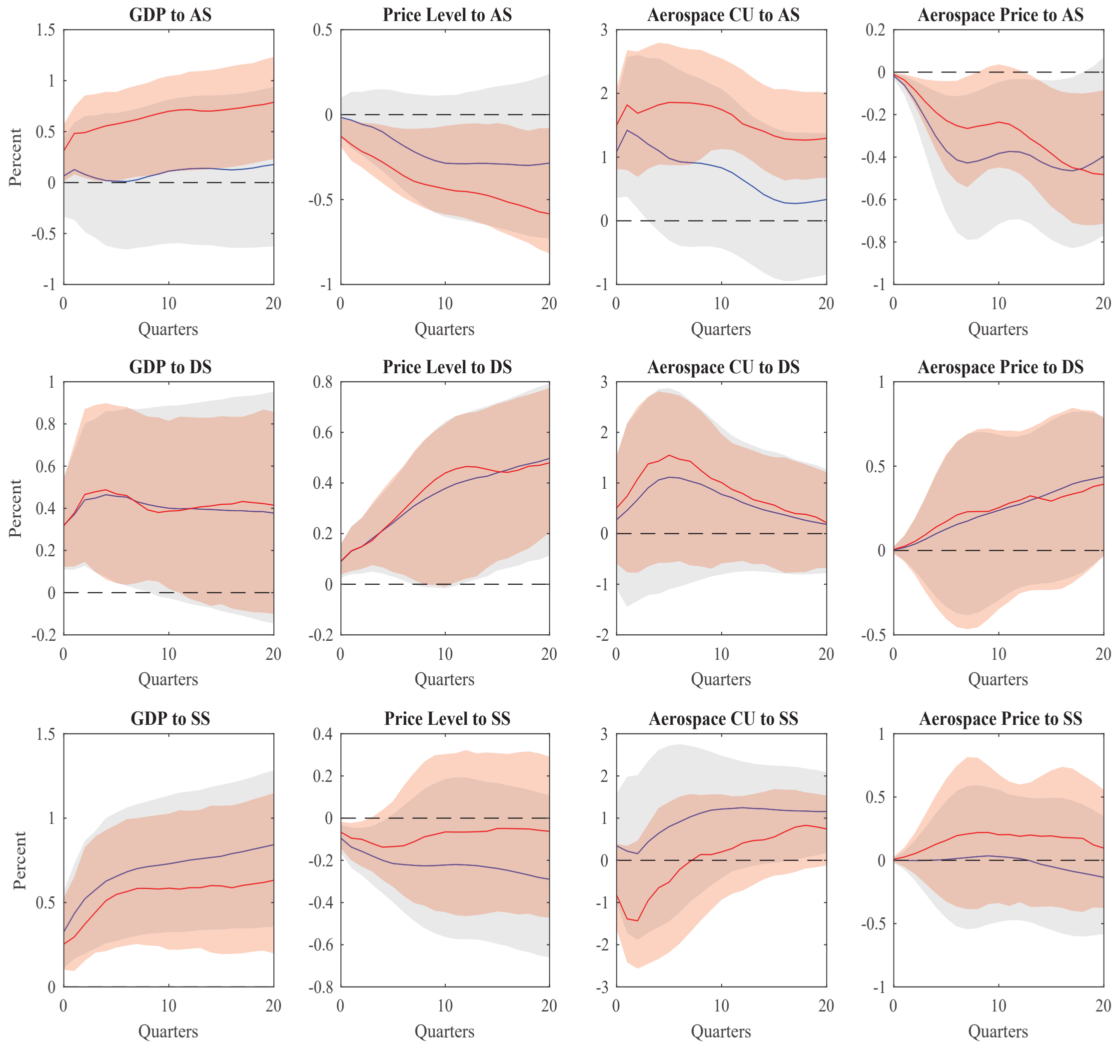

Figure 15: IRFs to One Standard Deviation Aerospace Shock: Event 3 and Negative Aerospace Prices

Note: Imposing a negative sign on aerospace prices upon impact. As if the aerospace shock was supply-driven. The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

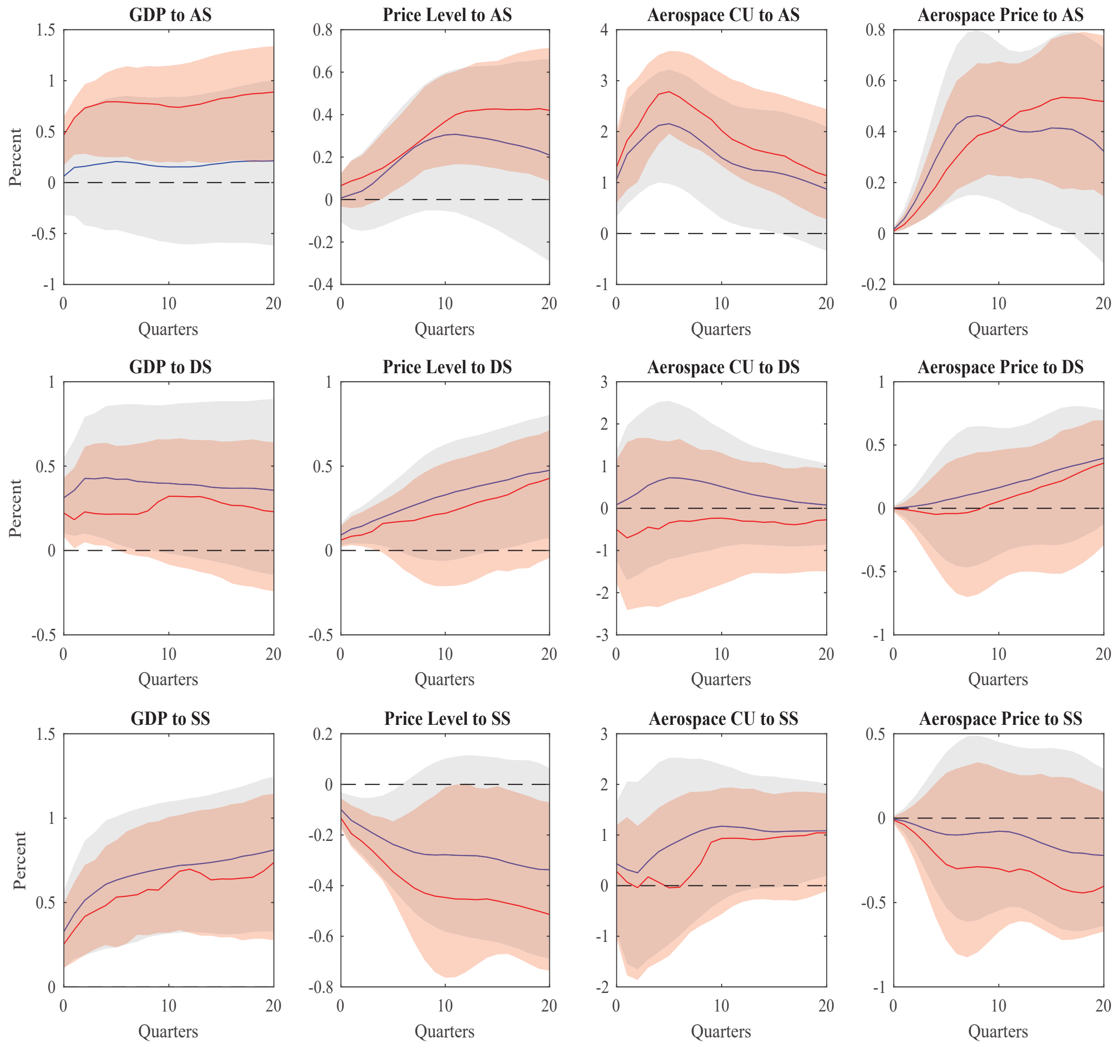

Figure 16: IRFs to One Standard Deviation Aerospace Shock: Event 4 and Positive Aerospace Prices

Note: Imposing a positive sign on aerospace prices upon impact. As if the aerospace shock was demand-driven. The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

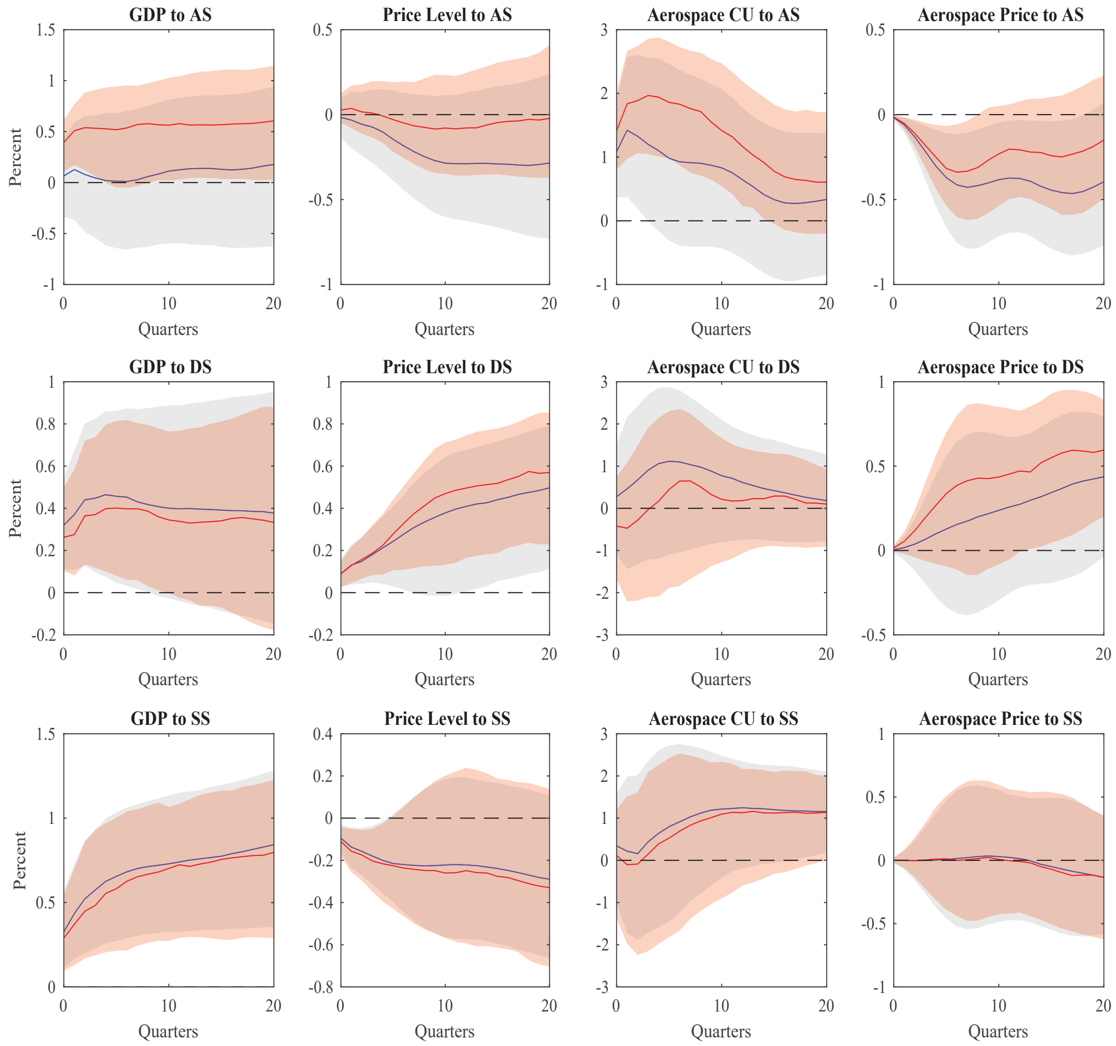

Figure 17: IRFs to One Standard Deviation Aerospace Shock: Event 4 and Negative Aerospace Prices

Note: Imposing a negative sign on aerospace prices upon impact. As if the aerospace shock was supply-driven. The first row exhibits the responses to the aerospace shock (AS), the second row to aggregate demand (DS) and the third row to aggregate supply (SS). The blue lines represent only the IRFs computed with the standard sign restriction identification outlined in Table 2. The red lines show the IRFs by additionally imposing the *Narrative Restriction*. Each entry shows the median and the 68% confidence bands.

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