How Sanctions Reshaped Iran's Economy: Sectoral Reallocation and Technology Downgrading

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Abstract

Economic sanctions can affect development not only by reducing aggregate output but also by changing the composition of production. This paper studies how Iran's post-2012 sanctions episode was associated with sectoral reallocation and manufacturing technology intensity. Using annual World Bank and UNIDO data for 1995–2023, we construct outcome-specific synthetic controls for real GDP, broad sectors, industrial subsectors, and manufacturing technology groups. Real GDP, industry, and services fall below their synthetic paths, with gaps that generally widen after sanctions were reimposed in 2018. Within industry, non-manufacturing activity shows the strongest underperformance. Within manufacturing, medium/high-technology value added displays a larger and more persistent shortfall than low- and medium-low-technology value added, and its share of total manufacturing also declines relative to a synthetic comparison. Agriculture does not show a comparable negative gap. The findings connect the macroeconomic costs of sanctions to a broader development concern: persistent external restrictions may weaken industrial upgrading as well as current output.

Keywords: economic sanctions; Iran; synthetic control; structural transformation; industrial upgrading; manufacturing

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1 Introduction

Economic sanctions are commonly evaluated through their effects on aggregate output, trade, investment, and financial conditions. Their development consequences, however, may extend beyond the size of the initial contraction. When external restrictions disproportionately damage more import-dependent, more productive, or more technology-intensive activities, they can alter the sectoral and technological path of development as well as current income (Felbermayr et al., 2021; Gutmann et al., 2023; McMillan et al., 2014; Rodrik, 2016).

For Iran, existing research has established substantial macroeconomic and social costs from the sanctions regime that intensified in 2011–2012. Synthetic-control and time-series studies document large output losses, weaker oil revenues and growth, exchange-rate depreciation, and persistent macroeconomic disruption, while related work finds adverse distributional consequences for vulnerable households and the middle class (Gharehgozli, 2017; Ghomi, 2022; Laudati and Pesaran, 2023; Farzanegan and Habibi, 2025). This evidence leaves a distinct question unresolved: did sanctions merely reduce the level of economic activity, or did they also reshape the composition of production?

That distinction matters because development depends not only on aggregate growth but also on the ability to sustain and expand productive and technologically dynamic activities. Manufacturing can generate learning, productivity, and linkage benefits, while access to imported intermediates, machinery, and foreign technologies can support productivity growth and domestic product expansion (Szirmai and Verspagen, 2015; Haraguchi et al., 2017; Amiti and Konings, 2007; Goldberg et al., 2010). Restrictions on finance, shipping, payments, imported inputs, and technology may therefore produce heterogeneous losses across sectors and may impede industrial upgrading even when aggregate output later recovers.

We study this question using annual country-level data for 1995–2023 and the synthetic control method (Abadie and Gardeazabal, 2003; Abadie et al., 2010, 2015; Abadie,

2021). For each outcome, we construct a weighted combination of comparison countries that reproduces Iran's pre-sanctions trajectory and observed characteristics. We treat 1995–2011 as the pre-treatment period and 2012 as the first post-treatment year. The outcomes include real GDP; industry, services, and agriculture; manufacturing and non-manufacturing industry; and low- versus medium/high-technology manufacturing. The manufacturing groups follow the technology classification used in UNIDO industrial statistics (Organisation for Economic Co-operation and Development, 2003; United Nations Industrial Development Organization, 2010, 2022, 2023).

The results reveal substantial heterogeneity across the production structure. Real GDP, industry, and services fall below their synthetic paths, and the gaps generally widen after sanctions were reimposed in 2018. The permutation evidence is strongest for industry and non-manufacturing industry. Within manufacturing, medium/high-technology value added displays a larger and more persistent shortfall than low- and medium-low-technology value added, and its share of total manufacturing declines relative to a constructed synthetic comparison. Agriculture does not display a similarly clear negative gap in this design.

The paper's contribution is therefore not another demonstration that sanctions were costly for Iran in aggregate. It shows, within a common and transparent counterfactual framework, that post-2012 underperformance differed across broad sectors, industrial components, and manufacturing technology groups. This extends Iran-specific evidence on aggregate and distributional effects, complements studies showing stronger labor and efficiency losses in import-dependent industries, and connects the sanctions literature to the development question of whether external restrictions can weaken structural transformation and industrial upgrading (Moghaddasi Kelishomi and Nisticò, 2022; Jabari et al., 2024; McMillan et al., 2014; Szirmai and Verspagen, 2015). Because each outcome has its own synthetic control, the estimates are parallel counterfactual comparisons rather than an additive decomposition of GDP. The evidence for technology downgrading is therefore interpreted as relative technological underperformance, not as a separately identified mechanism.

The remainder of the paper proceeds as follows. Section 2 describes the sanctions context. Section 3 reviews the related literature and positions the contribution. Section 4 describes the data, Section 5 presents the empirical design, Section 6 reports the main results, Section 7 presents robustness and sensitivity analyses, and Section 8 concludes.

2 Context

Iran's post-2012 sanctions episode forms part of a longer sequence of external restrictions and political shocks. Since the 1979 Revolution, the economy has experienced the Iran–Iraq War, restrictions on oil exports and foreign-exchange access, and recurrent trade and financial sanctions. The intensity and scope of these restrictions have varied over time, and their observed effects have also depended on domestic policy responses and structural features of the Iranian economy.

The empirical treatment begins in 2012 because the sanctions regime intensified sharply in 2011–2012 and combined oil-related restrictions with broader constraints on banking, insurance, shipping, international payments, and foreign trade. Financial sanctions can restrict access to international payment infrastructure, including the SWIFT network, while trade and financial restrictions can impede imports of machinery and intermediate inputs, investment, and production in sectors connected to external markets (Torbat, 2005; Cipriani et al., 2023; Ghomi, 2022; Laudati and Pesaran, 2023).

The post-treatment period contains meaningful changes in sanctions intensity rather than a single once-and-for-all intervention. The 2015 Joint Comprehensive Plan of Action (JCPOA) temporarily relaxed some external constraints. The United States' withdrawal from the agreement in 2018 and the subsequent reimposition of restrictions created a renewed shock (Ghomi, 2022; Laudati and Pesaran, 2023). The analysis therefore uses 2012 as the first post-treatment year while interpreting the subsequent trajectory as the response to a changing sanctions regime.

Iran's production structure makes heterogeneous responses plausible. Extractive and

resource-linked industry may react sharply to restrictions on oil exports, finance, insurance, and payments. Manufacturing may be exposed through imported machinery, specialized intermediates, technology access, external demand, and exchange-rate pressures. Services may adjust more gradually through domestic demand, financial constraints, and intersectoral linkages. Agriculture may be less directly exposed to international markets, but its counterfactual path is also shaped by weather, water scarcity, environmental conditions, and domestic support policies.

3 Related literature and contribution

This paper relates to four strands of literature. The first studies the economics of international sanctions. Reviews and cross-country evidence show that sanctions have become a prominent instrument of international economic coercion and that their effects vary across targets, sanction types, and transmission channels (Felbermayr et al., 2021; Morgan et al., 2023; Felbermayr et al., 2020). Sanctions reduce GDP growth, trade, consumption, investment, and foreign direct investment on average, with financial restrictions often producing particularly large effects (Neuenkirch and Neumeier, 2015; Gutmann et al., 2023). Firm- and trade-level research likewise documents targeted-firm losses, trade disruption, and unintended costs that extend beyond the formally sanctioned activities (Ahn and Ludema, 2020; Crozet and Hinz, 2020). This literature establishes substantial average costs and heterogeneity but says less about how sanctions reshape the internal production structure of a target economy.

A second strand studies Iran directly. Earlier work emphasizes the relative importance of financial restrictions and the dynamic macroeconomic effects of sanctions (Torbat, 2005; Dizaji and van Bergeijk, 2013). Structural and reduced-form studies document aggregate and distributional losses (Gharibnavaz and Waschik, 2018; Ghasseminejad and Jahan-Parvar, 2021). The two closest papers use synthetic control to estimate aggregate GDP losses: Gharehgozli (2017) studies the 2011–2014 episode, while Ghomi (2022)

documents persistent macroeconomic effects and poverty dynamics during and after the 2012–2015 sanctions. Laudati and Pesaran (2023) use a newspaper-based sanctions-intensity measure to identify effects through oil revenues, the exchange rate, inflation, and output growth. More recent evidence shows a substantial contraction of Iran's middle class after 2012 (Farzanegan and Habibi, 2025). These studies establish that sanctions imposed broad economic and social costs, but they do not provide a common counterfactual comparison across the production sectors and manufacturing technology groups studied here.

The Iran evidence also shows that the burden of sanctions is neither narrow nor perfectly targeted. Distributional analyses find important losses among vulnerable households and the middle class (Ghomi, 2022; Gharibnavaz and Waschik, 2018; Farzanegan and Habibi, 2025). Using text from meetings of publicly listed Iranian firms, Shamsi (2024) develops a firm-level measure of sanctions exposure and reports that politically connected and non-connected firms are affected alike; more exposed firms experience larger stock-market losses and lower sales and investment. This evidence supports a cautious fairness concern: measures directed at political decision-makers can impose substantial costs on households and ordinary firms with little influence over the targeted policies. The present paper does not estimate welfare incidence directly, but its sectoral evidence helps describe how widely those economic costs extend through production.

A third strand examines heterogeneous effects across firms, industries, and channels of external exposure. Iranian exporters redirected trade toward non-sanctioning destinations after sanctions (Haidar, 2017). Within manufacturing, Moghaddasi Kelishomi and Nisticò (2022) find stronger employment losses in labor-intensive and import-dependent industries, while Jabari et al. (2024) report larger energy-efficiency losses in industrial subsectors with greater import dependence. Related work documents changes in informal and shadow activity (Farzanegan, 2013; Farzanegan and Hayo, 2019). These findings imply that external finance, imported inputs, and international market access can make some activities more vulnerable than others. This paper extends that evidence from employment, efficiency, and trade outcomes to real value added across broad sectors,

industrial components, and manufacturing technology groups.

Finally, the paper speaks to the structural-transformation literature in development economics. Long-run development depends not only on aggregate growth but also on the allocation of activity toward more productive and technologically dynamic sectors (McMillan et al., 2014; Rodrik, 2016). Manufacturing remains an important, although increasingly difficult, route to growth and upgrading in developing economies (Szirmai and Verspagen, 2015; Haraguchi et al., 2017). Access to imported intermediates and foreign technologies can raise productivity and expand domestic product scope (Amiti and Konings, 2007; Goldberg et al., 2010). From this perspective, sanctions may matter not only because they lower current output but also because they can obstruct industrial upgrading by disproportionately weakening externally connected and technology-intensive activities. The paper provides evidence on this question by comparing Iran's broad sectors, industrial composition, and manufacturing technology groups within a unified synthetic-control framework.

Methodologically, the paper follows the synthetic-control literature initiated by Abadie and Gardeazabal (2003) and developed by Abadie et al. (2010, 2015). We follow the practical guidance in Abadie (2021) by disclosing donor selection and predictors, examining pre-treatment fit, reporting actual–synthetic paths, and using in-space and in-time placebo exercises. The analysis also recognizes that imperfect pre-treatment fit and researcher discretion over predictors can affect interpretation (Ferman and Pinto, 2021; Ferman et al., 2020); permutation rankings and RMSPE ratios follow the inferential logic discussed by Firpo and Possebom (2018). These are safeguards for a substantive comparative-case application rather than a methodological contribution.

4 Data

The analysis combines annual country-level data from the World Bank and the United Nations Industrial Development Organization (UNIDO) for 1995–2023. World Bank se-

ries provide real GDP and broad-sector value added, while UNIDO industrial statistics provide manufacturing outcomes and the variables used to construct manufacturing technology groups. Monetary outcomes are measured primarily in constant 2015 US dollars so that actual and synthetic paths are comparable in real terms.

The outcome set is designed to distinguish aggregate contraction from changes in the composition of production. The aggregate outcome is real GDP. The broad-sector outcomes are industry, services, and agriculture value added. Non-manufacturing industry is calculated as total industry value added minus manufacturing value added after harmonizing the component series to constant 2015 US dollars; the accounting identity was checked across the country-year panel. Manufacturing is divided into medium- and high-technology and low- and medium-low-technology activities using the OECD/UNIDO ISIC classification (Organisation for Economic Co-operation and Development, 2003; United Nations Industrial Development Organization, 2010). Table 14 reports the activities included in the medium- and high-technology group.

The donor pool is common across outcomes to preserve comparability. Countries with missing observations in one or more required sectoral or manufacturing variables are excluded even when their GDP series are complete. The remaining screening criteria are ex ante: we exclude countries subject to comparable sanctions or other major economic or political shocks likely to create substantial structural breaks, and countries for which economically important spillovers from sanctions on Iran were expected. These rules were fixed independently of the post-treatment estimates and placebo rankings. Table 2 lists the 36 retained countries.

Table 1 summarizes the balanced panel of Iran and the 36 donor countries. With 29 annual observations for 37 countries, the reported sample contains 1,073 country-year observations. The table describes macroeconomic size, broad-sector value added, trade exposure, and manufacturing indicators used to characterize the sample and construct the outcome-specific synthetic controls.

The data impose two principal limitations. First, country-level value-added series do

not observe firm-level mechanisms, input shortages, informal-sector responses, or reallocation within the reported categories. Second, sectoral outcomes may reflect measurement error, reporting changes, commodity prices, drought, water scarcity, and domestic policy. The estimates are therefore interpreted as net counterfactual gaps conditional on the synthetic-control design, not as direct evidence that any single transmission channel generated the observed paths.

5 Methodology

The synthetic control method constructs an explicit counterfactual for Iran from a weighted combination of untreated countries (Abadie and Gardeazabal, 2003; Abadie et al., 2010, 2015; Abadie, 2021). Rather than selecting a single comparison country, the method chooses nonnegative donor weights that reproduce the treated country's pre-intervention predictors and outcome trajectory.

Let country $i = 1$ denote Iran and countries $i = 2, \ldots, J + 1$ the donor pool. The baseline pre-treatment period is 1995–2011, and 2012 is the first post-treatment year. Let Y_{it}^N denote the potential outcome in the absence of the post-2012 sanctions regime and Y_{it}^I the observed outcome under that regime. For Iran after 2011, Y_{1t}^N is unobserved and must be approximated.

SCM approximates Iran's untreated counterfactual as a convex combination of donor countries. Let $W = (w_2, \ldots, w_{J+1})'$ be a vector of nonnegative weights such that

$$w_j \geq 0 \quad \text{for all } j = 2, \ldots, J + 1, \quad \sum_{j=2}^{J+1} w_j = 1. \tag{1}$$

The weights are chosen so that the synthetic control resembles Iran before the sanctions period.

The optimal weight vector is selected by matching pre-treatment predictors and lagged outcomes. Let X_1 be a vector of pre-treatment characteristics for Iran and let X_0 be the

corresponding matrix for the donor countries. The optimal weights solve

$$W^* = \arg\min_W (X_1 - X_0 W)' V (X_1 - X_0 W), \tag{2}$$

subject to the nonnegativity and adding-up constraints. The matrix V assigns relative importance to predictors and is selected to improve pre-treatment fit for the outcome.

The estimated no-sanctions path applies the fitted donor weights to post-treatment donor outcomes:

$$\widehat{Y}_{1t}^N = \sum_{j=2}^{J+1} w_j^* Y_{jt}, \quad t > T_0. \tag{3}$$

The estimated post-treatment counterfactual gap is

$$\widehat{\alpha}_{1t} = Y_{1t} - \widehat{Y}_{1t}^N = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt}. \tag{4}$$

Throughout the paper, $\widehat{\alpha}_{1t}$ is interpreted as a synthetic-control gap under the assumptions that the weighted donors approximate Iran's untreated trajectory and that the sanctions episode did not materially affect donor outcomes. The donor-screening rules are intended to reduce obvious violations of the latter condition, but the assumptions cannot be tested fully.

The procedure is implemented separately for every outcome. Predictor sets combine pre-treatment averages or lags of the outcome with macroeconomic and structural characteristics. Outcome-specific estimation improves the fit of each series but means that the sectoral gaps are not additive because different outcomes can select different weights. The sum of the separately estimated sectoral gaps is therefore not interpreted as the direct GDP effect. Predictor-balance and donor-weight tables make the specification transparent and reduce the risk that post-treatment results are driving specification choices (Ferman et al., 2020).

Inference combines pre-treatment fit with in-space permutations. For each outcome, the root mean squared prediction error (RMSPE) summarizes the actual–synthetic gap

before and after treatment, and the post/pre-RMSPE ratio measures how sharply fit deteriorates after 2011. A placebo unit is usable when its pre-treatment RMSPE, post-treatment RMSPE, and post/pre-RMSPE ratio are non-missing and its pre-treatment RMSPE is nonzero. No additional pre-treatment-fit threshold is applied. Iran's ratio is ranked against the usable placebo ratios obtained by assigning treatment to donor countries. The pseudo-p-value equals the number of usable placebo units with a ratio at least as large as Iran's, plus Iran, divided by the total number of usable units including Iran. For outcomes with a denominator of 34 rather than 35, one placebo unit could not produce a valid ratio because of a numerical calculation error. These values are interpreted as finite-sample randomization rankings rather than conventional large-sample significance tests (Abadie et al., 2010, 2015; Firpo and Possebom, 2018).

Robustness analyses evaluate different threats to interpretation. In-time placebos test whether comparable divergences appear at false pre-treatment dates. Leave-one-out estimates assess dependence on individual positive-weight donors. Direct, indirect, and accounting-aggregation constructions assess whether the main patterns depend on one implementation of sectoral accounting. Where pre-treatment fit is weaker or donor sensitivity is greater, the conclusions are correspondingly more cautious (Ferman and Pinto, 2021).

6 Results

The results move from aggregate output to progressively finer measures of production structure. Section 6.1 establishes the real-GDP benchmark. Section 6.2 compares the three broad sectors. Sections 6.3 and 6.4 then examine heterogeneity within industry and within manufacturing. Because every outcome has its own synthetic control, the comparisons identify differences across counterfactual paths rather than an accounting decomposition of GDP.

6.1 Aggregate effect of sanctions

The real-GDP specification provides the aggregate benchmark for the sectoral analysis. Table 3 reports the donor weights, and Table 4 compares Iran with synthetic Iran on the pre-treatment predictors. Pakistan receives the largest weight, followed by Norway, Korea, Kazakhstan, Indonesia, China, and Azerbaijan. The predictor balance and close pre-treatment tracking in Figure 1 support the synthetic path as a counterfactual benchmark; Table 5 reports the corresponding permutation diagnostics.

Figure 1 shows a persistent negative divergence after 2012. The actual and synthetic paths track closely before treatment. The gap opens during the initial sanctions period, narrows during 2016–2017 after the JCPOA, and widens again following the renewed tightening of sanctions in 2018.

The magnitude and timing are consistent with prior Iran evidence, while the longer sample documents persistence through 2023 (Gharehgozli, 2017; Ghomi, 2022; Laudati and Pesaran, 2023). The direct real-GDP gap is −37.70 billion US dollars in 2012 and −84.10 billion in 2015. It narrows in 2016–2017 and then reaches −147.34 billion in 2019. Actual GDP in 2019 was 431.11 billion US dollars, compared with an implied synthetic level of 578.45 billion, a shortfall of approximately 25.5 percent. The largest direct gap occurs before the COVID-19 shock, which is consistent with renewed sanctions after the US withdrawal from the JCPOA, although the design cannot exclude every contemporaneous domestic or external shock.

The permutation rankings support a large but not conventionally precise aggregate effect. Through 2015 and 2019, Iran's post/pre-RMSPE ratio ranks second among 35 comparisons (pseudo-$p = 0.057$); through 2023, it ranks third (pseudo-$p = 0.086$). The aggregate result therefore confirms the sign and persistence of earlier findings, but the main contribution of the paper lies in how the shortfall differs across the production structure.

6.2 Sectoral heterogeneity: industry, services, and agriculture

The broad-sector comparison asks whether the aggregate shortfall is concentrated in particular parts of the economy. Industry can be exposed directly through oil and resource extraction as well as through imported machinery, finance, and exchange-rate pressures. Services may adjust through domestic demand, financial constraints, and linkages with industry. Agriculture is less directly connected to many sanctions channels but is difficult to interpret because weather, water, and domestic policy also shape its path.

Industry exhibits the strongest broad-sector evidence. Table 6 reports the industry weights, and Table 7 documents pre-treatment predictor balance. Figure 2 shows that industrial value added follows synthetic Iran before treatment and then falls sharply below the counterfactual, with especially large volatility around the post-2018 sanctions period. Through 2023, industry's post/pre-RMSPE ratio ranks second among 35 comparisons (pseudo-$p = 0.057$), and it ranks first through both 2015 and 2019 (pseudo-$p = 0.029$). This extends the aggregate evidence of Ghomi (2022) and Laudati and Pesaran (2023) by locating a substantial part of the underperformance in production exposed to oil, finance, trade, and investment constraints.

Services display a slower but persistent divergence. Table 8 reports the donor weights, and Table 9 shows close matching on the principal pre-sanctions outcome lags. Figure 3 indicates that the services gap widens gradually rather than appearing as an immediate collapse. Through 2019, the post/pre-RMSPE ratio ranks third among 35 comparisons (pseudo-$p = 0.086$), while through 2023 it ranks fifth (pseudo-$p = 0.143$). The pattern is consistent with broader demand, investment, financial, and intersectoral effects documented in the macroeconomic literature, but the sector-level design does not identify these channels separately.

Agriculture does not show a comparable negative gap. Tables 10 and 11 report the agricultural specification, whose pre-treatment fit is weaker than for GDP and industry. Figure 4 shows observed agricultural value added generally above the synthetic path after 2012, and the 2023 placebo rank is twentieth among 35 comparisons (pseudo-$p = 0.571$).

This is best interpreted as an absence of a comparable negative result in the present design, not as evidence that sanctions benefited agriculture or left it unaffected.

Table 12 summarizes the annual sectoral gaps. Over 2012–2023, the average gap is approximately −41.0 billion US dollars for industry and −50.4 billion for services, while agriculture averages a positive 4.2 billion. The table's accounting-based aggregate is constructed from sectoral components, whereas the direct real-GDP column reports the outcome-specific GDP synthetic control. The difference between them reflects separate outcome-specific estimations and is used as a sensitivity comparison, not as an additive decomposition. Figure 5 provides complementary descriptive evidence on sectoral shares but is not included in the level-outcome permutation inference.

6.3 Heterogeneity within industry

The industrial results differ between manufacturing and non-manufacturing activity. Non-manufacturing industry is total industry value added minus manufacturing value added and therefore includes extractive activity, construction, utilities, and other non-manufacturing industrial production. This distinction separates the resource-linked component of industry from manufacturing activities that may respond through imported inputs, machinery, finance, and demand.

Figure 6 shows negative post-treatment gaps for both components, but non-manufacturing industry is more volatile and displays the stronger permutation evidence. Through 2023, its post/pre-RMSPE ratio ranks second among 35 comparisons (pseudo-$p = 0.057$), compared with ninth for total manufacturing (pseudo-$p = 0.257$). Through 2015, non-manufacturing industry ranks first (pseudo-$p = 0.029$). The result is consistent with earlier evidence that oil, external payments, and financial restrictions are central macroeconomic channels in Iran (Torbat, 2005; Ghomi, 2022; Laudati and Pesaran, 2023). It also provides a new sectoral-value-added counterpart to that channel evidence, although it does not isolate oil extraction from the other activities contained in the residual category.

The weaker manufacturing rank does not imply that manufacturing was unaffected. The level gap remains economically meaningful, but its position in the placebo distribution warrants more cautious language than for industry or non-manufacturing industry. The next subsection examines whether manufacturing underperformance is concentrated in activities with different technological intensity.

6.4 Heterogeneity within manufacturing

The technology-group comparison asks whether sanctions were associated with weaker performance in the more technology-intensive parts of manufacturing. The analysis divides manufacturing into medium- and high-technology and low- and medium-low-technology activities using the OECD/UNIDO classification. This distinction matters for development because industrial upgrading depends on manufacturing composition as well as total manufacturing output. Technology-intensive production may be particularly exposed to constraints on imported machinery, specialized inputs, foreign technology, finance, and international markets, but the country-level design does not identify these mechanisms separately.

Table 13 reports the pre-treatment balance for medium/high-technology manufacturing. The synthetic control closely matches GDP per capita, manufactured-goods imports, and the 2004–2010 outcome levels, while the 1998 lag is less closely matched. Figure 7 shows that both technology groups track their synthetic paths relatively closely before treatment, followed by a more pronounced and persistent divergence for medium/high-technology manufacturing.

The permutation evidence is consistent with, but does not prove, differential technological underperformance. Through 2023, the medium/high-technology post/pre-RMSPE ratio ranks third among 35 comparisons (pseudo-$p = 0.086$), and through 2019 it ranks second among 34 (pseudo-$p = 0.059$). Low- and medium-low-technology manufacturing ranks fourth among 34 through 2023 (pseudo-$p = 0.118$). The rankings do not establish a statistically sharp difference between the two groups, and the leave-one-out analysis

shows that the magnitude of the medium/high-technology path is sensitive to individual donors.

The technology pattern complements emerging industry-level evidence for Iran. Moghaddasi Kelishomi and Nisticò (2022) find stronger manufacturing-employment losses in import-dependent industries, and Jabari et al. (2024) find larger energy-efficiency losses in more import-dependent industrial subsectors. The imported-input literature also shows that access to foreign intermediates can raise productivity and product scope (Amiti and Konings, 2007; Goldberg et al., 2010). The present results extend those findings from employment and efficiency to manufacturing value added and composition: Figure 8 shows Iran's medium/high-technology share falling after the mid-2010s while the constructed synthetic share rises. Because the share comparison is descriptive and is not included in Table 5, "technology downgrading" denotes relative underperformance in technology-intensive outcomes rather than a separately identified causal mechanism.

7 Robustness and sensitivity analysis

7.1 Permutation inference and subperiods

Table 5 evaluates how unusual Iran's post-treatment deterioration in fit is relative to the donor countries. Reporting endpoints in 2015, 2019, and 2023 separates the initial sanctions episode, the pre-pandemic period after renewed sanctions, and the complete post-treatment sample. The strongest and most consistent rankings are for industry and non-manufacturing industry. GDP and medium/high-technology manufacturing also appear near the upper tail, whereas services and total manufacturing have economically large level gaps but weaker rankings, and agriculture has neither a negative gap nor an unusual ratio.

Table 15 complements the rankings with average dollar gaps over four policy-relevant

intervals. GDP and services gaps widen substantially after 2018. Industry and non-manufacturing industry partially recover from their 2018–2019 troughs but remain below their synthetic paths in 2020–2023. Medium/high-technology manufacturing continues to deteriorate in the final subperiod, while the low- and medium-low-technology gap is comparatively stable. These subperiods are descriptive summaries of a changing sanctions regime rather than estimates of separate treatments.

7.2 Alternative counterfactual constructions

Alternative constructions test whether the main conclusions depend on estimating each level outcome directly. The direct method applies SCM to the displayed outcome. The indirect method estimates sectoral shares and aggregate GDP separately and reconstructs sectoral value added by multiplying the synthetic share by synthetic GDP. The accounting-aggregation method constructs synthetic components and sums them. Differences across these paths measure sensitivity to counterfactual construction rather than distinct economic mechanisms.

Figure 9 shows that the main qualitative patterns for GDP and industry are visible across the available direct, indirect, and accounting-aggregation constructions. Services and agriculture display the direct and indirect paths available for those outcomes. Figure 10 provides the corresponding comparison for manufacturing. Agreement across constructions strengthens the directional findings, but it does not overcome weaker placebo rankings for services and manufacturing or the fit limitations of agriculture.

7.3 In-time placebo tests

Figure 11 re-estimates each synthetic control using artificial intervention dates before 2012 and only information preceding the false date. Across the eight outcomes, the false-date paths generally remain close before the actual sanctions period, while sustained divergences emerge later. The exercise is most informative for outcomes with strong

pre-treatment fit and should be interpreted together with the in-space rankings.

7.4 Leave-one-out sensitivity

Figures 12 and 13 assess dependence on individual positive-weight donors. Each displayed alternative removes the named donor and fully re-estimates the synthetic control. The direction of the principal GDP, industry, services, non-manufacturing, manufacturing, and medium/high-technology gaps is generally preserved. The magnitude of the medium/high-technology result is more donor-sensitive, especially when China is excluded, which is why the paper treats the technology-upgrading interpretation more cautiously than the core industry result. Leave-one-out exercises do not address shocks shared by several donors.

8 Conclusion

This paper reframes Iran's post-2012 sanctions episode as a question of production structure as well as aggregate output. Outcome-specific synthetic controls show a persistent real-GDP shortfall and substantial heterogeneity across sectors. Industry and services fall below their synthetic paths, while agriculture does not display a comparable negative result. Within industry, the strongest permutation evidence is for non-manufacturing activity. Within manufacturing, medium/high-technology production shows a more persistent shortfall than lower-technology production, and its share of manufacturing declines relative to a constructed synthetic comparison.

The estimates identify net counterfactual gaps rather than separate transmission mechanisms. Country-level data cannot distinguish the respective roles of oil exports, banking and payment restrictions, imported inputs, exchange-rate movements, domestic policy, or firm-level adjustment. The sectoral estimates are not additive because each outcome uses a different synthetic control. The manufacturing-share evidence is descriptive rather than permutation-based, and the magnitude of the medium/high-technology

result is sensitive to individual donors. Agriculture should therefore be interpreted as an absence of a comparable negative gap, not as evidence of a beneficial sanctions effect.

Subject to these limitations, the results suggest that the development costs of sanctions can extend beyond contemporaneous GDP losses. The clearest evidence concerns industry and resource-linked non-manufacturing activity, while the manufacturing results are consistent with weaker industrial upgrading. The broader implication is that external restrictions may influence not only how much an economy produces but also the productive capabilities it sustains. Establishing the underlying firm- and input-level mechanisms is an important direction for future research.

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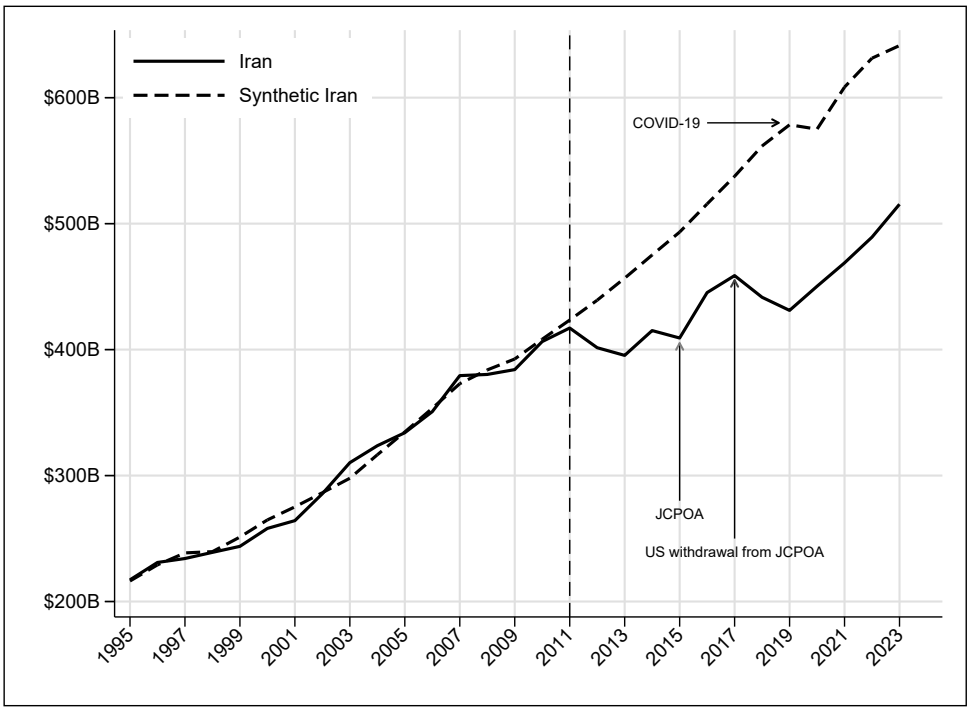
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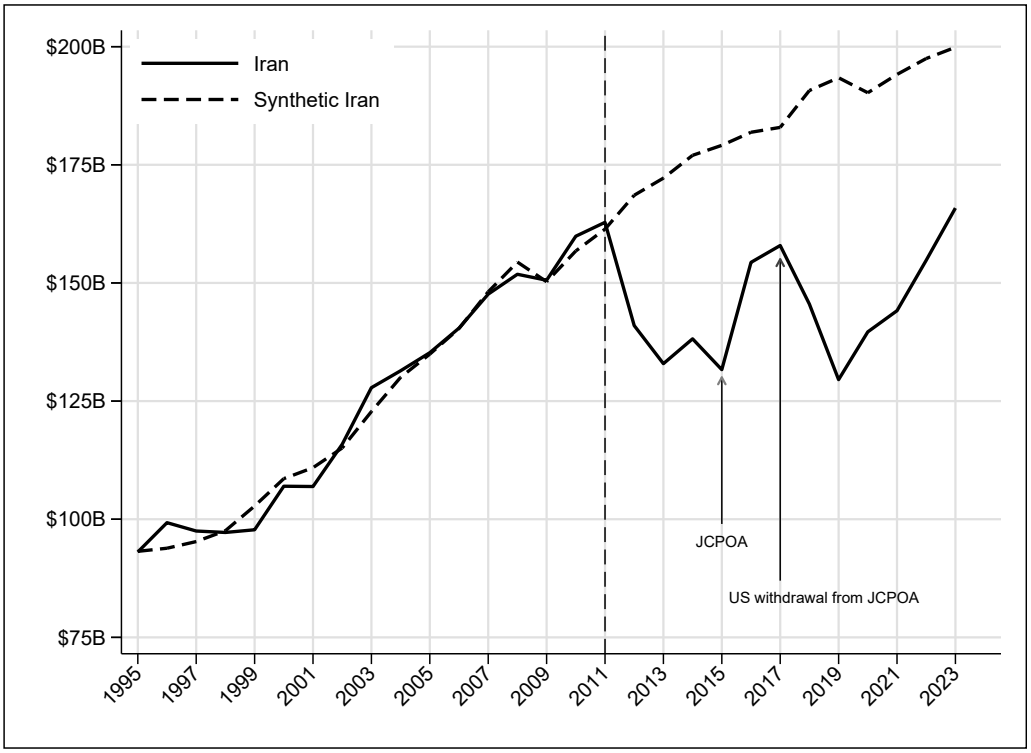
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Figure 1: Real GDP: Iran and synthetic Iran



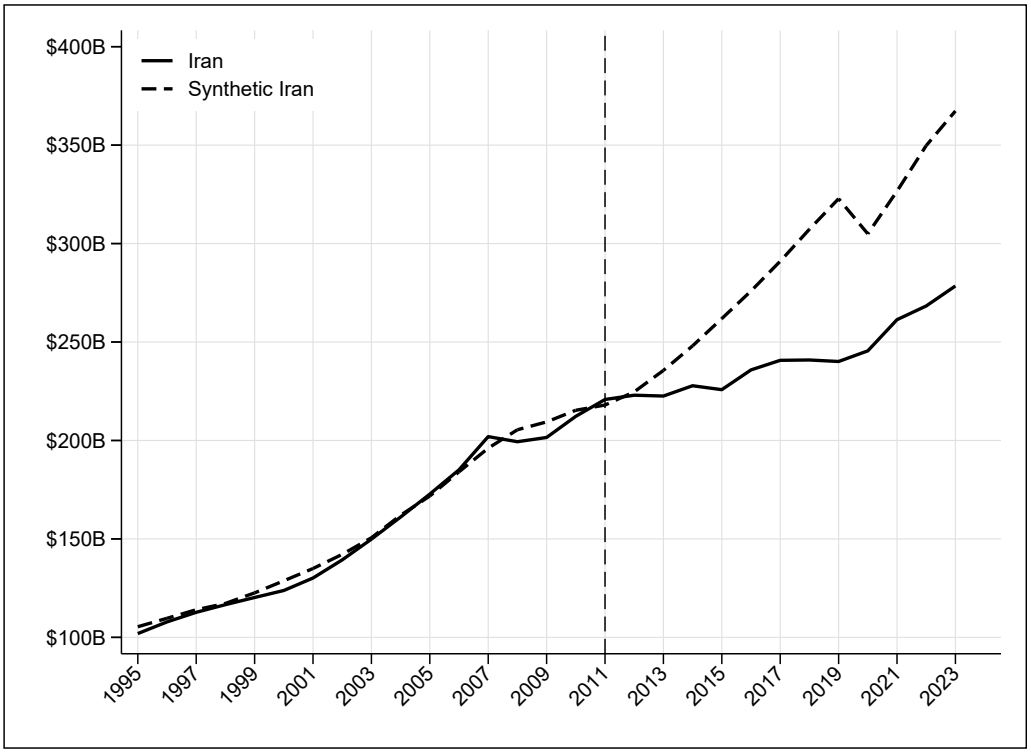
Notes: Real GDP is measured in billions of constant 2015 US dollars using the World Bank's World Development Indicators. The solid line is observed Iran and the dashed line is the outcome-specific synthetic control, a weighted average of donor countries selected to reproduce Iran's pre-treatment predictors and outcome path. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year.

Figure 2: Industry value added: Iran and synthetic Iran



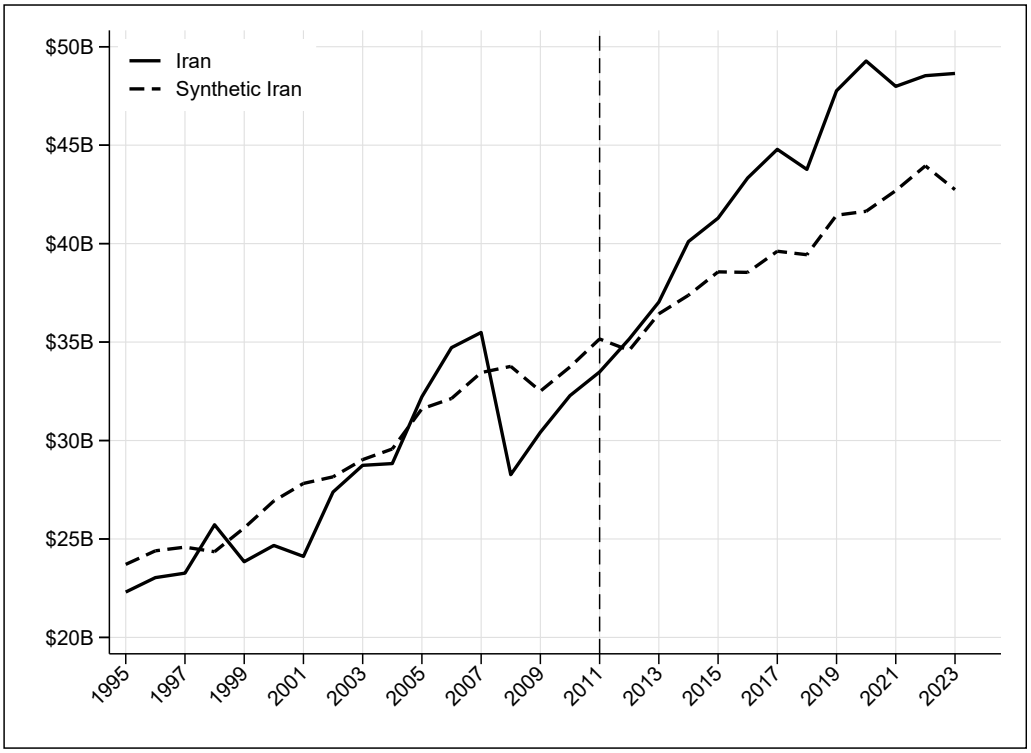
Notes: Industry value added, including construction, is measured in billions of constant 2015 US dollars using the World Bank's World Development Indicators. The solid line is observed Iran and the dashed line is the outcome-specific synthetic control. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year.

Figure 3: Services value added: Iran and synthetic Iran



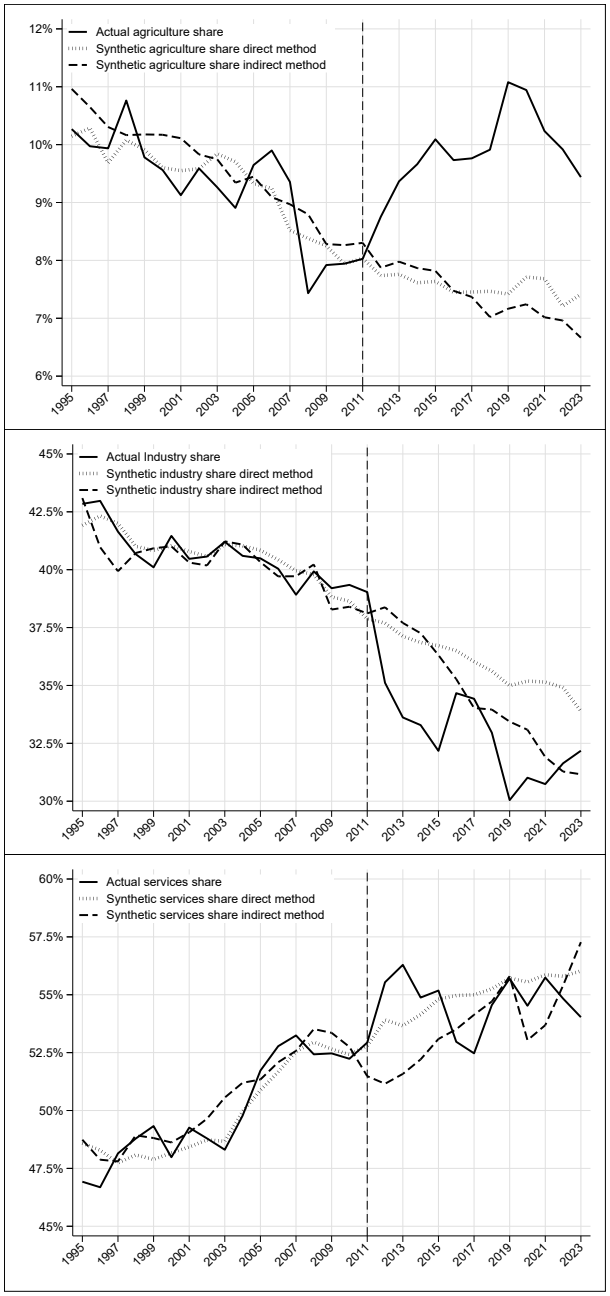
Notes: Services value added is measured in billions of constant 2015 US dollars using the World Bank's World Development Indicators. The solid line is observed Iran and the dashed line is the outcome-specific synthetic control. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year.

Figure 4: Agriculture value added: Iran and synthetic Iran



Notes: Agriculture value added is measured in billions of constant 2015 US dollars using the World Bank's World Development Indicators. The solid line is observed Iran and the dashed line is the outcome-specific synthetic control. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. Agriculture has weaker pre-treatment fit than the main GDP and industry specifications, so its post-treatment comparison is interpreted cautiously.

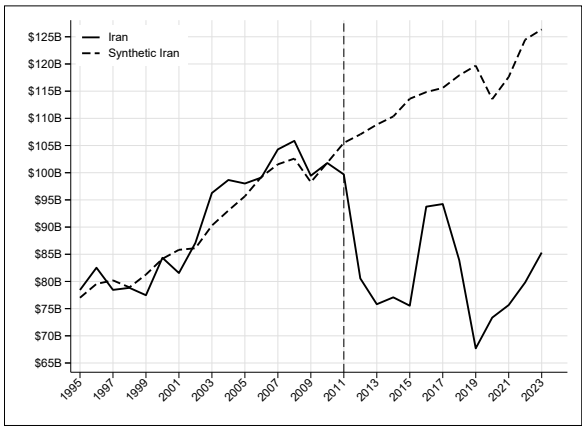
Figure 5: Sectoral shares of GDP: actual and synthetic comparisons



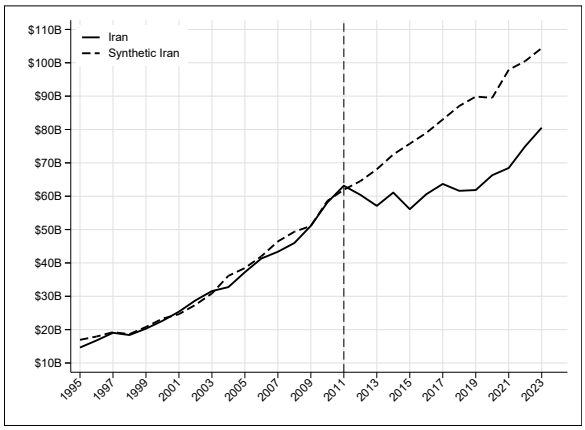
Notes: Panels (a)–(c) report agriculture, industry, and services value added as percentages of GDP. Observed shares are calculated from World Bank value-added and real-GDP series. The direct synthetic-share series applies synthetic control to the sector's GDP share itself; the indirect series divides the synthetic sectoral value-added path by the synthetic real-GDP path. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. These compositional comparisons are descriptive and are not included in the level-outcome placebo inference.

Figure 6: Industry subsectors: Iran and synthetic Iran

(a) Non-manufacturing industry



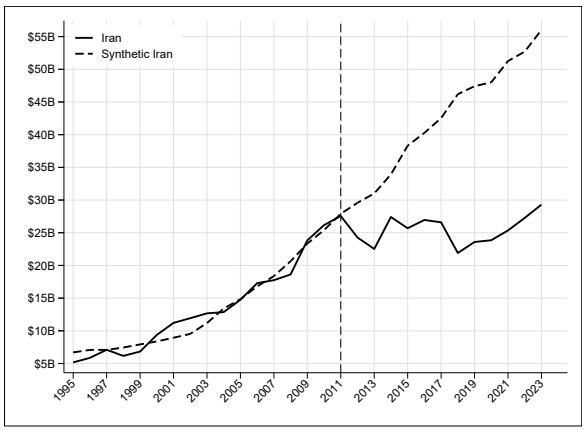
(b) Manufacturing



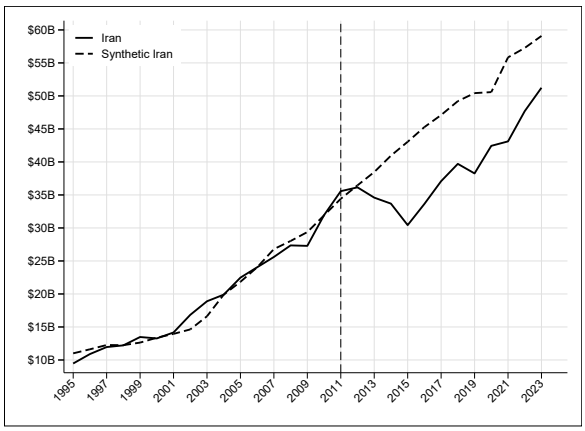
Notes: Panel (a) reports non-manufacturing industry and panel (b) reports manufacturing, both in billions of constant 2015 US dollars. Non-manufacturing industry equals total industry value added minus manufacturing value added and therefore includes extractive activity, construction, utilities, and other non-manufacturing industrial activity. The solid lines are observed Iran and the dashed lines are outcome-specific synthetic controls. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. Data are from the World Bank and UNIDO.

Figure 7: Manufacturing value added by technology intensity

(a) Medium- and high-technology manufacturing

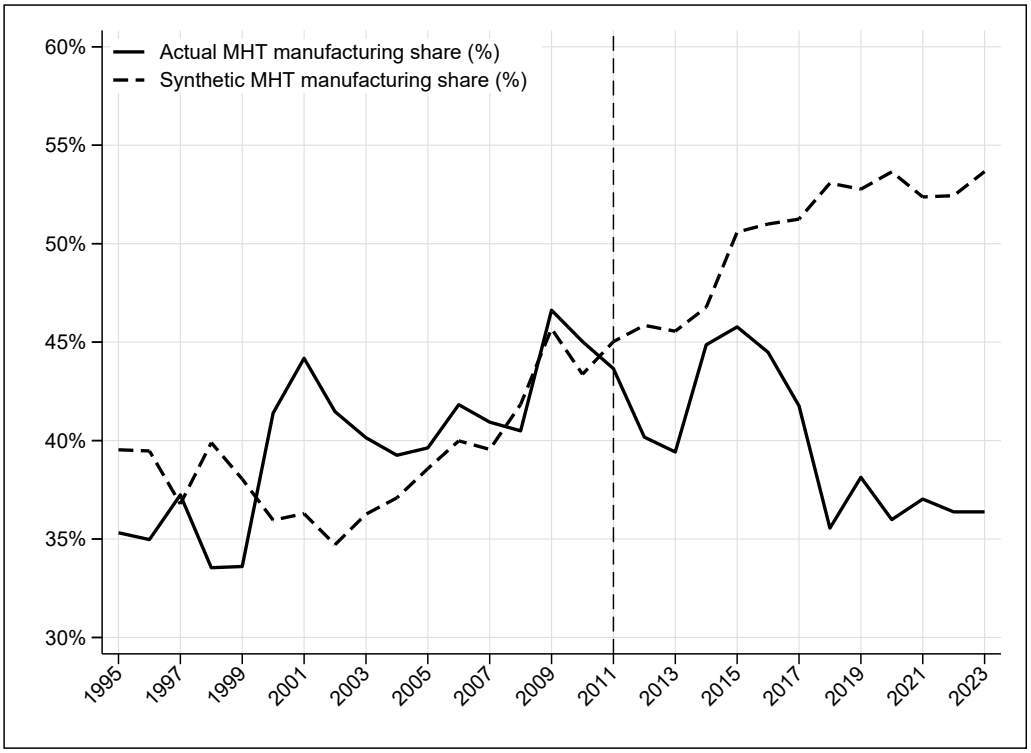


(b) Low- and medium-low-technology manufacturing



Notes: Panel (a) reports medium- and high-technology manufacturing value added and panel (b) reports low- and medium-low-technology manufacturing value added, both in billions of constant 2015 US dollars from UNIDO. Technology groups follow the OECD/UNIDO ISIC classification: the MHT group contains the categories listed in Table 14, and the remaining manufacturing activities form the low- and medium-low-technology group. The solid lines are observed Iran and the dashed lines are outcome-specific synthetic controls. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year.

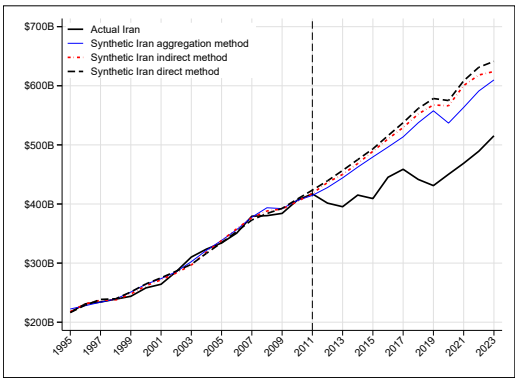
Figure 8: Medium- and high-technology manufacturing share of total manufacturing



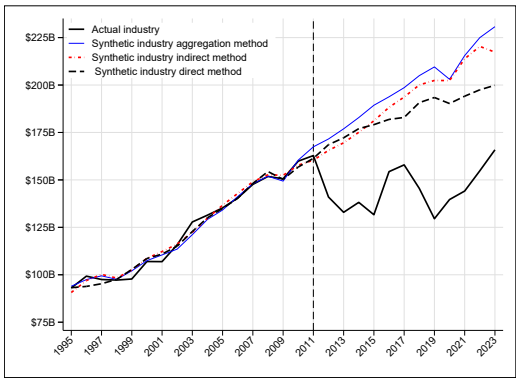
Notes: The figure reports medium- and high-technology manufacturing value added as a percentage of total manufacturing value added using UNIDO data. The solid line is Iran's observed share. The dashed line is the corresponding synthetic share constructed from the synthetic medium- and high-technology and total-manufacturing value-added paths. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. This comparison is descriptive and is not included in the paper's permutation inference.

Figure 9: Alternative counterfactual constructions for real GDP and major sectors

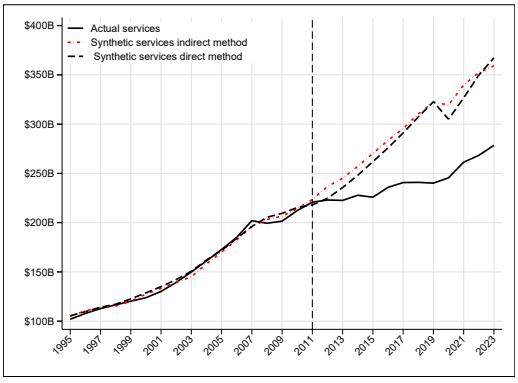
(a) Real GDP



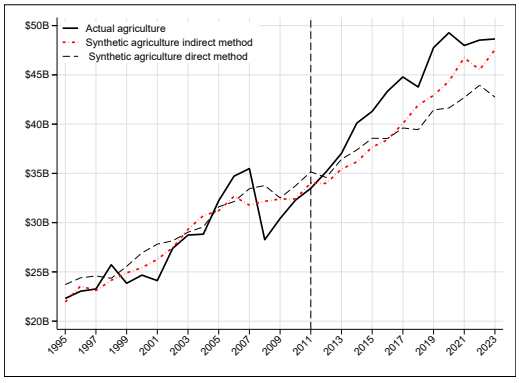
(b) Industry



(c) Services

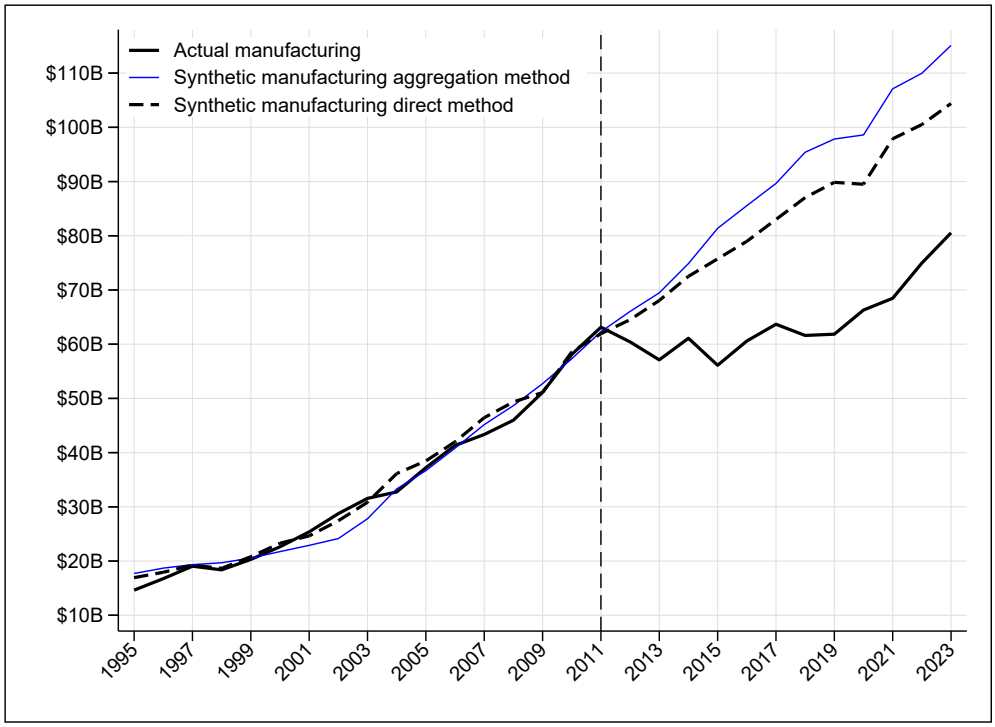


(d) Agriculture



Notes: Panels (a)–(d) report real GDP, industry, services, and agriculture in billions of constant 2015 US dollars. The direct method estimates synthetic control for the displayed level outcome. The indirect method reconstructs sectoral value added from separately estimated synthetic sectoral shares and synthetic aggregate GDP. The accounting-aggregation method sums synthetic sectoral components. Panels (a) and (b) show all three constructions; panels (c) and (d) show the direct and indirect constructions available for those outcomes. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. These comparisons assess sensitivity to counterfactual construction and do not replace the in-space placebo inference.

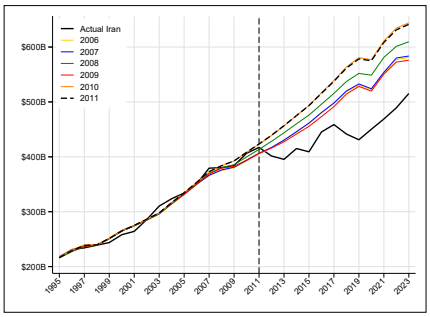
Figure 10: Alternative counterfactual constructions for manufacturing



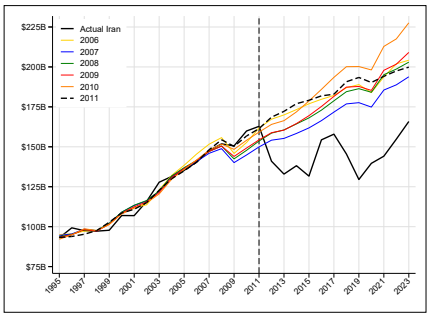
Notes: Manufacturing value added is measured in billions of constant 2015 US dollars. The observed line is actual manufacturing value added. The direct synthetic control is estimated for manufacturing itself, while the accounting-aggregation counterfactual is constructed by aggregating the synthetic manufacturing components. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. The figure is a sensitivity comparison and does not replace the in-space placebo inference.

Figure 11: In-time placebo tests across the main economic outcomes

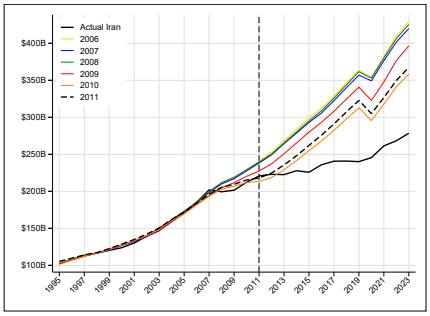
(a) Real GDP



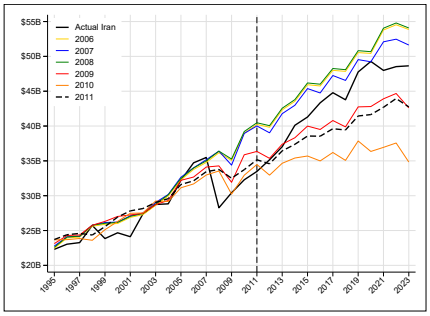
(b) Industry



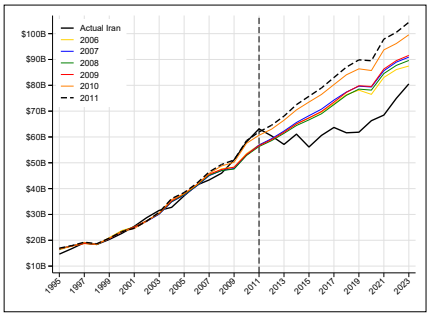
(c) Services



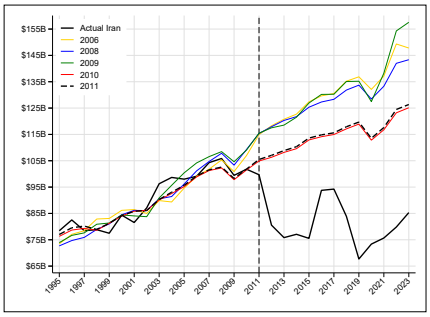
(d) Agriculture



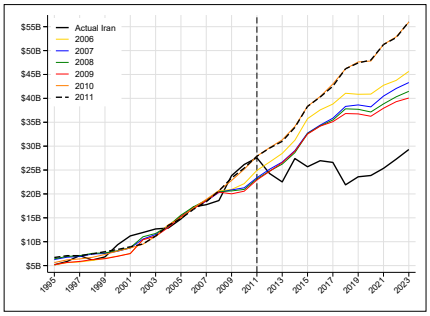
(e) Manufacturing



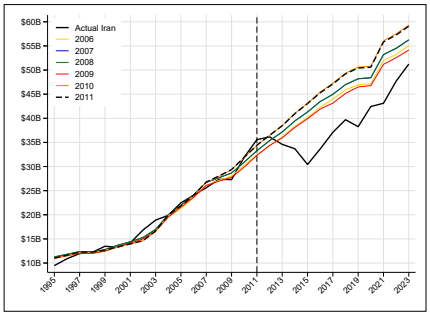
(f) Non-manufacturing industry



(g) Medium- and high-technology manufacturing

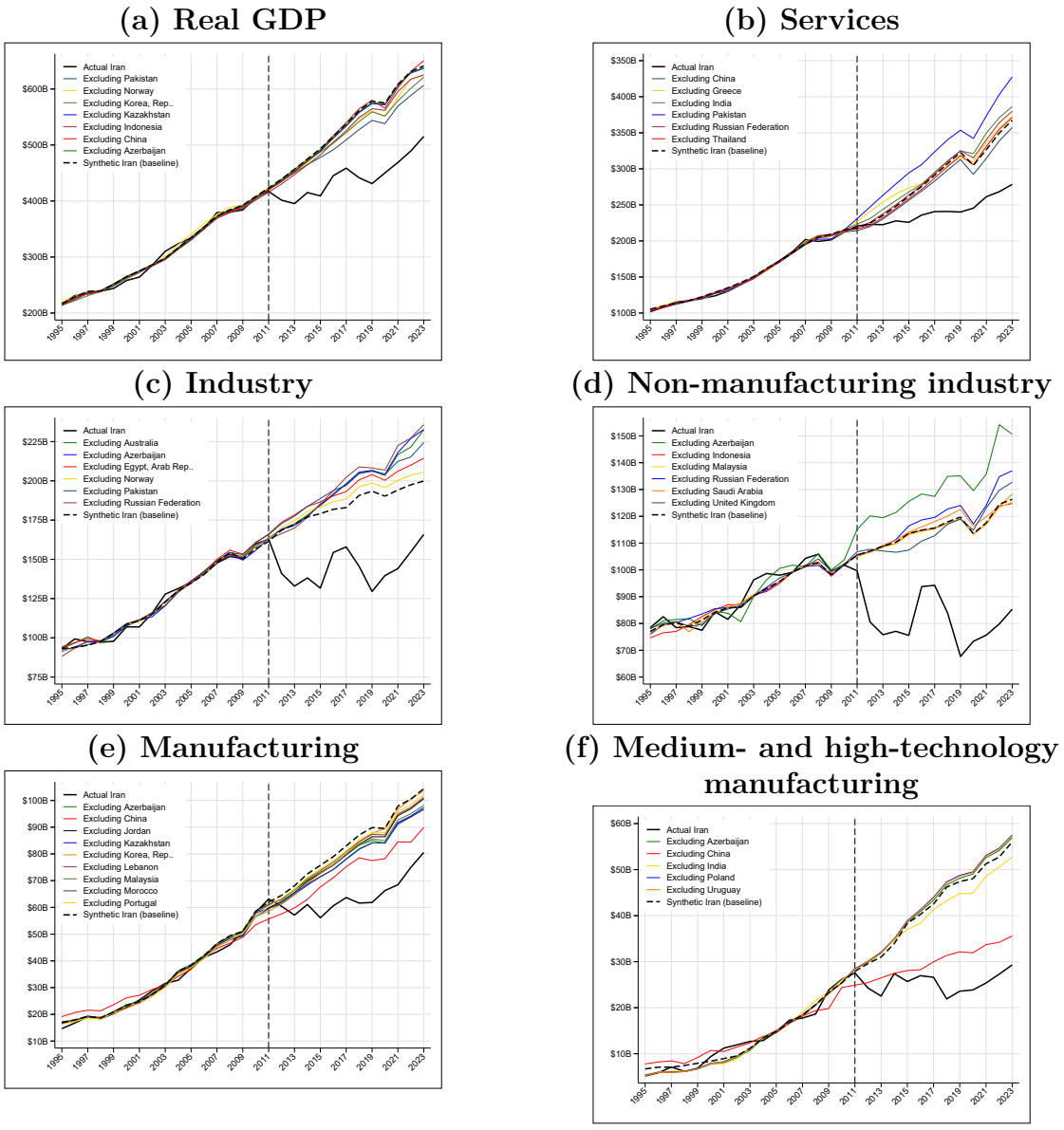


(h) Low- and medium-low-technology manufacturing



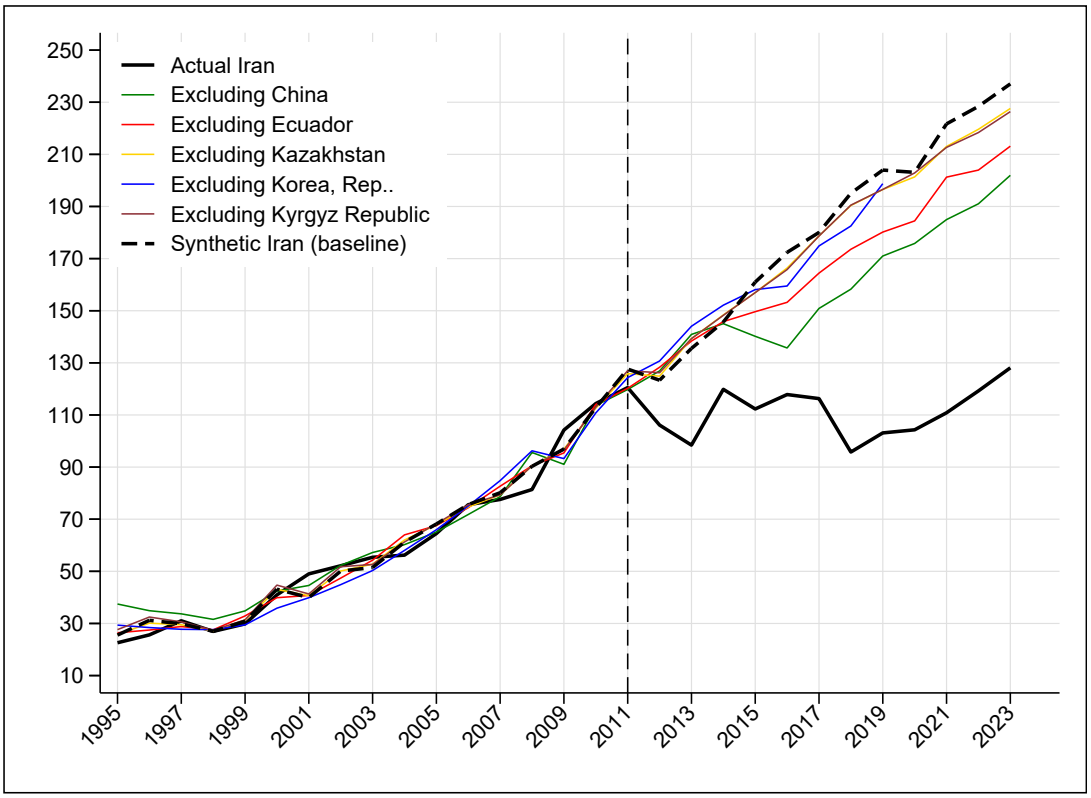
Notes: Panels (a)–(h) report in-time placebo tests for real GDP, industry, services, agriculture, manufacturing, non-manufacturing industry, medium- and high-technology manufacturing, and low- and medium-low-technology manufacturing. Each colored path assigns treatment to the pre-2012 year shown in the legend, restricts the fitting sample to years preceding that artificial treatment date, and fully re-estimates the synthetic control. "Actual Iran" is the observed outcome and the baseline path is the main specification. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. The exercise assesses whether divergences resembling the post-2012 gaps appear at false intervention dates.

Figure 12: Leave-one-out robustness tests across the main economic outcomes



Notes: Panels (a)–(f) report leave-one-out estimates for real GDP, services, industry, non-manufacturing industry, manufacturing, and medium- and high-technology manufacturing. The observed line is actual Iran, the baseline synthetic line is the original outcome-specific synthetic control, and each alternative path fully re-estimates the model after removing the positive-weight donor named in the legend. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. The main post-treatment directions are preserved, although the magnitude of medium- and high-technology manufacturing is particularly sensitive to excluding China.

Figure 13: Leave-one-out robustness test for the medium- and high-technology manufacturing index



Notes: The figure reports leave-one-out estimates for a medium- and high-technology manufacturing index normalized so that each country's 2008–2010 average equals 100. The solid black line is Iran's observed index, the dashed black line is the baseline synthetic control, and each colored path fully re-estimates the model after removing the positive-weight donor named in the legend. The vertical dashed line is drawn at 2011, the final pre-treatment year; 2012 is the first post-treatment year. The post-treatment direction is preserved across the displayed estimates, but the magnitude is sensitive to individual donors, particularly China.

Table 1: Summary statistics for key economic indicators, 1995–2023

Variable	N	Mean	SD	Min	Max
Population (millions)	1,073	116.132	284.154	3.189	1,438.070
Real GDP (constant 2015 US$, billions)	1,073	736.8	1,597	2.678	17,610
Sectoral value-added indicators					
Industry (including construction), value added (constant 2015 US$, billions)	1,073	225.2	597.2	0.8181	6,619
Industry (including construction), value added (% of GDP)	1,073	29.426	8.035	13.293	54.909
Services value added (constant 2015 US$, billions)	1,073	413.9	871.8	1.234	9,711
Services value added (% of GDP)	1,073	55.481	8.093	21.281	80.598
Agriculture value added (constant 2015 US$, billions)	1,073	48.84	137.6	0.4607	1,272
Agriculture value added (% of GDP)	1,073	6.944	5.834	0.491	32.909
Trade indicators					
Merchandise trade (% of GDP)	1,073	54.930	29.474	12.315	192.123
Merchandise imports from high-income economies (% of total merchandise imports)	1,073	68.638	14.982	22.002	95.913
Imports of manufactured goods (US$, billions)	1,073	113.9	200.2	0.5617	2,010
Imports of medium- and high-technology manufactured goods (US$, billions)	1,073	71.20	133.4	0.1311	1,340
Manufacturing indicators					
Manufacturing value added per capita (US$)	1,073	1,974.586	1,999.017	79.935	10,230.955
Manufacturing value added (% of GDP)	1,073	14.904	5.389	4.373	30.085
Manufacturing value added (constant 2015 US$, billions)	1,073	131.8	417.4	0.4035	4,782
Medium- and high-technology manufacturing value added (constant 2015 US$, billions)	1,073	52.26	174.9	0.0331	1,982
Low- and medium-low-technology manufacturing value added (constant 2015 US$, billions)	1,073	79.55	243.3	0.3614	2,800

Notes: The table summarizes a balanced panel comprising Iran and 36 donor countries observed annually from 1995 through 2023, for a total of 1,073 country-year observations. Monetary value-added variables are measured in constant 2015 US dollars and reported in billions, as indicated in the variable names. Import values are reported in current US-dollar billions, manufacturing value added per capita is reported in US dollars, population is reported in millions, and all shares are percentages. Data are from the World Bank's World Development Indicators and UNIDO industrial statistics.

Table 2: Countries in the donor pool

Countries in the donor pool			
Argentina	Denmark	Kazakhstan	Peru
Australia	Ecuador	Korea, Rep.	Poland
Austria	Egypt, Arab Rep.	Kyrgyz Republic	Portugal
Azerbaijan	El Salvador	Lebanon	Russian Federation
Brazil	Greece	Malaysia	Saudi Arabia
Chile	India	Mexico	Thailand
China	Indonesia	Morocco	Turkey
Colombia	Italy	Norway	United Kingdom
Czech Republic	Jordan	Pakistan	Uruguay

Notes: The donor pool contains 36 countries used as potential controls in every outcome-specific synthetic-control estimation. Selection was based primarily on complete data availability across the required aggregate, sectoral, and manufacturing variables. Countries subject to comparable sanctions or other major economic or political shocks were excluded, as were countries for which economically important spillovers from sanctions on Iran were expected. These criteria were fixed independently of the post-treatment estimates and placebo rankings.

Table 3: Donor weights for the real-GDP synthetic control

Country	Weight	Country	Weight
Pakistan	0.557	Indonesia	0.032
Norway	0.265	China	0.007
Korea, Rep.	0.068	Azerbaijan	0.007
Kazakhstan	0.064		

Notes: The table reports the nonnegative donor-country weights used to construct synthetic Iran for real GDP. Displayed weights are rounded to three decimal places; the unrounded weights satisfy the adding-up constraint and sum to one. Countries in the 36-country donor pool that are not shown receive a weight of zero or less than 10^{-4}. The weights are outcome-specific matching weights and should not be interpreted as measures of economic importance.

Table 4: Pre-sanctions predictor balance for real GDP

Predictor	Iran	Synthetic Iran
Log real GDP (constant 2015 US$)	26.43	26.19
Manufacturing value-added share of GDP (proportion)	0.10	0.11
Log manufacturing value added per capita	6.08	6.17
Services value added (% of GDP)	50.10	50.33
Merchandise imports from high-income economies (% of total merchandise imports)	76.72	76.71
Real GDP in 1998 (constant 2015 US$, billions)	239	240
Real GDP in 2002 (constant 2015 US$, billions)	286	286
Real GDP in 2006 (constant 2015 US$, billions)	351	353
Real GDP in 2010 (constant 2015 US$, billions)	406	408

Notes: The table compares Iran with its outcome-specific synthetic control on predictors used for the real-GDP specification. Unless a year is stated, predictors are averaged over the 1995–2011 pre-treatment period, subject to data availability. The manufacturing value-added share is expressed as a proportion, so 0.10 denotes 10 percent; services and merchandise-import shares are percentages. Log variables use natural logarithms. Lagged real-GDP values are billions of constant 2015 US dollars. Manufacturing variables are constructed from UNIDO data; the remaining variables are from the World Bank. Synthetic-Iran values are weighted averages of the donor countries using the real-GDP weights.

Table 5: RMSPE diagnostics and placebo rankings by post-treatment endpoint

Outcome	Pre-RMSPE	Post-RMSPE	Post/pre-RMSPE ratio	Placebo rank	Pseudo-p-value
Results through 2015					
Real GDP	6.050	56.400	9.320	2/35	0.057
Industry	2.770	34.800	12.564	1/35	0.029
Services	3.753	19.450	5.183	7/35	0.200
Agriculture	2.214	1.917	0.866	31/35	0.886
Manufacturing	1.680	11.400	6.827	7/35	0.200
Non-manufacturing industry	2.959	29.610	10.004	1/35	0.029
Medium/high-tech manufacturing	1.291	7.776	6.024	2/34	0.059
Low- and medium-low-technology manufacturing	1.130	6.762	5.985	4/34	0.118
Results through 2019					
Real GDP	6.050	83.800	13.851	2/35	0.057
Industry	2.770	38.800	14.008	1/35	0.029
Services	3.750	43.800	11.672	3/35	0.086
Agriculture	2.214	3.754	1.696	19/35	0.543
Manufacturing	1.675	17.630	10.522	6/35	0.171
Non-manufacturing industry	2.960	31.900	10.770	3/35	0.086
Medium/high-tech manufacturing	1.291	14.500	11.231	2/34	0.059
Low- and medium-low-technology manufacturing	1.130	8.837	7.821	5/34	0.147
Results through 2023					
Real GDP	6.050	101.600	16.799	3/35	0.086
Industry	2.772	40.770	14.708	2/35	0.057
Services	3.753	55.190	14.704	5/35	0.143
Agriculture	2.214	4.548	2.055	20/35	0.571
Manufacturing	1.675	20.420	12.192	9/35	0.257
Non-manufacturing industry	2.959	35.300	11.927	2/35	0.057
Medium/high-tech manufacturing	1.291	18.620	14.427	3/35	0.086
Low- and medium-low-technology manufacturing	1.130	9.132	8.083	4/34	0.118

Notes: The table reports in-space placebo diagnostics for post-treatment samples beginning in 2012 and ending in 2015, 2019, or 2023; the pre-treatment period is 1995–2011 in every specification. Pre-RMSPE and post-RMSPE are root mean squared prediction errors, reported in billions of constant 2015 US dollars. The post/pre-RMSPE ratio measures the deterioration in fit after treatment. A placebo unit is usable when its pre-treatment RMSPE, post-treatment RMSPE, and ratio are non-missing and its pre-treatment RMSPE is nonzero; no additional pre-treatment-fit threshold is applied. The placebo rank gives Iran's position among all usable units, including Iran. The pseudo-p-value equals the number of usable placebo units with a ratio at least as large as Iran's, plus Iran, divided by the total number of usable units including Iran. For outcomes with 34 rather than 35 usable units, one placebo estimate did not produce a valid ratio because of a numerical calculation error.

Table 6: Donor weights for the industry-value-added synthetic control

Country	Weight	Country	Weight
Pakistan	0.323	Russian Federation	0.124
Australia	0.295	Egypt, Arab Rep.	0.091
Azerbaijan	0.163	Norway	0.004

Notes: The table reports the nonnegative donor-country weights used to construct synthetic Iran for industry value added. Displayed weights are rounded to three decimal places; the unrounded weights satisfy the adding-up constraint and sum to one. Countries in the 36-country donor pool that are not shown receive a weight of zero or less than 10^{-4}. The weights are outcome-specific matching weights and should not be interpreted as measures of economic importance.

Table 7: Pre-sanctions predictor balance for industry value added

Predictor	Iran	Synthetic Iran
Log real GDP (constant 2015 US$)	26.43	26.27
Manufacturing value-added share of GDP (proportion)	0.10	0.10
Log manufacturing value added per capita	6.08	6.23
Log industry value added per capita	7.47	7.21
Industry value added in 1998 (constant 2015 US$, billions)	97	97
Industry value added in 2002 (constant 2015 US$, billions)	116	115
Industry value added in 2006 (constant 2015 US$, billions)	140	140
Industry value added in 2010 (constant 2015 US$, billions)	160	157

Notes: The table compares Iran with its outcome-specific synthetic control on predictors used for the industry-value-added specification. Unless a year is stated, predictors are averaged over the 1995–2011 pre-treatment period, subject to data availability. The manufacturing value-added share is a proportion, log variables use natural logarithms, and the lagged industry-value-added levels are billions of constant 2015 US dollars. Manufacturing variables are constructed from UNIDO data and the remaining variables from the World Bank. Synthetic-Iran values are weighted averages of the donor countries using the industry weights.

Table 8: Donor weights for the services-value-added synthetic control

Country	Weight	Country	Weight
Pakistan	0.413	India	0.09
Greece	0.355	Russian Federation	0.007
Thailand	0.132	China	0.004

Notes: The table reports the nonnegative donor-country weights used to construct synthetic Iran for services value added. Displayed weights are rounded to three decimal places; the unrounded weights satisfy the adding-up constraint and sum to one. Countries in the 36-country donor pool that are not shown receive a weight of zero or less than 10^{-4}. The weights are outcome-specific matching weights and should not be interpreted as measures of economic importance.

Table 9: Pre-sanctions predictor balance for services value added

Predictor	Iran	Synthetic Iran
Log real GDP per capita (constant 2015 US$)	8.37	8.21
Employment in services (% of total employment)	46.77	44.38
Log services value added	25	25
Log manufacturing value added	24	24
Merchandise imports from high-income economies (% of total merchandise imports)	76	76
Transport services (% of commercial service exports)	41	40
Services value added in 1998 (constant 2015 US$, billions)	117	117
Services value added in 2002 (constant 2015 US$, billions)	139	142
Services value added in 2006 (constant 2015 US$, billions)	185	184
Services value added in 2010 (constant 2015 US$, billions)	212	215

Notes: The table compares Iran with its outcome-specific synthetic control on predictors used for the services-value-added specification. Unless a year is stated, predictors are averaged over the 1995–2011 pre-treatment period, subject to data availability. Employment, merchandise-import, and transport-service variables are percentages. Log variables use natural logarithms, and lagged services-value-added levels are billions of constant 2015 US dollars. Manufacturing value added is constructed from UNIDO data; the remaining variables are from the World Bank and modeled ILO estimates distributed through the World Bank. Synthetic-Iran values are weighted averages of the donor countries using the services weights.

Table 10: Donor weights for the agriculture-value-added synthetic control

Country	Weight	Country	Weight
Argentina	0.259	Russian Federation	0.154
Colombia	0.243	Kazakhstan	0.075
Pakistan	0.235	Thailand	0.033

Notes: The table reports the nonnegative donor-country weights used to construct synthetic Iran for agriculture value added. Displayed weights are rounded to three decimal places; the unrounded weights satisfy the adding-up constraint and sum to one. Countries in the 36-country donor pool that are not shown receive a weight of zero or less than 10^{-4}. The weights are outcome-specific matching weights and should not be interpreted as measures of economic importance.

Table 11: Pre-sanctions predictor balance for agriculture value added

Predictor	Iran	Synthetic Iran
Permanent cropland (% of land area)	0.91	0.95
Employment in agriculture (% of total employment, modeled ILO estimate)	21.33	20.83
Log agriculture value added	24.05	23.88
Trade (% of GDP)	43	43
Agriculture value added in 1998 (constant 2015 US$, billions)	25	24
Agriculture value added in 2002 (constant 2015 US$, billions)	27	28
Agriculture value added in 2006 (constant 2015 US$, billions)	34	32
Agriculture value added in 2010 (constant 2015 US$, billions)	32	33

Notes: The table compares Iran with its outcome-specific synthetic control on predictors used for the agriculture-value-added specification. Unless a year is stated, predictors are averaged over the 1995–2011 pre-treatment period, subject to data availability. Permanent cropland, agricultural employment, and trade are percentages. Log agriculture value added uses the natural logarithm, and lagged agriculture-value-added levels are billions of constant 2015 US dollars. All variables are obtained from or constructed using World Bank data, including modeled ILO employment estimates. Synthetic-Iran values are weighted averages of the donor countries using the agriculture weights.

Table 12: Estimated counterfactual gaps in value added by sector and aggregate measure

	Gap between actual and synthetic value added (US$ billions)				
Year	Industry	Services	Agriculture	Accounting-based aggregate	Direct real GDP
2012	-27.57	-1.68	0.57	-26.32	-37.70
2013	-39.26	-13.00	0.59	-48.80	-61.32
2014	-38.83	-20.23	2.72	-47.32	-60.00
2015	-47.46	-36.09	2.72	-70.38	-84.10
2016	-27.53	-40.06	4.79	-51.07	-70.38
2017	-24.99	-50.32	5.17	-54.81	-78.84
2018	-45.19	-66.38	4.33	-95.88	-120.08
2019	-63.88	-82.67	6.31	-126.54	-147.34
Total 2012–2019	-314.73	-310.46	27.24	-521.16	-659.79
2011 actual	162.82	220.81	33.48	417.13	417.13
2019 actual	129.54	240.11	47.76	431.11	431.11
Average 2012–2019	-39.34	-38.80	3.40	-65.14	-82.47
2020	-50.60	-59.45	7.63	-86.58	-124.74
2021	-49.99	-65.26	5.29	-94.56	-139.51
2022	-42.69	-81.43	4.58	-101.89	-142.04
2023	-34.01	-88.85	5.90	-94.56	-125.98
Total 2012–2023	-492.04	-605.47	50.65	-898.77	-1,192.08
2023 actual	165.84	278.46	48.64	515.36	515.36
Average 2012–2023	-41.00	-50.45	4.22	-74.89	-99.34

Notes: All monetary values are billions of constant 2015 US dollars. Each gap equals the observed value minus its synthetic counterfactual, so negative values indicate underperformance relative to the counterfactual and positive values indicate overperformance. Industry, services, agriculture, and direct real GDP are estimated using separate outcome-specific synthetic controls. The accounting-based aggregate combines the synthetic sectoral components, including components outside the three displayed sectors, and is presented as a robustness comparison rather than an additive decomposition of the direct GDP estimate. Actual-value rows report observed levels, while totals and averages are calculated from the unrounded annual estimates; displayed entries are rounded to two decimals.

Table 13: Pre-sanctions predictor balance for medium- and high-technology manufacturing

Covariate	Iran	Synthetic Iran
Log real GDP per capita (constant 2015 US$)	8.38	8.37
Imports of manufactured goods (US$ billions)	27.10	28.10
Imports of medium- and high-technology manufactured goods (US$ billions)	17.00	17.00
Medium- and high-technology manufacturing value added, 1998 (constant 2015 US$, billions)	6.17	7.44
Medium- and high-technology manufacturing value added, 2004 (constant 2015 US$, billions)	12.90	13.40
Medium- and high-technology manufacturing value added, 2006 (constant 2015 US$, billions)	17.30	16.80
Medium- and high-technology manufacturing value added, 2010 (constant 2015 US$, billions)	26.20	25.40

Notes: The table compares Iran with its outcome-specific synthetic control on predictors used for the medium- and high-technology manufacturing specification. Unless a year is stated, predictors are averaged over the 1995–2011 pre-treatment period, subject to data availability. Real GDP per capita is expressed in natural logarithms. Manufactured-goods imports are current US-dollar billions, while lagged medium- and high-technology manufacturing value added is measured in billions of constant 2015 US dollars. Manufacturing data are from UNIDO and real GDP per capita is from the World Bank. Synthetic-Iran values are weighted averages of the donor countries using the outcome-specific weights.

Table 14: Medium- and high-technology (MHT) manufacturing categories

Manufacturing activity	ISIC Rev. 3 code
Manufacture of chemicals and chemical products	24
Manufacture of machinery and equipment	29
Manufacture of office, accounting, and computing machinery	30
Manufacture of electrical machinery and apparatus	31
Manufacture of radio, television, and communication equipment and apparatus	32
Manufacture of medical, precision, and optical instruments, watches, and clocks	33
Manufacture of motor vehicles, trailers, and semi-trailers	34
Manufacture of other transport equipment, excluding shipbuilding and repair activities	35

Notes: The table lists the ISIC Revision 3 manufacturing activities classified as medium- and high-technology in the analysis, following OECD (2003) and UNIDO (2010). Within ISIC Revision 3 code 35, building and repairing ships and boats (code 351) is excluded; the corresponding ISIC Revision 4 exclusions are codes 3011, 3012, and 3315. Manufacturing activities outside the listed MHT categories are assigned to the low- and medium-low-technology group.

Table 15: Average counterfactual gaps by subperiod

Outcome	2012–2015	2016–2017	2018–2019	2020–2023
Real GDP	-60.78	-74.61	-133.71	-133.07
Industry	-38.28	-26.26	-54.53	-44.32
Services	-17.75	-45.19	-74.52	-73.75
Agriculture	1.65	4.98	5.32	5.85
Manufacturing	-11.52	-18.85	-26.71	-25.51
Non-manufacturing industry	-32.71	-21.21	-42.99	-41.95
Medium/high-tech manufacturing	-8.23	-14.63	-24.05	-25.55
Low- and medium-low-technology manufacturing	-6.01	-10.82	-10.83	-9.57

Notes: Each entry is the average annual gap between the observed outcome and its outcome-specific synthetic counterfactual over the indicated subperiod, measured in billions of constant 2015 US dollars. Negative values indicate that the observed outcome was below the counterfactual; positive values indicate that it was above. The subperiods correspond to the initial sanctions intensification (2012–2015), the JCPOA period (2016–2017), the initial period after sanctions were reimposed (2018–2019), and the later post-reimposition period (2020–2023). Because each outcome is estimated separately, the rows should not be added to obtain the direct real-GDP gap.