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Macroeconomic impacts of the 2010 earthquake in Haiti

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Abstract In this paper, we use the synthetic control method to estimate the macroeconomic losses from the 2010 earthquake in Haiti, one of the most severe natural disasters in the modern era. The macroeconomic effects of the earthquake were equal to an average loss of up to 12% of gross domestic product over the period 2010–2015. While surges in imports and foreign aid supported a temporary increase in aggregate consumption, aggregate investment and services sector output experienced large contractions. The road transport sector was severely affected. Impacts on electricity use have been less pronounced. The data suggest that macroeconomic losses may be permanent. The earthquake is thus a case of an extreme natural disaster contributing to divergence in development outcomes.

Keywords Macroeconomic impact · Haiti · Earthquake · Synthetic control method

JEL Classification E21 · E22 · E23 · O11 · O54

1 Introduction

On 12 January 2010, Haiti was hit by a severe earthquake that struck near Port-au-Prince, its capital city. The earthquake caused over 200,000 deaths, more than 2% of

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Haiti's population (EM-DAT 2015). These impacts make the earthquake one of the worst natural disasters ever recorded for any nation. The earthquake registered 7.0 on the Richter scale.

In this paper, we use the synthetic control method (SCM) to assess the ongoing macroeconomic impacts of the earthquake in Haiti. The SCM—developed by Abadie and Gardeazabal (2003), Abadie et al. (2010), and Abadie et al. (2015)—allows measurement of macroeconomic losses over time through comparison of the actual outcome with a hypothetical counterfactual. The counterfactual is a weighted average of other similar economies that were not exposed to the earthquake. Existing work has used the synthetic control method to study a range of events, including German reunification (Abadie et al. 2015) and the second Intifada crisis (Horiuchi and Mayerson 2015). The SCM has also been used to investigate conflict within Spain (Abadie and Gardeazabal 2003), tobacco tax impacts in California (Abadie et al. 2010), and the US shale oil and gas boom (Munasib and Rickman 2015).

SCM analyses of earthquake impacts have found major local effects. For instance, duPont and Noy (2015) find adverse and long-term local impacts on gross domestic product (GDP) per capita from the 1995 Kobe earthquake. Barone and Mocetti (2014) show impacts for two earthquakes in different Italian regions, finding that a bad outcome is more likely in regions with lower institutional quality prior to the earthquake.

Existing analysis of the economic impact of the earthquake in Haiti provides a range of results. Using a regression approach with worldwide data on natural disasters from 1970 to 2008, an early estimate of monetary damages in Haiti was approximately US$8 billion in 2009 dollars (Cavallo et al. 2010).[1] While Cavallo et al. (2013) find that even extreme disasters in their global sample up to 2008 do not have a significant effect on economic growth when controlling for political changes, they note that the Haiti earthquake in 2010 was the most catastrophic disaster in the modern era. Using the distribution of disaster impacts, based on synthetic controls for countries from a comprehensive global dataset from 1970 to 2008, and assuming that the outcome for Haiti was in the most extreme 1% of disasters, Cavallo et al. (2013) project that income per capita in Haiti in 2020 (purchasing power parity (PPP) 2008 international dollars) could have been $1410 without the earthquake, compared to $1060 with the earthquake.[2] In contrast, the IMF (2015) uses a simple extrapolation of 2005–2006 GDP growth to conclude that GDP returned to the pre-earthquake trend by 2014. The projection by Cavallo et al. (2013) suggests the earthquake had a potentially permanent macroeconomic impact, while the IMF (2015) calculation indicates a large impact, but one that is transitory.

Our contribution is to quantify the macroeconomic losses resulting from the earthquake in Haiti using a systematic approach to modelling the counterfactual. We calculate the counterfactual using data for Haiti and a group of similar countries from before the earthquake, and data for the group of similar countries from after the earthquake. The approach contrasts with a simple extrapolation, which would only

[1] These damages relate to fixed assets and capital (including inventories), raw material and extractable natural resources, and mortality and morbidity that are a direct consequence of the earthquake.

[2] Not controlling for political changes.

use data for Haiti from before the earthquake. The paper uses more updated data than prior assessments of Haiti's earthquake and gives a detailed breakdown of impacts in different economic sectors. We also construct counterfactuals for a broader range of variables than other SCM papers to allow assessment of the underlying causes of GDP losses.

The results suggest that consumption was temporarily supported by large foreign inflows following the earthquake, but that production has suffered sustained losses. Aggregate consumption, including non-profit institution spending for households, increased in the initial emergency response. This increase was possible due to surges in imports and foreign aid. The services sector suffered a large contraction as a result of the earthquake. Investment remains adversely affected, and negative transmission impacts include a reduction in road transport energy use, hindering GDP recovery.

A detailed assessment of the macroeconomic effects of the 2010 earthquake in Haiti is important for a number of reasons. The extreme nature of the earthquake could imply that estimates of economic impacts using average losses from other studies are not directly applicable. Hallegatte et al. (2007) find that GDP losses increase sharply if the intensity and frequency of extreme events exceeds a threshold, suggesting that the high risk of future natural disasters in Haiti is a major issue. This paper also adds detail and context to the recent macroeconomic outcomes from the earthquake, emphasizing that disaster-resilient investment is likely to be important for reducing the impact of future natural disasters.

2 Before the earthquake

Haiti had a low level of socioeconomic development prior to the earthquake, with the Human Development Index value in the year 2000 ranking Haiti 134th out of 166 countries (UNDP 2016). More than half of the population of Haiti was living in extreme poverty prior to the earthquake. Nearly half of the population had no access to healthcare and over 80% had no clean drinking water (Échevin 2011). Chronic malnutrition affected nearly a fifth of children up to 6 years of age in Port-au-Prince in 2009. There were higher levels of malnutrition in other regions (Échevin 2011).

The Haitian economy was subject to a number of shocks prior to the earthquake. For instance, political instability leading up to 2004 coincided with the withdrawal of external economic support and weak economic performance (IMF 2015). In 2008, storms and floods led to over 500 deaths (EM-DAT 2015). These storms also had severe impacts on crop production in Haiti, with damages estimated at around 200 million US dollars (World Bank 2013). The impact on the agricultural sector affected a large proportion of the population, with around 40% of the labour force in agriculture (CIA 2016). Economic impacts were less pronounced as around half of economic output in Haiti in 2009 was from the services sector and around 20% from agriculture (UN 2016a). While Haiti's inflation rate was falling until 2008, global food price rises contributed to a spike in inflation in 2008 (IMF 2009). The rising food prices in 2008 also contributed to an increase in the current account deficit (IMF 2009).

For a range of socioeconomic variables shown in Table 1, Haiti was similar to the average of low-income countries. For GDP per capita, life expectancy, and health

Table 1 Socioeconomic characteristics in Haiti and other low- and lower-middle-income countries, 2009. *Sources*: World Bank (2016), Worldwide Governance Indicators (2015)

Variable	Haiti	Low income	Lower middle income
GDP per capita	1613	1411	4546
Life expectancy	61	57	66
Institutional quality	− 1.09	− 0.93	− 0.56
Trade openness	58	62	82
Health expenditure per capita	104	78	244

GDP per capita is in purchasing power parity constant 2011 international dollars. Life expectancy is in years. Institutional quality is an average of the six indicator values from the Worldwide Governance Indicators (2015). Trade openness is the sum of imports and exports as a % of GDP. Health expenditure per capita is in purchasing power parity constant 2011 international dollars. Income groups are based on World Bank classifications. The values are averages for 31 low-income (including Haiti) and 52 lower-middle-income countries

expenditure, Haiti was slightly above the low-income average, while for institutional quality and trade openness, Haiti was below the low-income average.

The socioeconomic context in Haiti prior to the earthquake was important in determining the scale of the earthquake impacts. Noy (2009) finds that determinants of higher resilience to disasters include higher income per capita, higher literacy rates, higher institutional quality, greater trade openness, and higher government spending. Based on natural disaster events from 1970 to 2006, Hochrainer-Stigler (2015) finds that disaster impacts likely depend on the socioeconomic situation before the disaster.

3 Method and data

The synthetic control method (SCM) provides a systematic approach to calculating a counterfactual outcome, using the weighted average of a group of similar countries called the donor pool (Abadie and Gardeazabal 2003; Abadie et al. 2010, 2015). The analysis includes $(J + 1)$ countries indexed by j, where $j = 1$ is Haiti and $j = 2$ to $j = J + 1$ are the donor pool countries that are unaffected by the earthquake. The synthetic control, $\boldsymbol{W}^*$, is a $(J \times 1)$ vector of weights written as:

$$\boldsymbol{W}^* = (w_2, \ldots, w_{J+1})', \tag{1}$$

with $0 \leq w_j \leq 1$ for $j = 2, \ldots, J + 1$, and $w_2 + \cdots + w_{J+1} = 1$.

3.1 Outcome variables

We calculate synthetic controls for Haiti's GDP, sectoral output, consumption, investment, and trade flows. We also investigate the earthquake's impact on Haiti's energy sector, including electricity use and road transport energy use. We consider government revenue and expenditure amounts, and also foreign flows from official development assistance (ODA) and remittances. Information on data sources is presented in Appendix Tables 3, 4, 5 and 6.

3.2 Calculation of weights

The synthetic control, $\boldsymbol{W}^*$, is calculated to be the closest possible match for Haiti in the period before the earthquake. The similarity between Haiti and the calculated counterfactual is based on k characteristics, including the outcome variable, in the period before the earthquake. These characteristics, or predictor variables, include consumption, investment, exports, imports, GDP per capita, population, and land area. Three values of the outcome variable are used as predictor variables in each case to improve the pre-earthquake fit of the synthetic control.[3]

The synthetic control can be produced by minimizing Eq. 2.

$$\sum_{m=1}^{k} \boldsymbol{v}_{\mathbf{m}} (X_{1m} - \boldsymbol{X}_{\mathbf{0}\boldsymbol{m}} \boldsymbol{W})^2 \tag{2}$$

$\boldsymbol{v}_{\mathbf{m}}$ is the weight showing the relative importance of each of the k characteristics for matching the experience of Haiti before the earthquake. $\boldsymbol{v}_{\mathbf{m}}$ is produced by minimizing the mean of the squared difference between actual and counterfactual values of the outcome variable in the period before the earthquake. X_{1m} is the value for the mth predictor variable for Haiti and $\boldsymbol{X}_{\mathbf{0}\boldsymbol{m}}$ is the $(1 \times J)$ vector for the mth predictor variable for donor pool countries.

3.3 Time period

In our main analysis, we use data for the eleven-year period 2004–2014 (World Bank 2016; UN 2016a; IEA 2016), with separate analyses with World Bank and UN data. World Bank GDP data are also available in 2015 for each country. We also consider a longer period of GDP per capita data as a robustness test, with a start date of 1998. Data on government expenditure and revenue are from the International Monetary Fund (2016). We label the number of years in the pre-earthquake period as T_0, and the number of years after the earthquake as T_1.

3.4 Donor pool

The donor pool is made up of countries that are not affected by the earthquake, but are otherwise similar to Haiti. The choice of the donor pool is an important part of the synthetic control method.

[3] The outcome variables in the years 2005, 2007, and 2009 are used as predictor variables. Four values are used for the robustness test in Fig. 21. Inflation is also a predictor variable when there are enough data to form a relatively large donor pool with World Bank (2016) data.

We construct the donor pool using a data-driven approach. From a sample of low-income and lower-middle-income countries with data available, we restrict the donor pools based on various thresholds, most notably a GDP per capita threshold. For robustness, we construct multiple donor pools with different data and criteria. If the outcomes of the synthetic controls are similar with different data and donor pool criteria, this suggests the findings are robust.

Using the World Development Indicators (WDI) data (World Bank 2016), we focus on a balanced panel including GDP and components of GDP, with variable names in Appendix Table 3. We restrict the donor pool to countries with GDP per capita PPP (in constant 2011 international dollars) of less than $4000 in 2009. For the WDI data, the donor pool of countries that are similar to Haiti is the following 22 countries: Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Cameroon, Kenya, Kyrgyz Republic, Liberia, Madagascar, Mali, Moldova, Mozambique, Nepal, Nicaragua, Rwanda, Senegal, Sierra Leone, Sudan, Tanzania, Togo, and Uganda.

When using the United Nations (UN) data, we focus on GDP and sectors of production. We restrict the potential donor pool to countries with GDP per capita (constant 2005 prices) of less than US$1000 in 2009. From this larger balanced panel with complete GDP and sectoral production data, we also remove countries with significantly different growth experiences to Haiti. Specifically, we remove countries with GDP per capita growth that differs from Haiti by more than 15% points in total over either the pre-earthquake period (2004–2009) or the post-earthquake period (2010–2014). We also exclude countries that have State Fragility Index (Marshall and Cole 2014) values that increase by four or more points in a single year.[4]

For the UN data, the donor pool of countries that are similar to Haiti is the following 20: Benin, Burkina Faso, Cameroon, Chad, Comoros, Côte d'Ivoire, Democratic Republic of the Congo, Guinea, Guinea-Bissau, Kenya, Kyrgyz Republic, Lesotho, Mauritania, Nepal, Niger, Pakistan, Senegal, Somalia, Tanzania, and Togo.

If there were spillover effects from the earthquake to donor pool countries, the difference between the synthetic control and the actual outcome could either be underestimated or exaggerated (Abadie et al. 2010). The Dominican Republic shares an island with Haiti, but is already excluded based on its higher per capita GDP. The earthquake would not have had major impacts on donor pool countries via Haitian trade flows. Nearly 90% of Haitian exports were to the USA in 2009 (Simoes and Hidalgo 2011). Haitian imports were also mostly from countries that have been excluded from the analysis based on higher income.

3.5 Difference between actual and counterfactual

We calculate the macroeconomic impact of the earthquake as the difference between the outcome variable for Haiti and the outcome variable for the synthetic control. The outcome variable for Haiti is labelled Y_1, while Y_j is used to refer to the outcome variables for the countries in the donor pool. The effect of the earthquake and aftermath

[4] Larger values of the State Fragility Index are for more fragile states.

at time t can be written as:

$$Y_{1t} - \sum_{j=2}^{J+1} \mathbf{w}_j^* Y_{jt} \tag{3}$$

We calculate the total impact by summing over time:

$$\sum_{t=T_0+1}^{T_0+T_1} \left(Y_{1t} - \sum_{j=2}^{J+1} \mathbf{w}_j^* Y_{jt} \right). \tag{4}$$

The existence of other major shocks after the earthquake, such as weather and political events (Burke and Leigh 2010; Dell et al. 2012), would potentially confound our estimates. Haiti did experience shocks following the earthquake including Hurricane Sandy in 2012 that caused 54 deaths (USAID 2013). There was also a major cholera outbreak that started in late 2010. The cholera outbreak was caused by bacteria introduced into Haiti (Lantagne et al. 2013), with this introduction likely occurring during the earthquake aftermath and recovery period (Katz 2013). The link between the earthquake and the cholera outbreak suggests that both events can be considered together as one larger event. Shocks in donor pool countries could also impact the results. Globally common shocks do not pose a problem for the synthetic control method, as these would affect both the actual outcome and the counterfactual, and not affect the difference between these variables.

3.6 Inferential tests

One way to test the significance of the output gap is an inferential test based on the ratio of post-earthquake to pre-earthquake Mean Square Prediction Error (MSPE). The prediction error is the difference between actual and counterfactual for the outcome variable. The test based on MSPE has been used in previous SCM work (Abadie et al. 2010).

Taking the ratio of the post-earthquake MSPE to the pre-earthquake MSPE can show the extent of the impact after the earthquake, while controlling for the pre-earthquake fit of the synthetic control. A small MSPE in the pre-earthquake period would indicate that the synthetic control closely matches the actual case. For the post-earthquake period, a large MSPE would indicate that the earthquake had a large impact.

We calculate the ratio of MSPE for Haiti, and also for every other country in the donor pool, after constructing synthetic controls for each country in the donor pool. A distribution of synthetic controls can then be found. This allows a permutation test alternative to the standard inferential testing for statistical significance. The MSPE inferential test is based on the uncertainty that the synthetic control is adequate, rather than uncertainty that a sample is an adequate reflection of an aggregate population.

3.7 Data issues

The accuracy of data for low-income countries needs to be considered. Measurement errors and considerable unreported economic activity in informal sectors (Henderson et al. 2012) can affect GDP data accuracy. Haiti's statistical capacity is ranked 138 out of 153 countries for the period 2005–2013 (World Bank 2015), indicating that sizeable GDP measurement error is possible. Further, the massive disruption of the earthquake may have amplified measurement error issues. Haiti's average statistical capacity score has improved in recent years, but the results still need to be interpreted with data quality caveats in mind. To lessen these concerns, we use multiple data sources and construct counterfactuals for multiple variables. Some variables may be subject to less measurement error than others. For instance, imports may be better measured than some types of domestic production or consumption, particularly in the earthquake aftermath when domestic production may have been more difficult to measure than imports coming through limited entry points. Some energy data are likely to be of higher quality than GDP data. Electricity generation from centralized sources, for example, is technically easier to measure than GDP.

4 Results

4.1 Impacts on GDP

Our main finding is that the earthquake has led to large and sustained GDP losses for Haiti. We calculate the GDP lost in the first 6 years following the earthquake to be approximately $6 billion, in total, in constant 2010 US dollars. This is calculated by integrating the difference between the actual and counterfactual in Fig. 1. The average of the annual percentage loss is 12%. In contrast, extrapolation of average

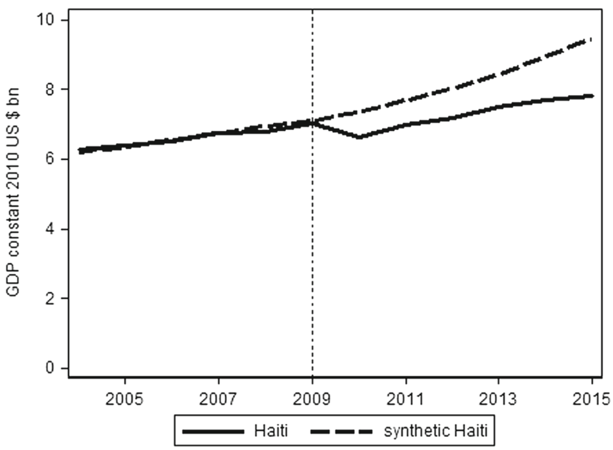

Fig. 1 GDP (constant 2010 US dollars, billions) for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

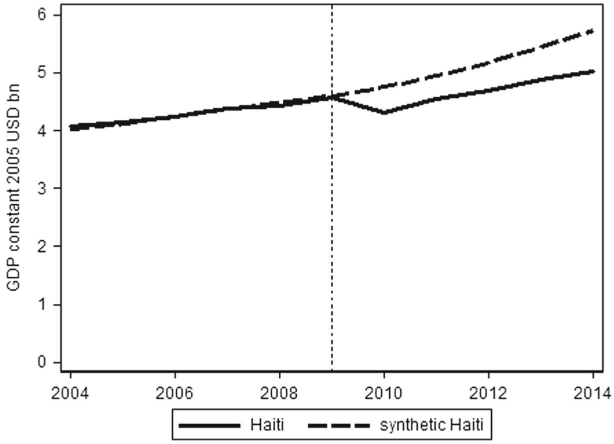

Fig. 2 GDP (constant 2005 US dollars, billions) for Haiti versus Synthetic Haiti. *Sources*: UN, author calculations

GDP growth from 2004 to 2009 produces a 4% average GDP loss. Figure 1 suggests the potential for a permanent impact on GDP, without subsequent convergence to the counterfactual. If this is true, the output losses from the earthquake will continue to accumulate over time. Apparently permanent losses to annual GDP are consistent with the finding that aggregate output is a unit root process in some cases (Nelson and Plosser 1982; Ben-David et al. 2003; Darné 2009).[5]

Figure 2, using UN data in constant 2005 US dollars, produces a similar outcome. There is a slightly smaller average loss of 10% for the 5 years to 2014 in Fig. 2, rather than the 12% average loss for the 6 years to 2015 in Fig. 1. In both cases, it appears that the effect on annual GDP is permanent rather than transitory.

Based on the data used in Fig. 2, Haiti had the second highest ratio of MSPE in the post-earthquake period to MSPE in the pre-earthquake period, as we show in Fig. 3. The probability is 2/21 that Haiti would randomly have a ratio within the top two from the sample including Haiti and the 20 donor pool countries. This corresponds to statistical significance at the 10% level.

The synthetic control using UN data in Fig. 2 closely matches the actual outcome in the period before the earthquake. Similarity of other predictor variables is also important. Table 2 shows that Haiti is indeed similar to Fig. 2 synthetic control for most of the predictor variables. The synthetic control is closer to Haiti than the equally weighted average for the donor pool for most of the variables. The exception is investment as a % of GDP.[6]

[5] The null hypothesis of Haiti's GDP having a unit root is not rejected at the 10% level based on an augmented Dickey–Fuller test with trend term.

[6] The optimization process is in respect of all of the predictor variables, so it is possible that a small number of synthetic control predictor variables could be further from the actual outcome in Haiti than the equally weighted donor pool.

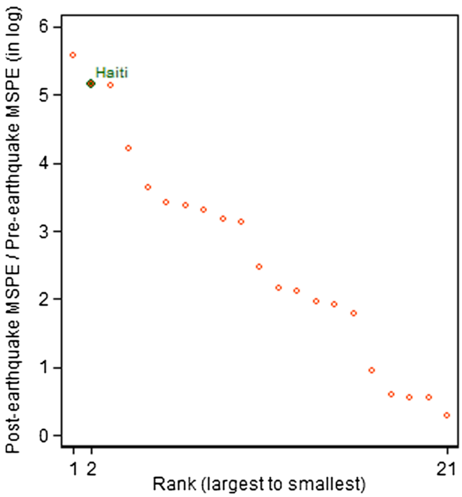

Fig. 3 Ratio of MSPE in the post-earthquake period to MSPE in the pre-earthquake period in log for GDP. *Sources*: UN, author calculations

Table 2 GDP predictor variable averages prior to the 2010 earthquake. *Sources*: WDI, UN

Predictor variable	Haiti	Synthetic Haiti	Donor pool
Consumption (%)	100	99	93
Exports (%)	15	25	26
Imports (%)	43	43	41
Investment (%)	28	18	22
Land area (sq. km)	27,560	242,826	537,101
Population (million)	9.5	7.9	22.8
GDP per capita USD	454	459	554
GDP billion USD (2005)	4.2	4.1	12.7
GDP billion USD (2007)	4.4	4.4	14.1
GDP billion USD (2009)	4.6	4.6	14.9

The predictor variables (except for GDP) are averaged over 2004–2009 as the pre-earthquake period. Consumption, exports, imports, and investment are a % of GDP. Investment is gross capital formation. 'Donor pool' is an equally weighted average of the 20 countries in the donor pool

We also show results for GDP per capita. Figure 4, using WDI data in PPP constant 2011 international dollars, shows a loss of 7% in the year of the earthquake and an average loss of 6% in the 6 years following the earthquake. This is comparable to the loss in GDP in Fig. 2, when taking into account the major loss in population.

There are six countries with nonzero weights in the donor pool used in Fig. 4. The synthetic control includes Burundi at 45%, Cameroon with a 28% weight, Senegal at 17%, Liberia at 5%, Nicaragua with 3%, and Nepal at 2%. Appendix Tables 7, 8, 9, 10 and 11 contain the weights for each figure.

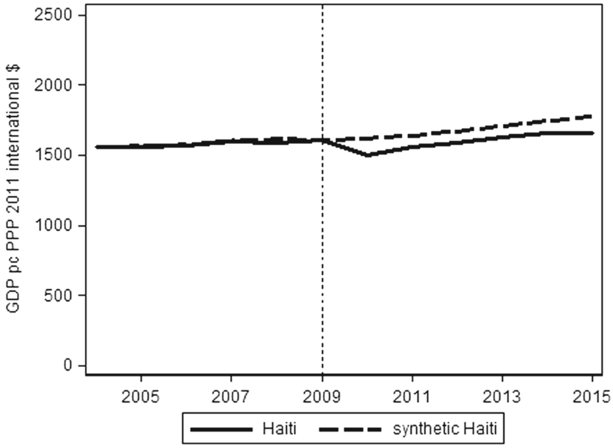

Fig. 4 GDP per capita PPP (constant 2011 international dollars) for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

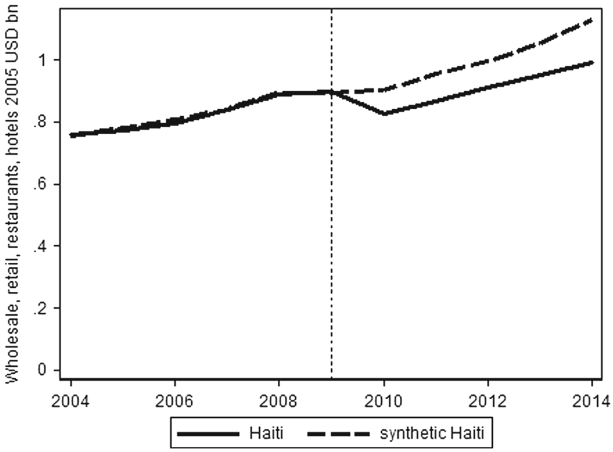

Fig. 5 Wholesale, retail, restaurants, hotels output (constant 2005 USD, billions) for Haiti and Synthetic Haiti. *Sources*: UN, author calculations

4.2 Sectoral impacts

Output losses for Haiti's services sector have been large and ongoing. Retail and tourism were particularly hard hit, suffering 26 and 25% contractions, respectively (Government of the Republic of Haiti 2010). Most commercial buildings in the centre of Port-au-Prince were damaged or destroyed, including hotels and restaurants. Service sector impacts can be seen through the dramatic initial fall in Fig. 5 and the ongoing gap below the counterfactual. Multiplying the sector weight in GDP of approximately 20% (UN 2016a) by the average difference between actual and counterfactual of 10% in Fig. 5 indicates that approximately one-fifth of the loss of GDP relates to the wholesale, retail, restaurants, and hotels sector.

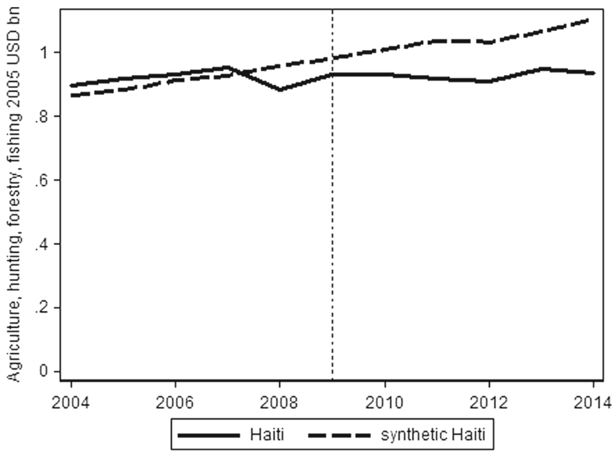

Fig. 6 Agriculture, hunting, forestry, fishing output (constant 2005 USD, billions) for Haiti and Synthetic Haiti. *Sources*: UN, author calculations

The large gap between actual services output and Haiti's counterfactual is also statistically significant at the 10% level, based on the MSPE test. Haiti has the second highest MSPE ratio for the wholesale, retail, restaurants, and hotels components of the service sector, among donor pool countries, as shown in Appendix Fig. 22.

Direct earthquake impacts for the agricultural sector were also evident, as shown in Fig. 6, but not to the same extent as for the services sector in the initial aftermath. This is due to the earthquake's location close to Port-au-Prince, the hub of service sector activity. The agricultural sector is more geographically dispersed and less reliant on earthquake-vulnerable buildings. In the years following the earthquake, agricultural production growth stagnated in Haiti. Transmission of negative impacts to the agricultural sector occurred through damage to road transport. Further, the cholera outbreak in the earthquake aftermath led to a preference for imported food over domestically produced food (Katz 2013). The average difference between actual and counterfactual for agriculture is similar to Fig. 5, and the agriculture sector is similar in size to the wholesale, retail, restaurants, and hotels sector, implying a similar impact on GDP, although the pre-earthquake fit between actual and synthetic control is not as good in Fig. 6. Seasonal variation and ongoing natural disaster risk makes it more difficult to calculate a suitable synthetic control for agricultural production in Haiti. For example, shocks experienced in Haiti in the pre-earthquake period included four storms in 2008 (World Bank 2013).

Haiti's manufacturing output contracted sharply in the year of the earthquake, but then rebounded more quickly than other sectors, as evident in Fig. 7. This suggests some degree of success in rebuilding damaged businesses, although there is still a considerable loss in the manufacturing sector. There is an average difference between actual and counterfactual of 8% in Fig. 7. As manufacturing is approximately 10% of output in Haiti, this implies that the manufacturing loss would account for approximately one-tenth of the GDP loss.

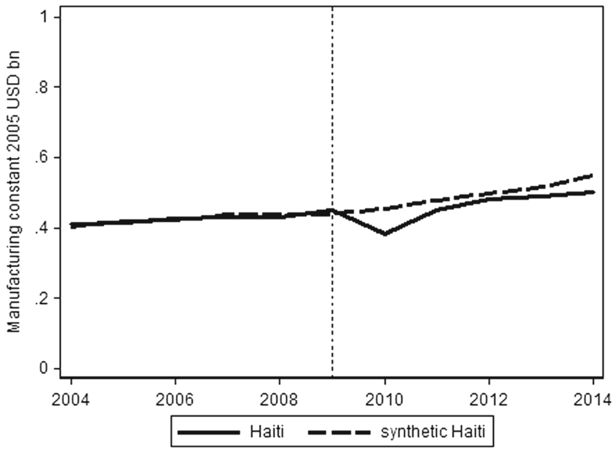

Fig. 7 Manufacturing output (constant 2005 USD, billions) for Haiti and Synthetic Haiti. *Sources*: UN, author calculations

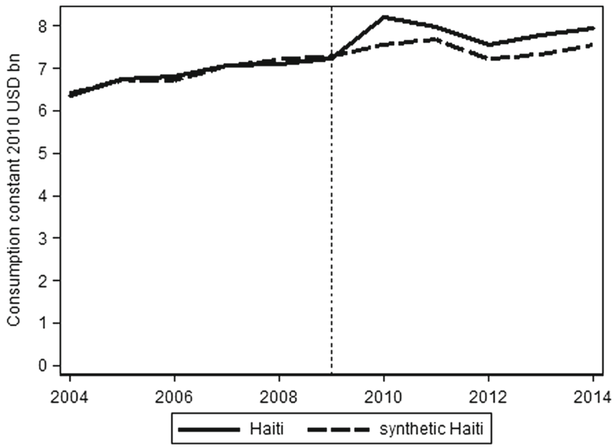

Fig. 8 Final consumption expenditure (constant 2010 USD, billions) for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

4.3 Consumption

Aggregate consumption increased after the earthquake, before subsequently declining towards the SCM counterfactual, as shown in Fig. 8.[7] The surge in the consumption variable is consistent with the extent of the emergency spending required to alleviate the severe earthquake impacts. The relief effort involved many aspects including supply of food and access to water and health care. The change in aggregate consumption

[7] Appendix Fig. 23 shows a synthetic control for consumption as a % of GDP. This produces a more stable synthetic control than Fig. 8 with consumption increasing above counterfactual and then returning towards the counterfactual, but the variable in Fig. 23 includes impacts of both consumption increases and GDP losses.

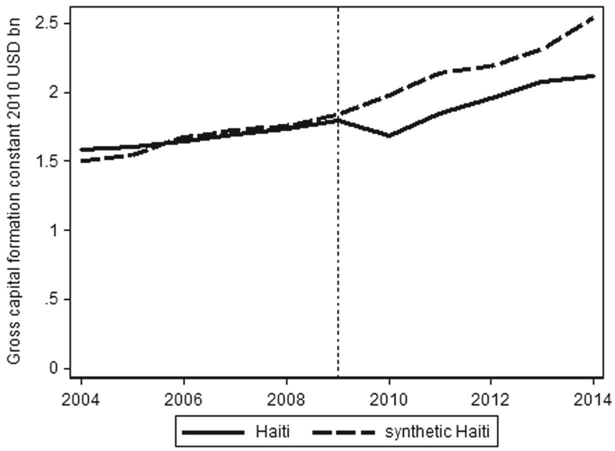

Fig. 9 Gross capital formation (constant 2010 USD, billions) for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

was mostly due to private consumption changes, as government consumption is only a small proportion of total consumption in Haiti.[8] The initial increase in household consumption was partly driven by aid inflows, as household consumption includes expenditure of non-profit institutions serving households. The urgency of consumption needs in the earthquake aftermath has potential to bring forward future consumption.

4.4 Investment

Investment decreased in Haiti in the aftermath of the earthquake, and there has not been a return to the counterfactual path in Fig. 9. The initial drop relates to the diversion of resources to consumption in the emergency and recovery period. The ongoing gap of actual investment below the counterfactual increases the prospects that the economic impacts of the earthquake will be permanent rather than transitory.

Investment can potentially play an important role in earthquake recoveries, with different predictions depending on which economic theory is used. In neoclassical models, the expected economic effects of an earthquake depend on relative changes in capital and labour. Initial reductions in capital per worker can be followed by an increase in capital accumulation and a temporary surge in economic growth (Okuyama 2003), but reductions in effective workers can hinder growth (Loayza et al. 2012). With increasing returns to inputs (Romer 1986), loss of capital could lead to a permanently lower growth path, but installation of more productive capital investment during a rebuilding stimulus could lead to faster long-term growth. For Haiti, the reduction in investment could lead to extended macroeconomic losses, unless investment productivity and quantity increase.

[8] Government consumption expenditure was less than 10% of aggregate consumption for Haiti in each of the 11 years to 2014 (UN 2016a).

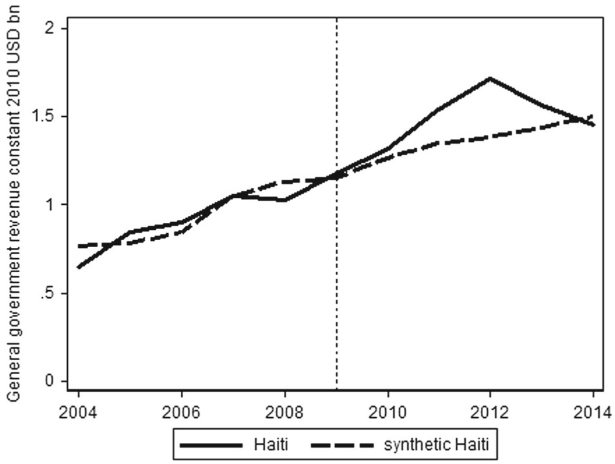

Fig. 10 General government revenue, in billions of constant 2010 US dollars (revenue as a % of GDP, multiplied by GDP), for Haiti versus Synthetic Haiti. *Sources*: IMF, WDI, author calculations

4.5 Government

Low levels of revenue are an ongoing constraint for Haiti's government. Official development assistance has not been channelled through the Haitian government in most cases (UN 2016b). Figure 10 shows government revenue generally increasing, although there has been a decline following 2012. The differences between actual and counterfactual in the period prior to the earthquake make it difficult to draw conclusions on the impact of the earthquake on government revenue.

Fiscal constraints faced by the government hindered the potential for a domestic fiscal stimulus from public sources. Government expenditure has increased and is above the counterfactual, evident in Fig. 11, although the pre-earthquake fit is not ideal. Figure 11 also shows an expenditure decrease following 2013.

4.6 Trade impacts

A large initial increase in imports of consumption goods and services supported Haiti's temporary post-earthquake increase in consumption. Haiti's initial increase in imports was necessary due to the loss of productive capacity following the earthquake and heightened demand for some products such as building supplies. Figure 12 shows that imports were above the counterfactual in the years immediately following the earthquake and then fell below the counterfactual, although the calculated counterfactual varies considerably in the case of imports. Larger proportionate changes in GDP components such as imports are more likely than in GDP, as fluctuations in the output of one component may be offset by fluctuations in another.

Exports have increased to a minor extent since the earthquake, as evident in Fig. 13. The synthetic control for exports increases sharply in the year to 2012, raising questions

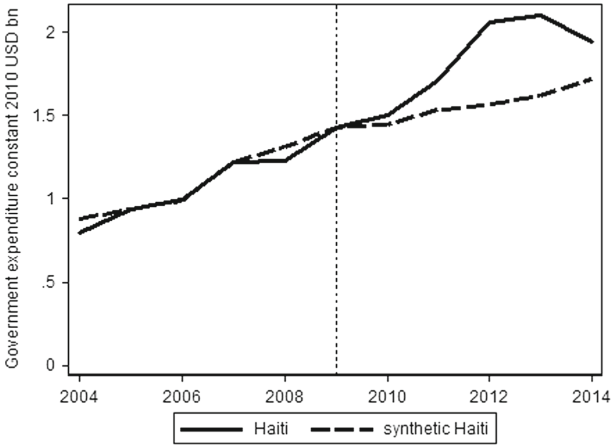

Fig. 11 General government total expenditure, in billions of constant 2010 USD, (expenditure as a % of GDP, multiplied by GDP), for Haiti versus Synthetic Haiti. *Sources*: IMF, WDI, author calculations

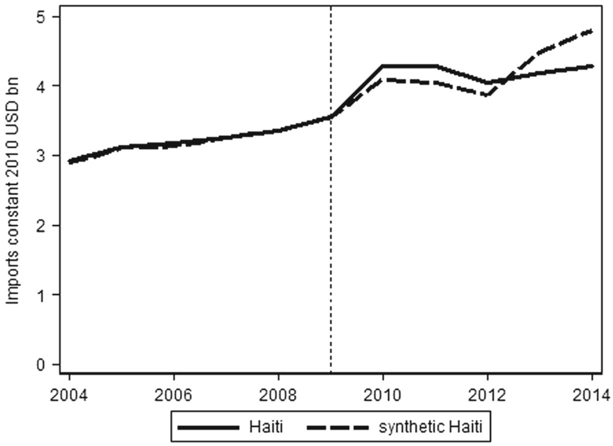

Fig. 12 Imports, in billions of constant 2010 USD, for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

over the suitability of the synthetic control in this case.[9] The difficulty in finding a suitable synthetic control for exports partly relates to the size and concentration of the export sector in Haiti. The export sector in Haiti is small and focussed on light manufacturing, with over 80% of exports coming from textiles (Simoes and Hidalgo 2011). The continued upward trend in exports is partly a result of the recovery in the manufacturing sector.

[9] While the actual and synthetic control are very similar prior to the earthquake, there was an unusually large increase in exports of over 150% in Burkina Faso from 2009 to 2012 compared to an average of 44% for the donor pool. Burkina Faso makes up over 45% of the synthetic control for exports.

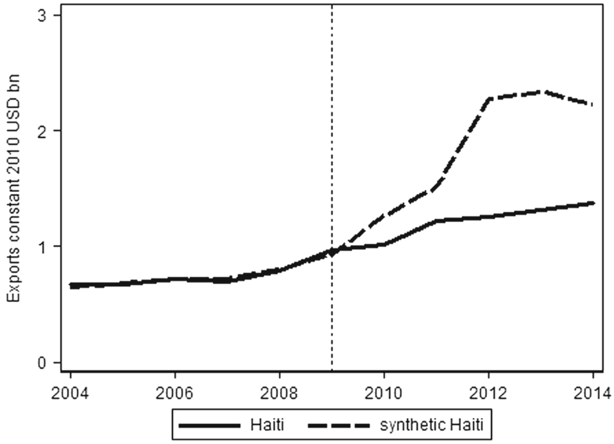

Fig. 13 Exports, in billions of constant 2010 USD, for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

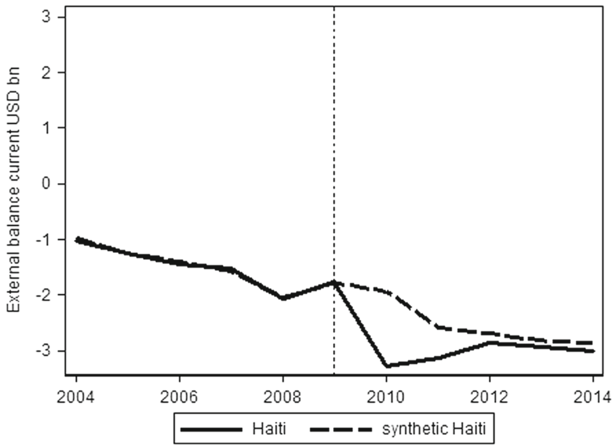

Fig. 14 External balance, in billions of current USD, for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

In line with the major increase in imports, Haiti experienced an initial deterioration in its external balance on goods and services following the earthquake.[10] Figure 14 shows the initial shock to the external balance, followed by a return to the counterfactual. The absolute size of the external deficit had grown considerably by 2014.

[10] The World Bank defines external balance on goods and services as exports of goods and services minus imports of goods and services.

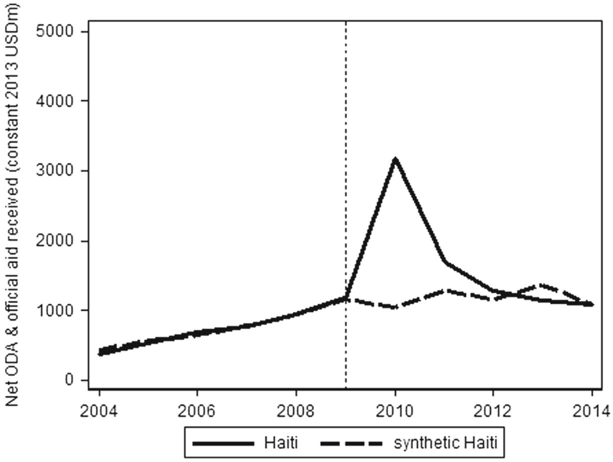

Fig. 15 Net official development assistance and official aid received (constant 2013 USD) for Haiti versus Synthetic Haiti in millions. *Sources*: WDI, author calculations

4.7 Official development assistance and remittances

Inflows of funds to developing countries can support recoveries after natural disasters and are particularly needed if an absence of insurance markets hinders private consumption smoothing. The impact of foreign assistance following natural disasters depends on the amount, timing, and effectiveness of the flows. Foreign financing can have a positive impact through greater availability of resources, or there can be negative impacts if institutions lack the capacity to effectively use funds.

There was a major surge in net official development assistance (ODA) to Haiti in 2010. While the median increase in ODA after natural disasters is generally modest (Becerra et al. 2014), for Haiti there was an increase of 173% in real terms from 2009 to 2010. This large increase in ODA was in response to the extreme nature of the earthquake's impacts in Haiti.

The timing and consistency of official development assistance have important implications for short-term recovery and long-term development. Figure 15 shows a large increase in net ODA and official aid in 2010, but a subsequent fall towards the counterfactual. Appendix Fig. 24 shows that Haiti had the second highest ratio of MSPE among donor pool countries, for net ODA and official aid received, despite the drop after the initial surge.

Even though there was a large initial increase in aid to Haiti, the impact of the aid also depends on its composition. The initial surge in aid was primarily for emergency response needs rather than long-term investment. The proportion of net ODA to Haiti for humanitarian assistance increased from an average of 7% in the previous 12 years, to 51% in 2010 (OECD 2015). In contrast, the total amount of aid classified as technical cooperation was lower in the 4 years after the earthquake than the 4 years before the earthquake (OECD 2015). Also, intermediaries such as nongovernmental organizations and private contractors received large amounts of aid, making it difficult to determine the final use of these funds (Ramachandran and Walz 2012) and to determine likely outcomes.

There have also been aid inflows with a greater focus on long-term development. For instance, the US government supported efforts to make the electoral process more transparent through actions such as creation of Electoral Information Centers to increase publicly available electoral information (US Department of State 2015). For urban infrastructure, the US government provided shelter solutions for more than 300,000 people who were displaced following the earthquake (US Department of State 2015), although tens of thousands were still living in tents 5 years after the earthquake (Miami Herald 2015). Development of road infrastructure is another priority. Road quality has been a major problem in Haiti, due in part to earthquake damage and also seasonal flooding, including for agricultural producers such as those in the Fond Baptiste area (USAID 2012). Roads rehabilitated in 2010 by the United Nations Office for Project Services (UNOPS) have included construction of retaining walls for a road linking Port-au-Prince and Jacmel (UNOPS 2011). More work remains to be done, as the ongoing threat to infrastructure from natural disasters was evident in the impact of Hurricane Matthew, with the destruction of the main road between Port-au-Prince and the southern part of Haiti (BBC 2016). The Haiti Reconstruction Fund, a partnership between the Government of Haiti and the international community, has also targeted infrastructure development. For instance, the development of the Caracol Industrial Park in the north of Haiti aims to decentralize economic growth, adding over 10,000 jobs in sectors such as garment manufacture (Haiti Reconstruction Fund 2016).

It is possible that spillover impacts from the earthquake in Haiti could affect aid received by other countries and the calculation of the synthetic control. For instance, there is a possibility that other countries in the donor pool received less in aid due to the large increase in aid to Haiti. Despite this possibility, evidence of major falls in total aid for other countries was not pronounced in the data. On average, donor pool countries received more in net ODA and official aid in the 4 years after the earthquake than the 4 years before the earthquake. Further, net official development assistance and official aid on a global basis, excluding Haiti, increased in each of the 4 years from 2010, except for 2012 (World Bank 2016).

Large aid inflows can also have economic side effects, potentially appreciating the exchange rate, increasing wage inflation, and reducing export competitiveness (Rajan and Subramanian 2011). Exchange rate impacts for the Haitian gourde were muted, partly due to the build-up of foreign currency reserves (IMF 2015). The short-term aid surge could also have been inflationary, but consumer price inflation remained below 10%, shown in Fig. 16.

Other foreign flows like remittances also contributed more to consumption than investment after the earthquake (IDB 2014). Remittances have increased since the earthquake, but the trend does not exhibit a noticeable change following the earthquake. The pre-earthquake fit between actual and synthetic control is not as good as some of the other variables, as shown in Fig. 17. Remittances can be constrained by a number of factors, including lack of financial development. For instance, Posso (2015) finds that an increase in the proportion of the population using microfinance is associated with an increase in remittance inflows. There was potential for remittances to fall following the

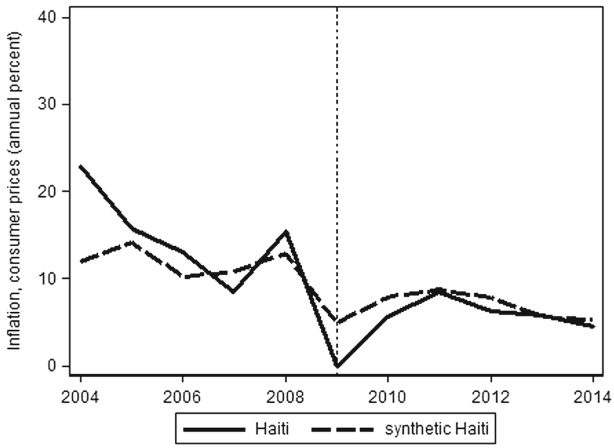

Fig. 16 Inflation in consumer prices, annual per cent, for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

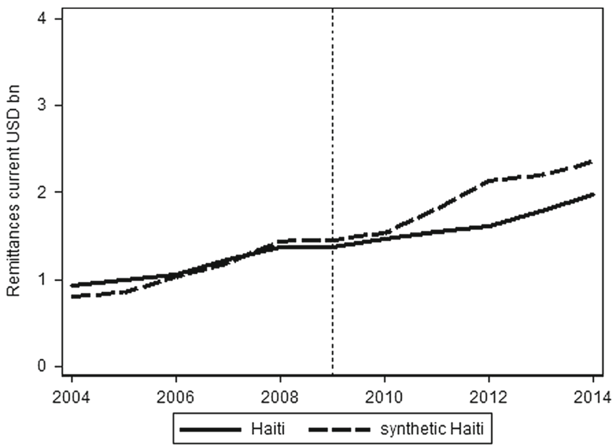

Fig. 17 Personal remittances received, current USD, billions. *Sources*: WDI, author calculations

global financial crisis, but Ruiz and Vargas-Silva (2012) note that remittance growth in 2008 was positive for many Latin American countries including Haiti.

4.8 Energy use

Energy and electricity use were at low levels prior to the earthquake in Haiti, although there had been a trend of modest increase. Following the earthquake, primary energy consumption in Haiti continued its upward trend (Appendix Fig. 25). Electricity generation also increased from 2010 to 2012, after a minor initial fall in the year of the earthquake, but stagnated after 2012, as shown in Fig. 18. Long-term structural issues in electricity supply in Haiti (IMF 2015) could be more important determinants of the level and trend of electricity generation.

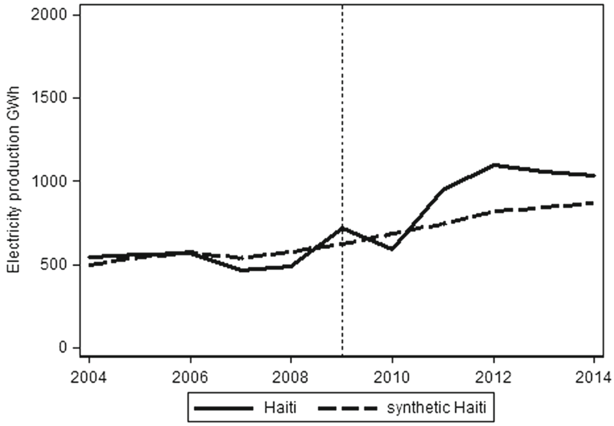

Fig. 18 Electricity production (GWh) for Haiti and Synthetic Haiti. *Sources*: IEA, WDI, author calculations

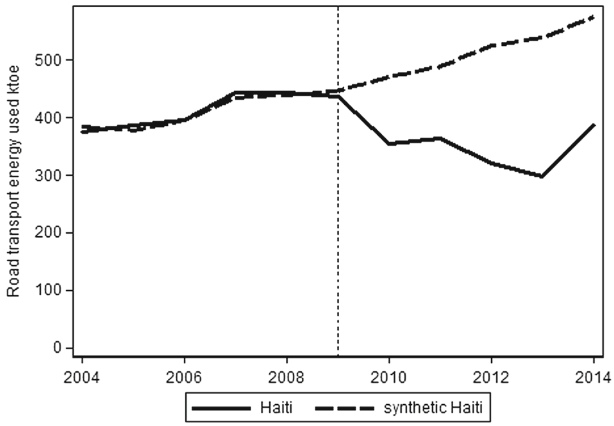

Fig. 19 Road transport energy use (thousand tonnes of oil equivalent) for Haiti and Synthetic Haiti. *Sources*: IEA, WDI, author calculations

The impact of the earthquake on road transport is starkly evident in Fig. 19, with energy used for road transport falling sharply in the year of the earthquake. Many roads were damaged by the earthquake, including around 70 km of main roads (Government of the Republic of Haiti 2010). Damage to roads contributed to the transmission of economic impacts after the earthquake, providing an impediment to the economic recovery.

4.9 Population in Port-au-Prince

The earthquake caused pronounced social dislocation in Port-au-Prince. The major impact of the earthquake and the aftermath on the population size of Port-au-Prince is evident in Fig. 20, with a large gap below the counterfactual up to 2014. In addition

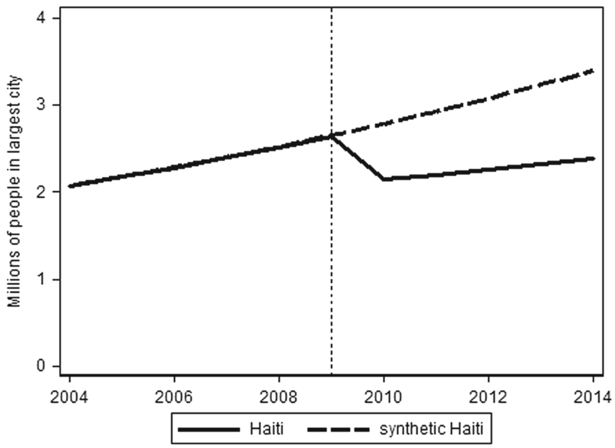

Fig. 20 Millions of people living in largest city for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

to the social impacts, the large-scale internal displacement has major implications for economic outcomes in Haiti. Permanent migration of skilled workers away from disaster-affected areas can accelerate poverty traps (Hallegatte and Dumas 2009).

5 Robustness tests for GDP per capita

One robustness test is to consider a longer time horizon. We have repeated the SCM analysis with WDI data starting from 1998. We chose not to use the longer time period in the main analysis due to the difficulty in finding synthetic controls to closely match Haiti's longer run macroeconomic experience. Haiti's GDP per capita growth between 1998 and 2009 was lower than most countries and was characterized by two distinct periods. From 1998 to 2004, annual economic growth was negative, and from 2004 to 2009 annual growth was positive. Haiti's economic performance prior to 2004 was substantially affected by political instability (IMF 2015).

The SCM outcome with the longer series produces a GDP per capita loss of 8% in the year of the earthquake and 9% on average for the 5 years following the earthquake, as evident in Fig. 21. This again indicates that the economic impacts of the earthquake were severe. The donor pool is expanded for Fig. 21 to include countries with GDP per capita growth that was as low as Haiti's GDP per capita growth, for the period from 1998 to 2009. This donor pool expansion occurs through the omission of inflation as a predictor variable.

A robustness test for the synthetic control using UN data is to restrict the donor pool to countries that are similar to Haiti across extra dimensions. We have used a small donor pool of five countries that are similar to Haiti in terms of land area, population size, state fragility, and economy. More specifically, countries are included that have land area less than 150,000 km^2 (Haitian land area is 27,560 km^2), 2009 population less than 30 million (Haiti in 2009 had a population of 10 million), and average State Fragility Index (Marshall and Cole 2014) within 2 points of Haiti over 2004–2009.

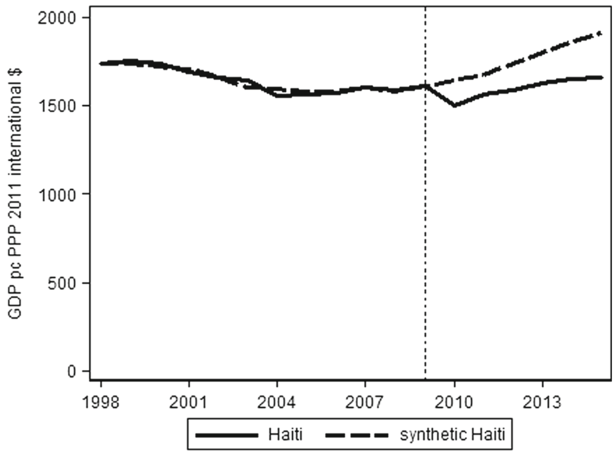

Fig. 21 GDP per capita PPP (constant 2011 international dollars) for Haiti versus Synthetic Haiti. *Sources*: WDI, author calculations

The same criteria from the main analysis are also used: GDP per capita (2005 constant USD) of less than $1000 in 2009, GDP per capita growth within 15% points of growth in Haiti for the period 2004–2009, GDP per capita growth within 15% points of growth in Haiti for the period 2010–2014, and excluding countries that had a one-year increase of 4 or more points in the State Fragility Index (Marshall and Cole 2014). Countries that do not meet all of these criteria or have missing data are excluded, leaving five countries: Benin, Comoros, Lesotho, Nepal, and Togo. The synthetic control using these five countries in the donor pool produces a 7% average GDP per capita gap between actual and counterfactual, with a 9% gap in the year of the earthquake. The 7% average loss in GDP per capita for the small donor pool is in between the 6% average loss for Fig. 4 and the 9% average loss in Fig. 21. Appendix Fig. 26 shows the synthetic control for the small donor pool. The five countries in the small donor pool that meet the additional criteria also make a disproportionately large contribution to the other synthetic controls. On average, these countries make up 26% of the synthetic controls listed in Appendix Table 7, 53% for Table 8, 24% for Table 9, and 50% for Table 10.

6 Conclusion

The loss of over 200,000 lives was a devastating outcome of the 2010 earthquake in Haiti, and the initial destruction also contributed to large output losses. We calculate the gap between actual and counterfactual GDP to be approximately 12% on average in the 6 years to 2015. In aggregate terms, we calculate the total loss to be approximately $6 billion (constant 2010 US dollars) over the 6 years to 2015.

The $6 billion of production losses calculated in this paper is similar in magnitude to the $8 billion in monetary damages initially estimated by Cavallo et al. (2010), although it is difficult to make precise comparisons for a number of reasons. One reason is that the $6 billion loss calculated in this paper does not include future production losses for all years in the future. While the present value of total production losses from a natural disaster in a no-reconstruction scenario is theoretically equivalent to initial asset losses, equivalence is based on strong assumptions, such as the discount rate equalling the return on capital, and shocks being marginal (Hallegatte 2014). The massive impact of the earthquake in Haiti reduces the relevance of the theoretical loss equivalence in this case. Further, the $6 billion loss in this paper is in 2010 US dollars while the $8 billion is in 2009 US dollars.[11] While it is difficult to compare different loss calculations, the losses calculated in this paper are severe.

While GDP losses have been major and ongoing, the earthquake had differing impacts on various parts of the Haitian economy. Aggregate consumption increased in the short term, due in part to a temporary surge in foreign inflows. Investment has not recovered, nor has the services sector, but the smaller manufacturing sector showed reversion towards the no-earthquake counterfactual. While electricity generation was lower in the year of the earthquake than the previous year, the difference was minor, and there have been some modest electricity production increases followed by some stagnation. Road transport energy use was considerably lower after the earthquake.

While it is perhaps too early to determine if the macroeconomic impacts of the earthquake are indeed permanent, the fact that GDP remains well below the counterfactual several years after the event means that a permanent effect is probable. The gap of actual investment below counterfactual suggests that GDP losses may persist, unless investment quantity and productivity increase. There is evidence that other shocks, including World War II and the Great Depression, have had permanent impacts on economic output elsewhere (Barro 2009). The potentially permanent output impact from the earthquake is consistent with findings that aggregate output sometimes has a unit root (Nelson and Plosser 1982; Ben-David et al. 2003; Darné 2009). Permanent impacts of natural disasters, such as the earthquake in Haiti, can contribute to explanations of lower levels of economic development in more disaster-prone countries.

The earthquake in Haiti is a case of massive economic damage that can result from unexpected natural disasters, especially in countries with relatively low disaster risk preparedness. Risk escalation from potential climate change and population growth is likely to increase the importance of investment for risk reduction in coming years.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Data and computer code availability The datasets of this paper (1. data, 2. code including instructions) are collected in the electronic supplementary material of this article.

[11] Using 2010 constant US dollars rather than 2009 constant US dollars gives GDP values that are approximately 6% higher; the loss estimations would be similar using either currency base year when rounding to the nearest billion.

Appendix

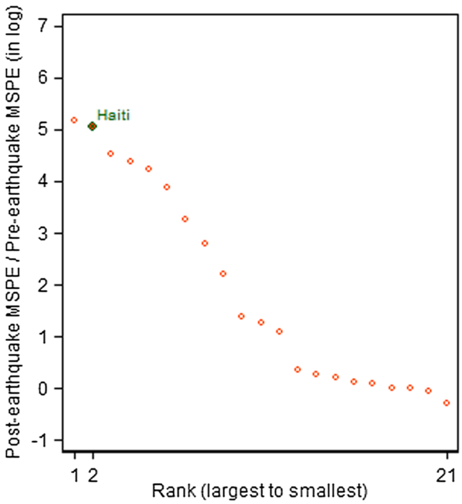


Fig. 22 Ratio of MSPE in the post-earthquake period to MSPE in the pre-earthquake period in logs for wholesale, retail, restaurants, hotels. *Sources*: UN, author calculations

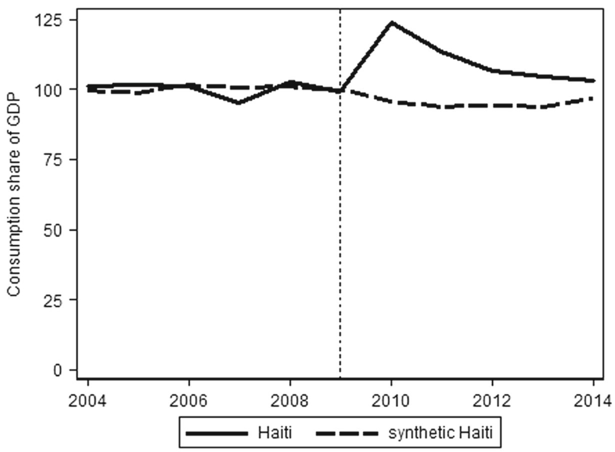
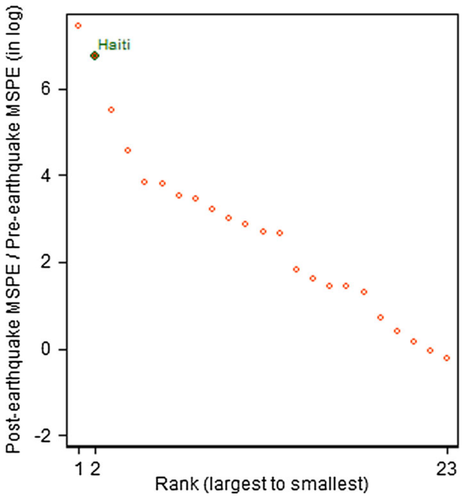


Fig. 23 Consumption share of GDP for Haiti and Synthetic Haiti. *Sources*: WDI, author calculations

Fig. 24 Ratio of MSPE in the post-earthquake period to MSPE in the pre-earthquake period in logs for Net ODA and official aid received. *Sources*: WDI, author calculations



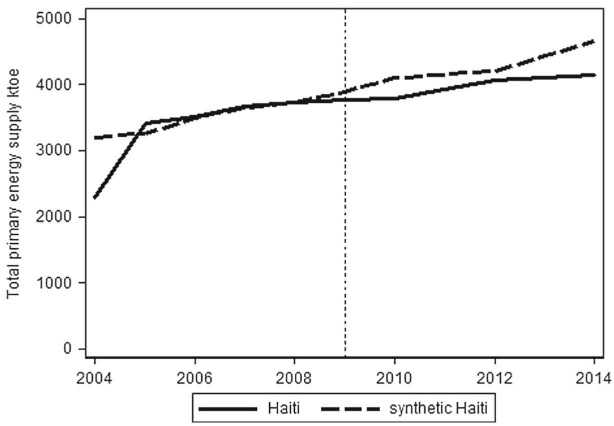


Fig. 25 Total primary energy supply (thousand tonnes of oil equivalent) for Haiti and Synthetic Haiti. *Sources*: IEA, WDI, author calculations

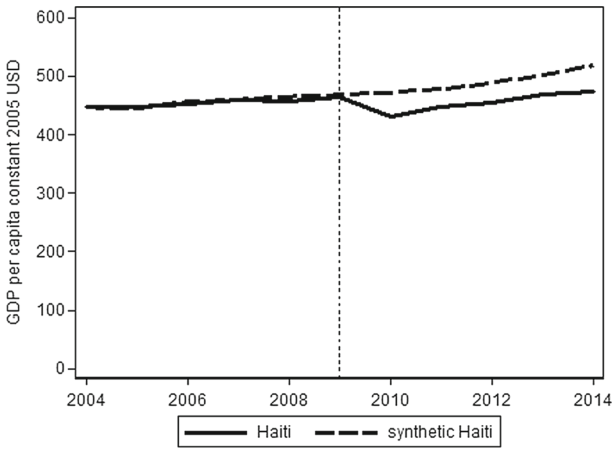


Fig. 26 GDP per capita (constant 2005 US dollars) for Haiti versus Synthetic Haiti, donor pool of five countries. *Sources*: UN, author calculations, WDI

Table 3 Variables from the World Bank (2016) World Development Indicators

Variable
GDP (constant 2010 US $)
GDP per capita, PPP (constant 2011 international $)
Final consumption expenditure, etc. (% of GDP)
Final consumption expenditure, etc. (constant 2010 US $)
Gross capital formation (% of GDP)
Gross capital formation (constant 2010 US $)
Imports of goods and services (% of GDP)
Imports of goods and services (constant 2010 US $)
Exports of goods and services (% of GDP)
Exports of goods and services (constant 2010 US $)
External balance on goods and services (current US $)
Land area, km^2
Personal remittances received (current US $)
Population in largest city
Population
Net official development assistance and official aid received (constant 2013 US$)
Inflation, consumer prices (annual %)

Table 4 Variables from UN (2016a)

Variable
GDP (constant 2005 US$)
Final consumption expenditure (constant 2005 US$)
Gross capital formation (constant 2005 US$)
Imports of goods and services (constant 2005 US$)
Exports of goods and services (constant 2005 US$)
Agriculture, hunting, forestry, fishing output (constant 2005 US$)
Manufacturing output (constant 2005 US$)
Wholesale, retail trade, restaurants, and hotels output (constant 2005 US$)

Table 5 Variables from IEA (2016)

Variable
Dataset: World Energy balances: Total: Road: thousand tonnes of oil equivalent (ktoe)
Dataset: World energy statistics: Electricity (GWh) Production
Dataset: World Energy balances: Total: Total primary energy supply (ktoe)

Table 6 Variables from IMF (2016)

Variable
General government revenue, % of GDP
General government total expenditure, % of GDP

Table 7 Weights of countries in the donor pool for figures using WDI data

Country	Fig. 1 GDP	Fig. 4 GDP pc	Fig. 8 Cons.	Fig. 23 Cons %	Fig. 9 GCF	Fig. 10 Gov. Rev.	Fig. 11 Gov. Exp.
Bangladesh	0	0	0	0	0	0	0
Benin	0	0	0	0	0	0	0.184
Burkina Faso	0	0	0	0	0	0	0
Burundi	0	0.451	0.218	0.192	0.494	0.619	0.402
Cambodia	0	0	0	0	0	0	0.050
Cameroon	0.199	0.277	0	0	0.285	0	0
Kenya	0	0	0	0	0	0	0
Kyrgyz Rep.	0	0	0	0	0	0.155	0
Liberia	0.016	0.049	0	0.053	0.046	0	0
Madagascar	0	0	0.099	0	0	0	0
Mali	0	0	0	0	0	0	0
Moldova	0.055	0	0.161	0	0	0	0.142
Mozambique	0	0	0	0	0	0	0
Nepal	0	0.019	0	0.755	0	0.137	0.059
Nicaragua	0	0.037	0	0	0.175	0.087	0
Rwanda	0	0	0	0	0	0.002	0.163
Senegal	0	0.168	0	0	0	0	0
Sierra Leone	0	0	0	0	0	0	0
Sudan	0	0	0.078	0	0	0	0
Tanzania	0	0	0	0	0	0	0
Togo	0.730	0	0.444	0	0	0	0
Uganda	0	0	0	0	0	0	0

Table 7 continued

Country	Fig. 12 Imp.	Fig. 13 Exp.	Fig. 14 Ex. bal.	Fig. 15 ODA	Fig. 16 Infl.	Fig. 17 Remit	Fig. 20 Pop.
Bangladesh	0	0	0.149	0	0	0.072	0.057
Benin	0	0	0	0	0	0	0
Burkina Faso	0	0.453	0	0	0	0	0
Burundi	0.272	0.202	0.480	0	0.187	0	0.444
Cambodia	0	0	0	0	0	0	0
Cameroon	0	0	0	0	0	0	0
Kenya	0	0	0	0.326	0	0.420	0
Kyrgyz Rep.	0	0	0	0	0	0	0
Liberia	0.031	0.031	0	0.038	0	0	0
Madagascar	0	0	0	0	0.309	0	0
Mali	0	0	0	0	0	0	0
Moldova	0	0	0.027	0	0.484	0.093	0.073
Mozambique	0	0	0	0	0	0	0
Nepal	0.334	0	0	0	0	0	0
Nicaragua	0.043	0	0.345	0	0	0.415	0
Rwanda	0	0	0	0	0	0	0
Senegal	0.104	0	0	0	0	0	0
Sierra Leone	0	0	0	0	0.019	0	0
Sudan	0.076	0	0	0.095	0	0	0
Tanzania	0	0	0	0	0	0	0.426
Togo	0.140	0.300	0	0.541	0	0	0
Uganda	0	0.013	0	0	0	0	0

Table 8 Weights of countries in the donor pool for figures using UN data

Country	Fig. 2 GDP	Fig. 5 WRRH	Fig. 6 Ag.	Fig. 7 Man.
Benin	0	0.142	0	0
Burkina Faso	0	0.007	0	0
Cameroon	0.146	0	0	0
Chad	0	0	0	0
Comoros	0.094	0.028	0	0.270
Côte d'Ivoire	0	0	0	0
Democratic Republic of the Congo	0	0	0	0
Guinea	0.006	0	0	0
Guinea-Bissau	0	0.348	0	0
Kenya	0	0	0	0
Kyrgyz Republic	0	0.283	0	0
Lesotho	0	0	0.312	0
Mauritania	0	0	0	0.143
Nepal	0	0.180	0.005	0.561
Niger	0	0	0	0
Pakistan	0	0.013	0	0
Senegal	0	0	0	0
Somalia	0.229	0	0.683	0
Tanzania	0	0	0	0.026
Togo	0.524	0	0	0

Table 9 Weights of countries in the donor pool for figures using IEA and WDI data

Country	Fig. 25 Energy	Fig. 18 Electr.	Fig. 19 Road
Bangladesh	0	0	0
Benin	0.525	0	0
Cambodia	0	0	0
Cameroon	0	0	0
Côte d'Ivoire	0	0	0
Ghana	0	0.023	0
Kenya	0	0	0
Kyrgyz Republic	0	0	0
Moldova	0.166	0.028	0
Mozambique	0	0	0
Nepal	0.105	0	0
Nicaragua	0	0	0.490
Niger	0.116	0.949	0.240
Senegal	0	0	0.268
Sudan	0	0	0
Tanzania	0	0	0.002
Togo	0.088	0	0

The donor pool includes countries that meet the income threshold, and with a balanced panel for GDP per capita, consumption, investment, imports, exports, inflation, land area, population, and the three energy variables

Table 10 Weights of countries in the donor pool for Fig. 21 using the longer series of WDI data

Country	Fig. 21 GDP pc
Bangladesh	0.077
Benin	0.284
Burkina Faso	0
Burundi	0
Cambodia	0
Cameroon	0
Central African Republic	0
Chad	0
Côte d'Ivoire	0.088
Democratic Republic of the Congo	0
Ghana	0.020
Guinea	0
Kenya	0
Madagascar	0
Mali	0
Malawi	0.156

Table 10 continued

Country	Fig. 21 GDP pc
Moldova	0
Mozambique	0
Nicaragua	0
Niger	0
Rwanda	0
Senegal	0
Sierra Leone	0
Sudan	0
Tanzania	0
Togo	0.219
Uganda	0
Uzbekistan	0
Zimbabwe	0.156

Table 11 Weights of countries in the donor pool for Fig. 26 using the smaller donor pool of five countries

Country	Fig. 26 GDP pc
Benin	0.240
Comoros	0.128
Lesotho	0
Nepal	0.277
Togo	0.355

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