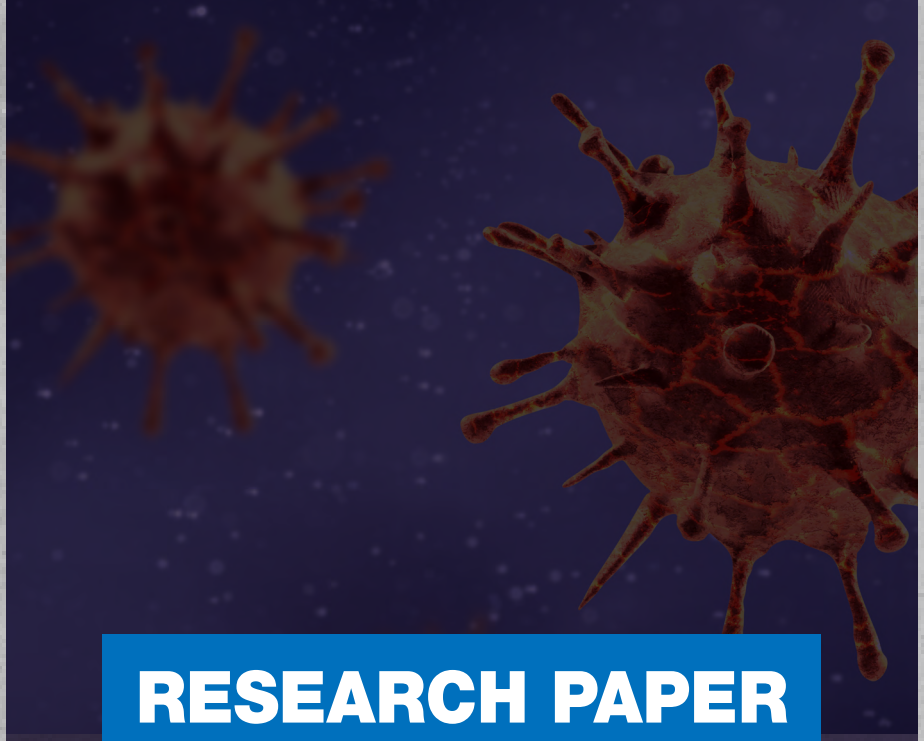

RESEARCH PAPER

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THE IMPACT OF COVID-19 IN MOROCCO: MACROECONOMIC, SECTORAL AND REGIONAL EFFECTS

By

Eduardo A. Haddad | Karim El Aynaoui | Abdelaaziz Ait Ali | Mahmoud Arbouch | Inácio F. Araújo

POLICY CENTER FOR THE NEW SOUTH
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The Impact of COVID-19 in Morocco: Macroeconomic, Sectoral and Regional Effects

By Eduardo A. Haddad[1], Karim El Aynaoui[2], Abdelaaziz Ait Ali[3], Mahmoud Arbouch[4] & Inácio F. Araújo[5]

1. Introduction

The COVID-19 pandemic has hit the Moroccan economy hard, as elsewhere in the world. A collapse in external demand and a lockdown lasting more than three months have profoundly altered economic activity in Morocco, causing its first recession since 1995. The implementation of the confinement and social distancing measures was strict and came two weeks after the detection of the first cases of COVID-19 in Morocco on March 2, 2020. The lockdown was extended three times and lasted around 14 weeks. This strategy prevented a sharp increase in cases in the early part of the pandemic, and enabled the preparation of health infrastructure to deal with potentially more severe waves of contamination. However, the price was the consequent economic downturn. What are the daily economic costs of the control measures adopted in the country to prevent the spread of COVID-19? What are the impacts of mitigation measures implemented by the central government? How do flexibility measures affect the economic recovery? This study quantifies the regional and sectoral economic impacts of preventive measures related to the coronavirus pandemic in Morocco.

2. Methodology

Main transmission channels embedded in the modeling framework

To assess the economic costs of the pandemic in Morocco and provide a comprehensive analysis of its impact, we rely on the methodology developed by Haddad et al (2020a) for assessing the daily economic costs of control strategies for mitigating the effects of COVID-19. This methodology is based on the partial hypothetical extraction approach to input-output systems, which consists of removing partially a sector or an economic bloc from the system and drawing comparisons between the baseline scenario (before the removal) and the hypothetical scenario representing the new equilibrium (after the removal). We analyze Morocco to identify, in addition to aggregate macroeconomic impacts, which regions are most sensitive to the restrictive measures, and which sectors are most affected.

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This methodology has been used to inform regional and national governments in Brazil (Haddad et al, 2020b) and Colombia (Bonet et al, 2020ab) about the potential regional and sectoral economic costs of different lockdown strategies. Simulated scenarios based on different durations and intensities of the control measures help in designing sectoral and territorial-based policies to ease lockdown and monitor economic recovery once a downward trend in the growth rate of new infections is reached.

We calibrate the Moroccan model using the interregional input-output system developed for the country (Haddad et al, 2020c), and the micro data from the HCP 2014 Demographic Census. Additionally, we have used National Accounts data to update the information system to 2019, which serves as the benchmark for our results. We estimate economic loss by comparing the base scenario with the hypothetical scenarios. The model takes into account sectoral and regional interdependence in Morocco through sectoral linkages. We disaggregate workers in each sector in each region by age group, and we segment the labor market into formal and informal workers. The adopted methodology allows us to include the effects of isolation both on the supply and on the demand sides. Additional effects on household demand and external demand are included. Household demand relates to the direct loss of income in each region, as production is partly disrupted and exports are affected by changes in foreign demand. Government transfers to households also affect consumption demand[6].

3. Assumptions

3.1. Channels

Starting from the first day of implementation of lockdown measures in Morocco (March 20, 2020), we simulate the model for the first 14 weeks during which the control measures were in place. The simulations take into account the three main channels of the short-run impacts described in the PCNS Policy Brief, 'La Stratégie Du Maroc Face Au Covid-19' (Ait Ali et al, 2020), namely: (i) supply shocks and domestic value chain effects; (ii) income effects on household demand; and (iii) external demand effects.

> *"L'impact de cette crise peut être catégorisé en trois champs : (i) d'abord du côté de l'offre, les chaînes de valeurs nationales sont suspendues ou fortement ralenties du fait de problème de trésorerie, de recul de la demande et de faillite de certaines TPME ; (ii) sur le terrain de la demande, comme effet de second ordre, le ralentissement engendre la perte de certains emplois, notamment dans les services, et donc une perte de revenus. Cela engendre un recul de la consommation nationale; (iii) un recul de la demande internationale adressée aux produits marocains mais également, sur le plan financier, un recul des IDE, des transferts courants et recettes du tourisme, pesant sur les réserves internationals." (p. 12)*

i. Supply Shocks and Domestic Value Chain Effects

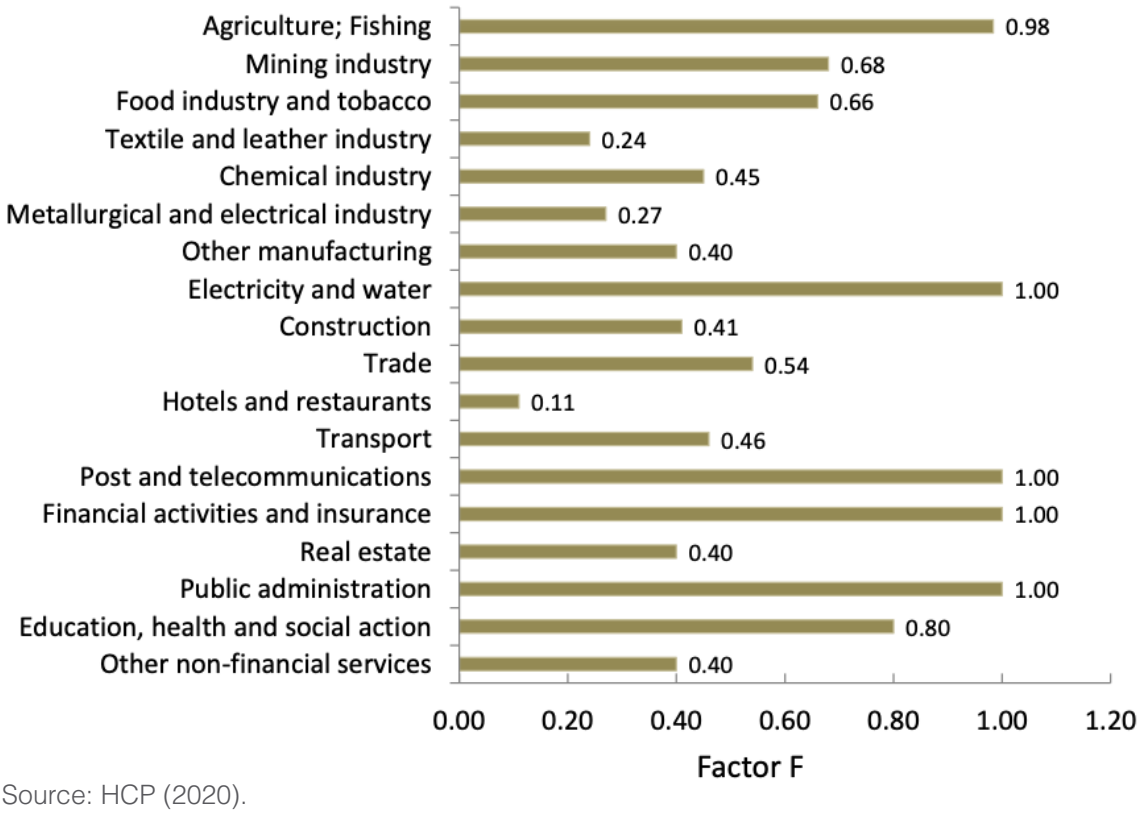
To define sectoral supply shocks and domestic value chain effects, we rely on estimates by HCP (2020) of the share of firms in temporary or permanent shutdown ('Enquête de

6. See a full description of the methodology in the Appendix.

Conjoncture sur les Effets du Covid-19 sur l'Activité des Entreprises'). The pandemic shock has triggered a partial shutdown of the economic activity. In early April 2020, the HCP conducted a survey of firms operating in different sectors of the economy to assess the extent of exposure to the pandemic shock. The results indicated that over 57% of firm in the sample had suspended their production lines either temporarily or permanently. The impact varies significantly across sectors. Accommodation and restaurants were the most affected with 86% of companies in shutdown, while the fishing industry seemed more resilient with 76% of total firms still in operation. The results available for 17 subsectors enable us to provide an initial snapshot of the damage to the domestic fabric caused by COVID-19.

The extent of exposure per sector will serve then as the benchmark to calibrate supply parameters in the interregional input-output system, denominated from now on as adjustment factors $\mathbf{F}$. We calculate the output of the economy in a hypothetical scenario of isolation through the partial extraction of the sectorial flows in the input-output matrix. We define, for each sector, an adjustment factor $\mathbf{F}$, which measures the degree of exposure of the sector considering those sectors that must continue in operation ($\mathbf{F}$=1) up to those that may stop operating ($\mathbf{F}$=0). The $\mathbf{F}$ factors were calibrated according to information provided in the HCP survey (Figure 1). We then extract from the employed labor force a hypothetical percentage in similar proportions of formal and informal workers in each sector and in each region.

Figure 1: Share of Firms Still in Operation During the Confinement Period, by Sector



Source: HCP (2020).

According to this modeling strategy, we estimate that in the most restricted week of confinement (March 27 to April 2, 2020), 3.9 million workers (38.1% of the employed workforce) were affected by the lockdown measures, and 38.6% of those employed in informal activities. During the last week (the fourteenth week) of confinement (June 19-25, 2020) 1.4 million workers (13.4% of the employed workforce) were still restricted in their jobs (43.3% employed in informal activities). Like sectors, regions were affected in different ways, with the main urbanized areas facing stronger restrictions (Figures 2 and 3).

Figure 2: Estimates of Number of Workers in Lockdown: Morocco, by Regions (Week 14: June 19 to June 25)

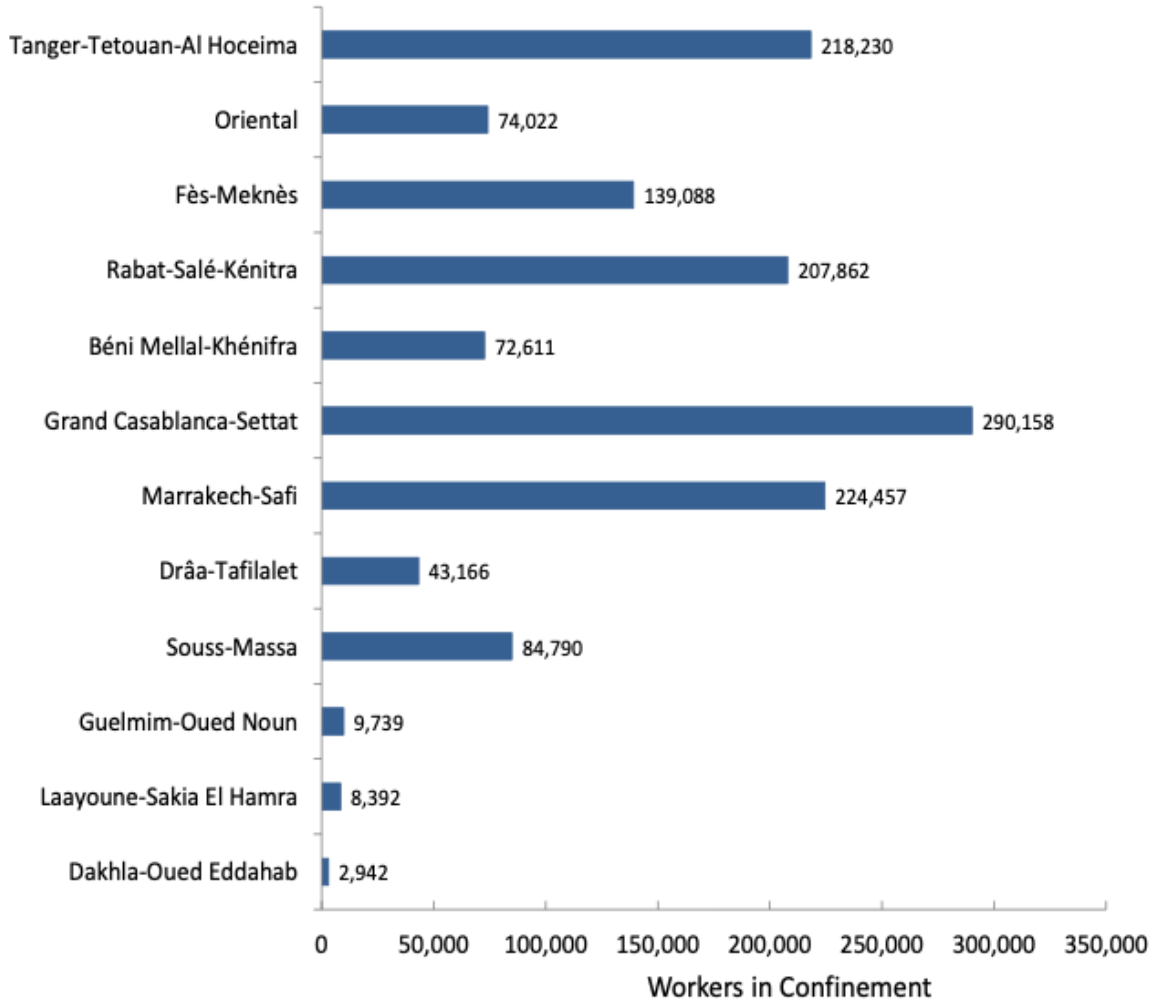
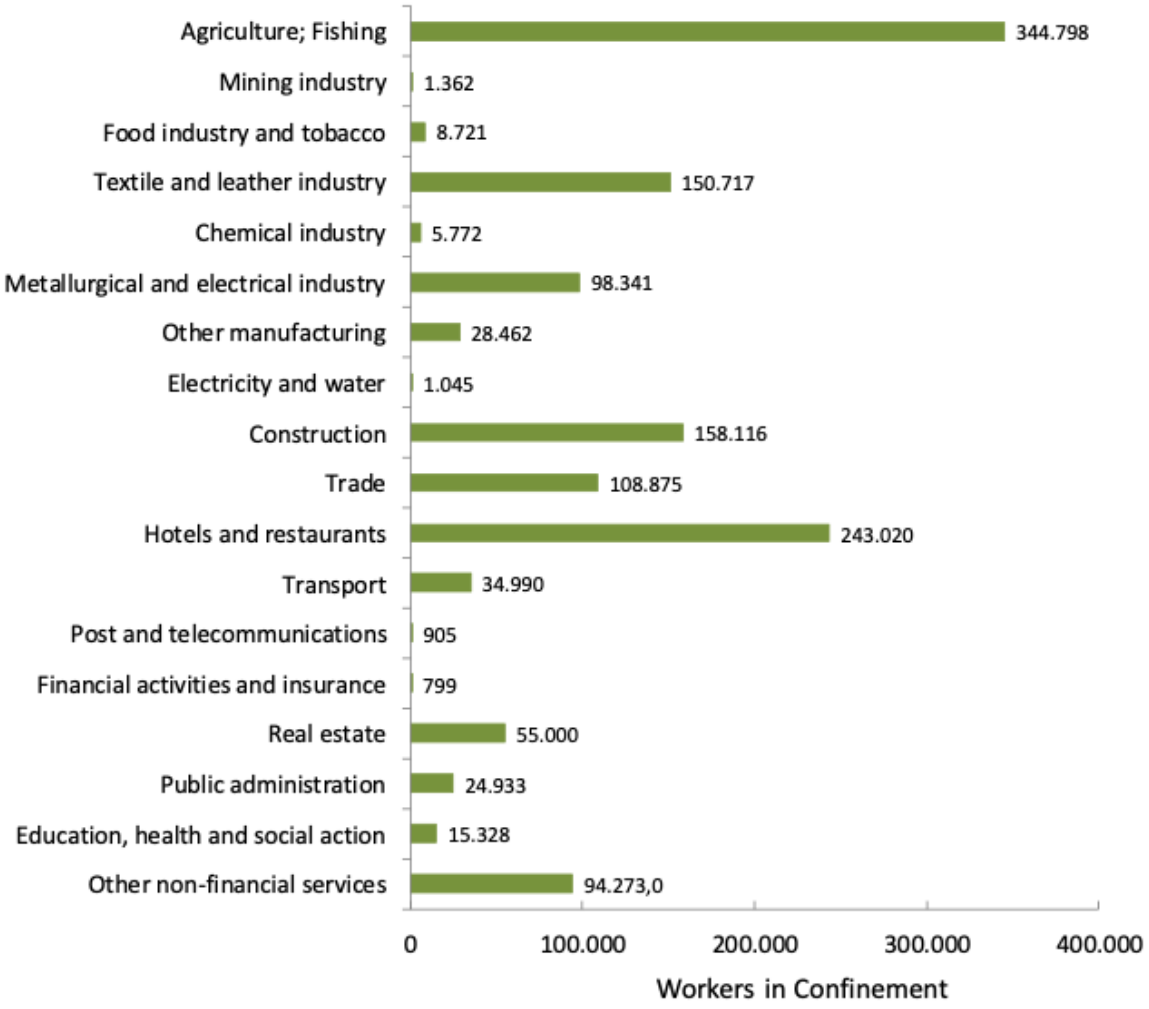


Figure 3: Estimates of Number of Workers in Lockdown: Morocco, by Sectors (Week 14: June 19 to June 25)



ii. Income Effects on Consumption

The effectiveness of the income channel is highly sensitive to the prevalence of informality, given that informal workers are generally left behind and lack social safety nets. Thus, we define, for each group of workers, the fraction of income they were able to maintain during the confinement period. For formal workers, we assume around 30% of their income is lost during the lockdown period. Informal workers initially lose all their income, but then receive lump sum income transfers from the government, according to parameters described in the Action Plan that aims to mitigate the income impact through targeted social assistance. The fall in income will proportionally hit household final demand.

iii. External Demand

We assume a 25% decrease in Moroccan exports during 2020, based on OECD[7] and WTO projections for different scenarios for the world economy.

7. See https://www.oecd.org/coronavirus/en/.

3.2. Government Mitigation Measures: the Creation of the Fund, Lump Sum Transfers and Other Economic Buffers

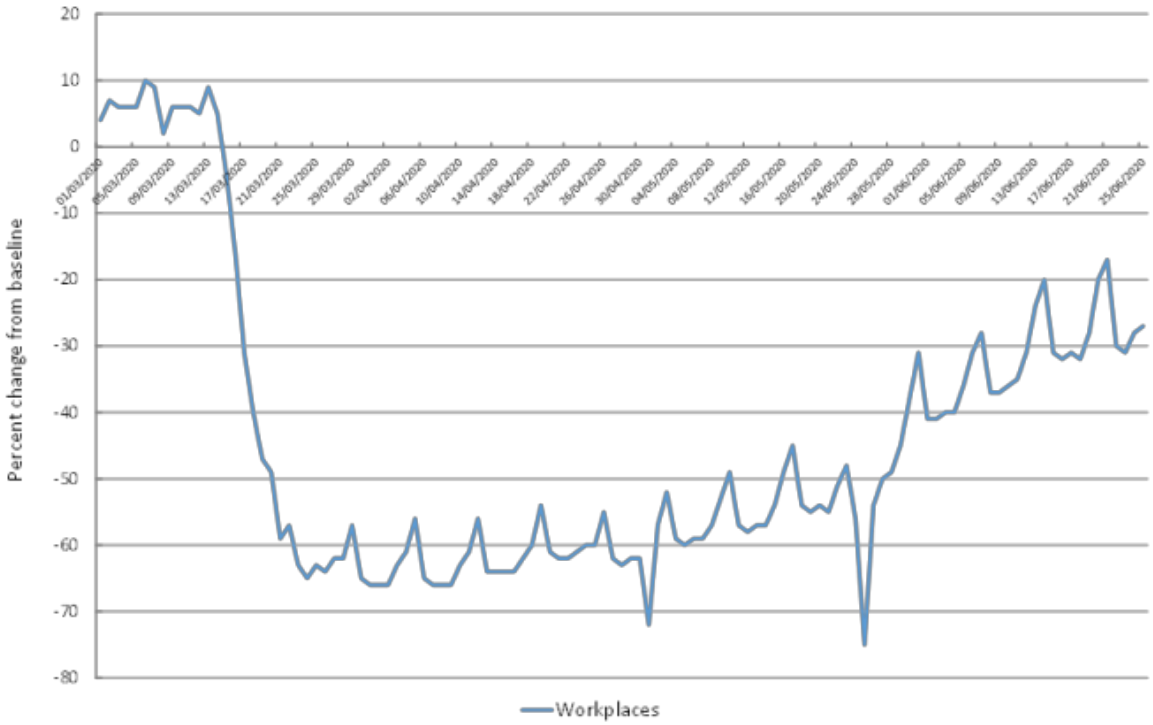
To cushion the pandemic wave over the Moroccan economy, authorities have put in place a special fund valued in late June 2020 at 33 billion Moroccan dirhams or about 3% of GDP, including one third from central and local authorities. In addition, this fund builds on the contributions from both the public and the private sectors, which committed to support this facility. Until late June, it was dedicated to the upgrading and acquisition of health equipment (2 billion dirhams), loan guarantees for hard-hit companies (5 billion dirhams for the Caisse Centrale de Garantie), but mostly to supporting financially vulnerable people who lost their jobs during the pandemic[8]. For informal workers, authorities have transferred over 11 billion dirhams (1000 dirhams per household in average), equivalent to 1% of GDP. Meanwhile, formal workers have benefited from a lump-sum transfer of 2000 dirhams, amounting to 7 billion dirhams in total. The transfers relate to the period from March 15 to June 30, 2020. From an input-output perspective, the fund expenses are included as extra demand in the economy and are expected to mitigate the initial losses. Therefore, household final demand will rebound by the equivalent lump sum transfers and government final demand will adjust by the extra health expenses. The distribution of the additional demand will align to the initial structure.

3.3. Adjusting for Containment Compliance and the Relaxation Measures During the 14-week Lockdown: Using Google Mobility Data

Morocco entered a strict lockdown on March 20. It was extended twice until June 10, when the containment strategy entered a new phase until June 25, when provinces were classified into two categories. The first category, A1, where the rate of infections was lower, witnessed containment relaxation, and some economic activities were allowed to resume. In the second category, A2, economic activity was still subject to confinement rules. Nevertheless, during the whole period, it was argued that some economic activities might have restarted their operations and fully or partially recovered, as they were not initially subject to shutdown decisions. For instance, the automotive industry resumed production well before the end of confinement. The question then is how to account for this in our simulations? We rely on community mobility data made available by Google on a daily basis, which shows movement trends across different categories of places, including commuters going to work (Figure 4).

8. For an extensive analysis of the Moroccan strategy in face of COVID-19, refer to 'La Stratégie du Maroc Face au Covid-19', Policy Center for the New South, 2020.

Figure 4: Changes in Community Mobility to Workplaces



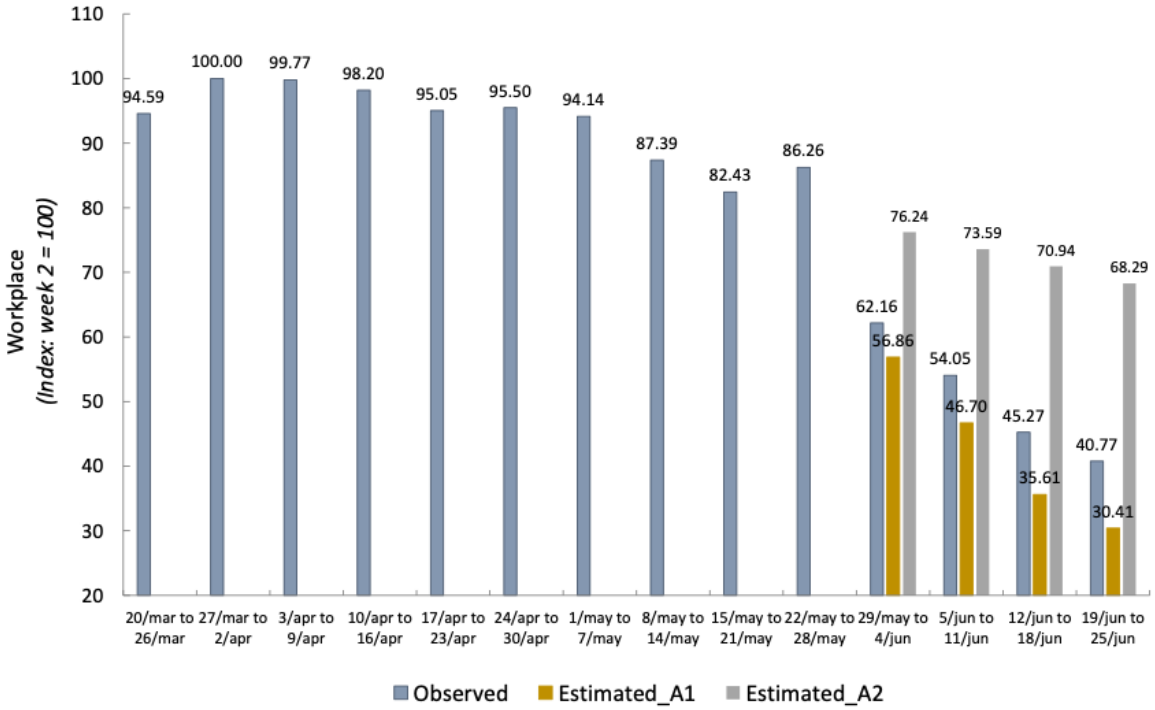
Source: Google Covid-19 Community Mobility Report

Community mobility to workplaces shrank significantly on March 20, the starting date for the strict confinement in Morocco. Worker mobility stayed at 60%[9] below the baseline for about a month, which can be seen as the period required for some activities to put in place safety measures for a gradual business resumption. Then, commuting by people to workplaces increased, to a level of 20% below the baseline on June 25, the date of the end of confinement in Morocco. This mobility data enables us to fine tune the factor **F** during the confinement period, on a weekly basis. Each week, the factor **F** is adjusted proportionally upward (downward) if mobility to workplaces increases (decreases). Unfortunately, the indicator is available at national level with no meaningful sectoral desegregation. In these circumstances, the factor **F** is rescaled proportionally for all regions and sectors.

Starting from June 10, community mobility was different in different Moroccan provinces because they were classified into two categories with different mobility restriction measures, as discussed above. Since the mobility indicator is available only at aggregate national level, we relied on a linear projection to estimate the level of community mobility in the provinces still under confinement, based on historical mobility. Thus, community mobility in A1 is retrieved, such that the weighted average of the mobility estimate in A1 and A2 is equal to observed mobility (Figure 5). As containment-easing decisions concerned provinces, each region may contain provinces classified in A1, and others classified in A2. The level of community mobility across regions is then calculated as a population-weighted average across provinces. After June 10, less-populated regions were already fully freed from confinement restrictions (Table 1). Figure 6 presents the estimated share of workers in confinement on a weekly basis. We have also assumed older workers remained at home during the whole period.

9. In Figure 1, we have for each date, the percentage change in mobility from a baseline scenario, related to mobility in a normal times.

Figure 5: Community Mobility Projections According to the Two Areas (A1-A2)

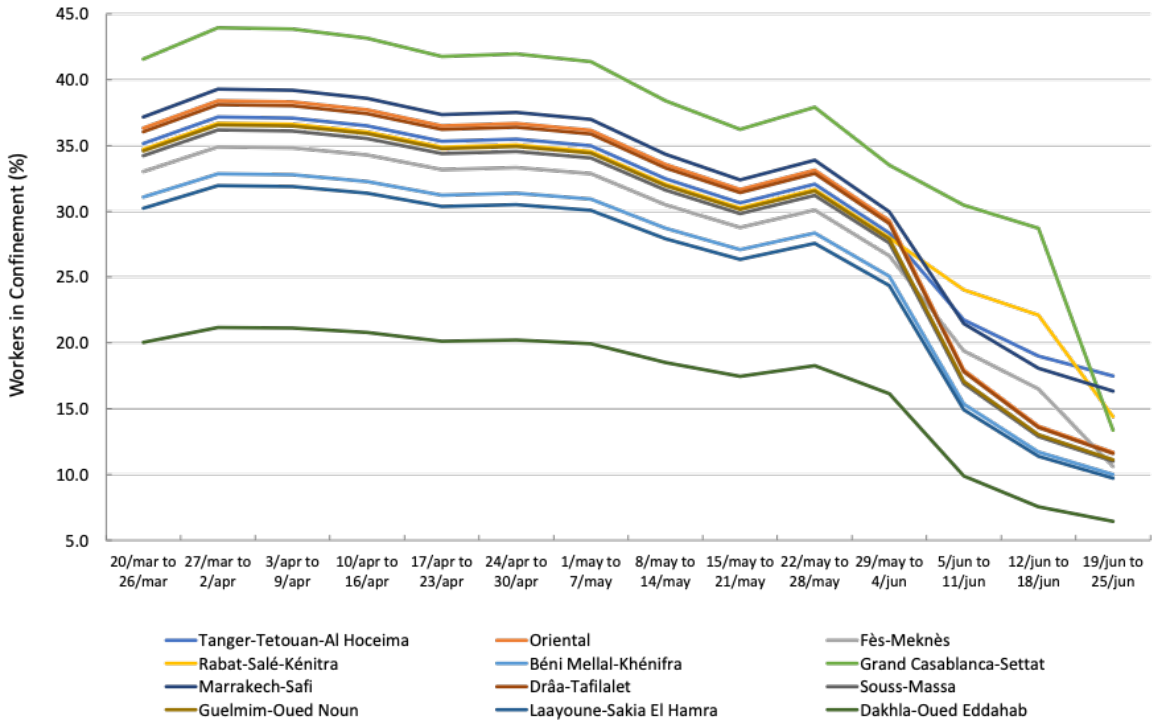


Source: Google COVID-19 Community Mobility Report and authors' estimates

Table 1: Share of Regional Population under A2 Restrictions

Region	June 10th to June 24th	From June 25th
Tanger-Tetouan-Al Hoceima	43.9%	43.9%
Oriental	0.0%	0.0%
Fès-Meknès	33.0%	0.0%
Rabat-Salé-Kénitra	69.8%	23.2%
Béni Mellal-Khénifra	0.0%	0.0%
Grand Casablanca-Settat	84.2%	0.0%
Marrakech-Safi	29.4%	29.4%
Drâa-Tafilalet	0.0%	0.0%
Souss-Massa	0.0%	0.0%
Guelmim-Oued Noun	0.0%	0.0%
Laayoune-Sakia El Hamra	0.0%	0.0%
Eddakhla-Oued Eddahab	0.0%	0.0%

Figure 6: Share of Workers in Confinement: March 20 to June 25



4. Results

We first computed the sectoral GDP loss during the partial lockdown measures in the 14-week period. Table 2 presents the summary of the results for Morocco both in monetary values and as a percentage of 2019 GDP. We observe a potential global loss of 10.13% of annual GDP. The largest loss in monetary values occurs in real estate (19,240 million dirhams), corresponding to 15.62% of sectoral GDP, and the largest relative loss in sectoral GDP occurs in hotels and restaurants (21.53% of sectoral GDP), corresponding to 5,483 million dirhams. Casablanca is the region that faces the largest GDP loss, both in monetary (37,351 million dirhams) and in relative terms (11.96% of regional GDP).

The main take-away from the regional and sectoral exercise is that the main losses are concentrated in the regions that most contribute to the country's GDP, which coincide with the most densely populated areas, and that the most affected sectors are labor and flow-intensive. More densely populated regions are also the main vectors for promoting contamination.

In what follows, we present further highlights of the results, focusing on different aspects of the main findings.

Table 2: Summary of Economic Impacts: Weeks 1-14 (March 20 to June 25)

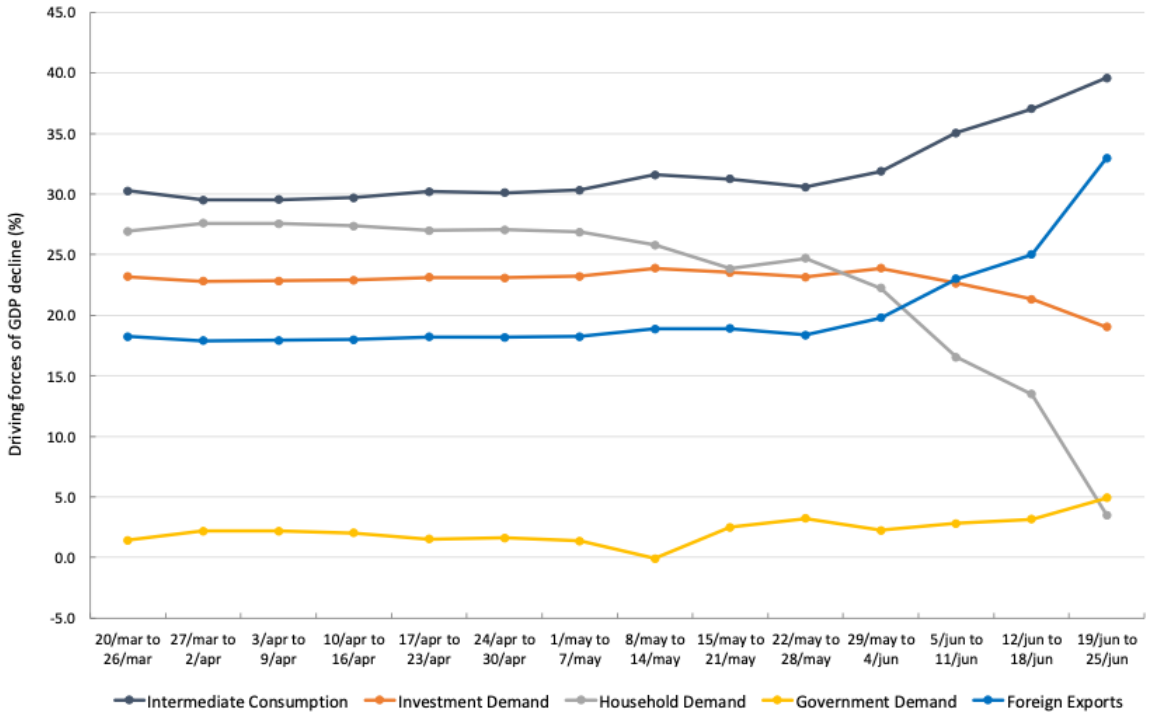
Sector	R1 Tanger-Tetouan-Al	R2 Oriental	R3 Fès-Meknès	R4 Rabat-Salé-Kénitra	R5 Béni Mellal-Khénifra	R6 Grand Casablanca-Settat	R7 Marrakech-Safi	R8 Drâa-Tafilalet	R9 Souss-Massa	R10 Guelmim-Oued Noun	R11 Laayoune-Sakia El Hamra	R12 Dakhla-Oued Eddahab	Morocco	% of sectorial GDP
Agriculture; Fishing	-761	-805	-1,815	-1,307	-1,448	-1,537	-1,548	-629	-1,042	-198	-73	-153	**-11,316**	**-7.23**
Mining industry	0	-230	-39	-157	-2,859	-14	-2,088	-668	-6	0	-525	0	**-6,586**	**-17.02**
Food industry and tobacco	-248	-85	-468	-272	-175	-2,514	-309	-18	-711	-36	-79	-30	**-4,946**	**-7.37**
Textile and leather industry	-849	-32	-445	-409	-2	-2,184	-88	0	-3	0	0	0	**-4,012**	**-20.79**
Chemical industry	-92	-32	-107	-189	-10	-2,353	-268	-2	-53	0	-55	0	**-3,162**	**-15.15**
Metallurgical and electrical industry	-1,983	-346	-355	-665	-44	-4,340	-50	-4	-90	0	-3	0	**-7,880**	**-20.16**
Other manufacturing	-646	-120	-366	-418	-77	-3,757	-361	-9	-271	-12	-70	-9	**-6,115**	**-17.86**
Electricity and water	-130	-65	-106	-252	-50	-288	-125	-19	-78	-8	-15	-1	**-1,137**	**-5.74**
Construction	-1,100	-853	-795	-1,196	-579	-1,900	-1,328	-518	-540	-85	-209	-21	**-9,127**	**-13.99**
Trade	-1,362	-1,332	-1,463	-1,756	-766	-3,838	-1,474	-256	-898	-157	-135	-34	**-13,469**	**-13.59**
Hotels and restaurants	-389	-155	-343	-227	-47	-670	-2,011	-150	-1,453	-11	-13	-13	**-5,483**	**-21.53**
Transport	-438	-448	-552	-814	-254	-1,607	-529	-133	-360	-84	-69	-19	**-5,308**	**-13.40**
Post and telecommunications	-38	-83	-12	-44	-2	-331	-30	-11	-26	-8	-10	-1	**-596**	**-2.00**
Financial activities and insurance	-170	-160	-171	-738	-77	-1,934	-282	-32	-164	-13	-14	-2	**-3,759**	**-6.78**
Real estate	-957	-946	-1,148	-4,102	-482	-8,631	-1,610	-233	-902	-104	-98	-27	**-19,240**	**-15.62**
Public administration	-69	-35	-44	3	-56	-157	-120	-22	-45	-30	-75	-10	**-659**	**-0.61**
Education, health and social action	-167	-181	-314	-391	-139	-652	-256	-61	-196	-32	-38	-15	**-2,442**	**-2.39**
Other non-financial services	-188	-133	-177	-456	-93	-641	-301	-38	-127	-16	-15	-5	**-2,188**	**-13.52**
Total	**-9,588**	**-6,042**	**-8,719**	**-13,390**	**-7,161**	**-37,351**	**-12,777**	**-2,804**	**-6,963**	**-795**	**-1,497**	**-339**	**-107,424**	
% of regional GDP	**-11.36**	**-9.00**	**-8.33**	**-8.41**	**-9.60**	**-11.96**	**-10.81**	**-9.05**	**-9.77**	**-5.79**	**-8.13**	**-5.92**	**-10.13**	

Macroeconomic Impacts

The estimated overall GDP loss during the 14-week restriction period is close to 107 billion dirhams, equivalent to -10.13% of GDP. Figure 7 presents results from a structural decomposition analysis comparing the pre-crisis structure of the Moroccan economy with the structure in the first and fourteenth weeks of lockdown. At the aggregate level, this shows the contribution of different macroeconomic components to the weekly results, with GDP losses driven by changes in final demand in both weeks (responsible for 69.74% of total losses in week 1, and 60.41% in week 14). A lower income multiplier associated with domestic value chain effects also tends to decrease national income in both periods, contributing 30.26% of total GDP loss in week 1 and 39.59% in week 14. Changes in final demand were the main factor during the whole period, reducing overall GDP in Morocco by around 74 billion dirhams.

The changing relevance of specific final demands components when comparing the two extreme weeks is noteworthy. While household demand played a greater role in GDP decline at the beginning of the pandemic, as government mitigation policies were put in place, together with the flexibility of control measures in some areas of the country, decreasing foreign exports became the leading component of final demand affecting GDP growth. Throughout the whole period, lower investments also played a prominent role in explaining GDP reductions, while government demand helped mitigate the economic impacts, especially in the first weeks.

Figure 7: Contribution of Macroeconomic Aggregates to GDP Changes

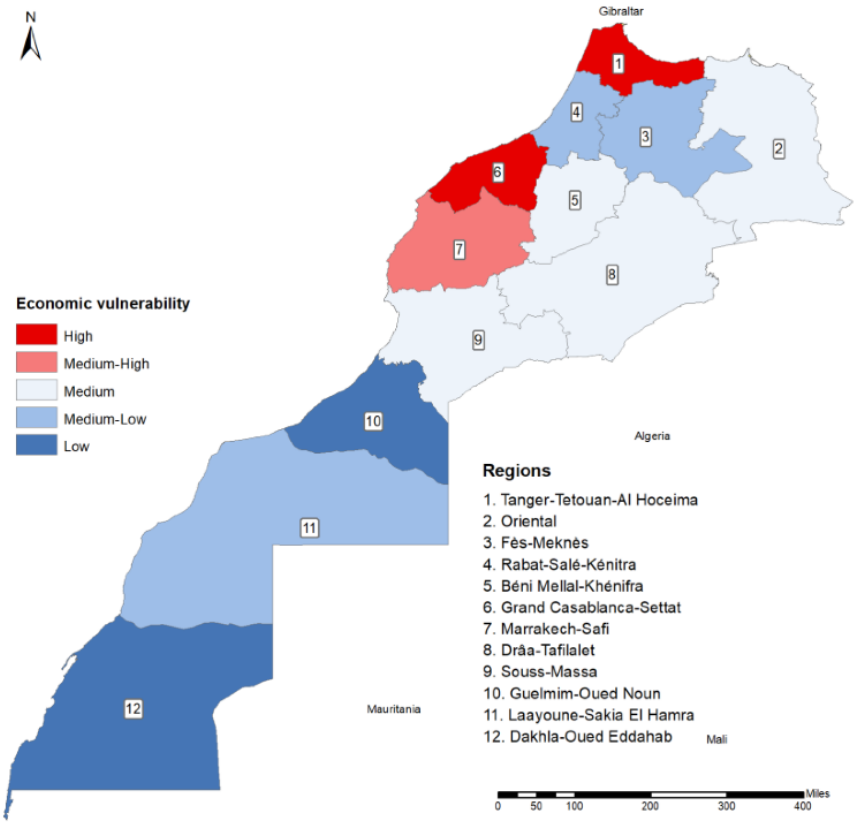


Economic Vulnerability

The economic consequences of the COVID-19 crisis are likely to affect regions within Morocco very differently, depending on their economic structure. In general, regions with a greater proportion of informality in the labor market and a lower share of government activities in their GRP tend to be affected more heavily, facing initially a steeper economic recession, with larger shares of jobs at risk. As pointed out by the OECD[10], the importance of tourism and local consumption—including retail stores and restaurants along with culture and entertainment—partially explains the relatively higher number of jobs potentially at risk in tourist destinations and metropolitan areas.

We define economic vulnerability as the share of a region in total GRP loss in relation to the region's contribution to GRP. We then create an economic vulnerability index by normalizing the results so that the index varies from zero to one. It seems to be the case of Morocco, where most vulnerable regions are located in Casablanca and Tangier, followed by the more touristic destination of Marrakech. Figure 8 presents a map of regional economic vulnerability due to the lockdown measures in Morocco. This measure was divided into five categories (e.g. high, medium-high, medium, medium-low, and low). We present in Figure 9 a similar index for the 18 sectors in the model. We observe that three sectors are highly economically vulnerable. Most vulnerable is the hotel and restaurants sector, followed by the textile and metallurgical industries.

Figure 8: Regional Economic Vulnerability to Lockdown Measures in Morocco



10. 'Coronavirus (COVID-19) From pandemic to recovery: Local employment and economic development' (https://read.oecd-ilibrary.org/view/?ref=130_130810-m60ml0s4wf&title=From-pandemic-to-recovery-Local-employment-and-economic-development).

Figure 9: Sectorial Economic Vulnerability to Lockdown Measures in Morocco

Rank	*Sector*	*Index*	*Vulnerability*
1	Hotels and restaurants	1.000	High
2	Textile and leather industry	0.965	High
3	Metallurgical and electrical industry	0.934	High
4	Other manufacturing	0.824	Medium-High
5	Mining industry	0.784	Medium-High
6	Real estate	0.717	Medium
7	Chemical industry	0.695	Medium
8	Construction	0.640	Medium
9	Trade	0.620	Medium
10	Other non-financial services	0.617	Medium
11	Transport	0.611	Medium
12	Food industry and tobacco	0.323	Medium-Low
13	Agriculture; Fishing	0.317	Medium-Low
14	Financial activities and insurance	0.295	Medium-Low
15	Electricity and water	0.245	Low
16	Education, health and social action	0.085	Low
17	Post and telecommunications	0.067	Low
18	Public administration	0.000	Low

Mitigation

The impact of mitigating part of the economic losses through lump sum transfers to workers and additional government expenditures on health reduces the overall impact on GDP by almost 2 percentage points (Figure 11), benefiting relatively more the following regions: Guelmin-Oued Noun, Fés-Meknés, and Souss-Massa.

Figure 11: Impact of Mitigation Policies

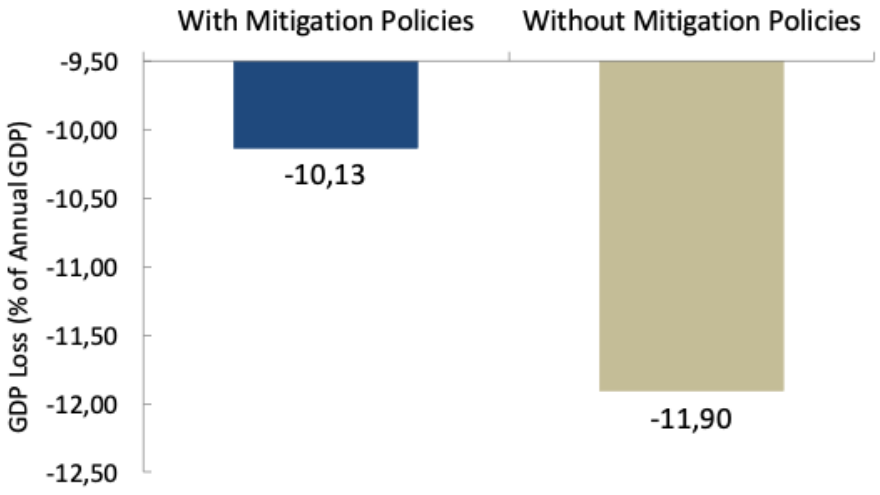


Figure 12: Impact of Mitigation Policies, by Region

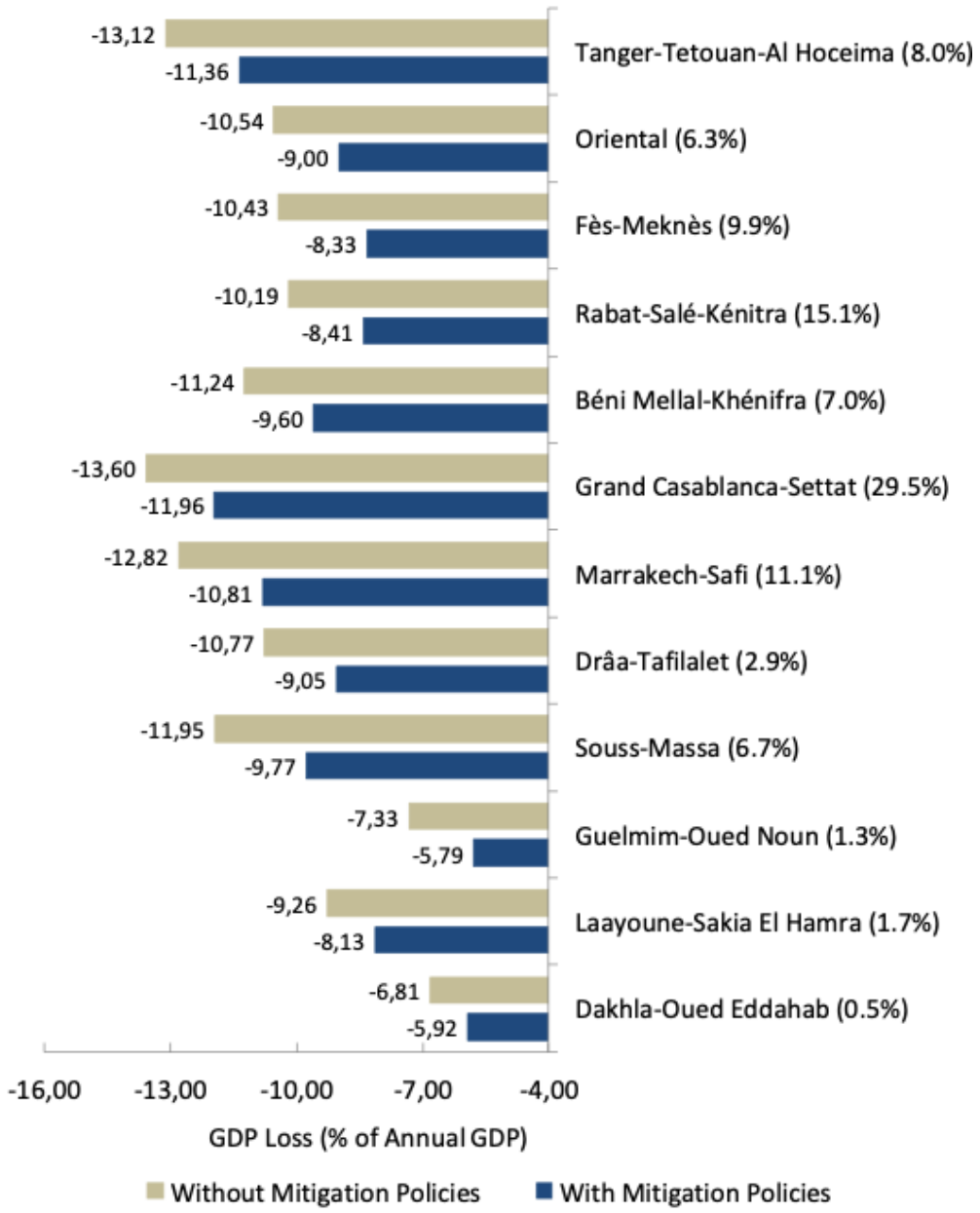


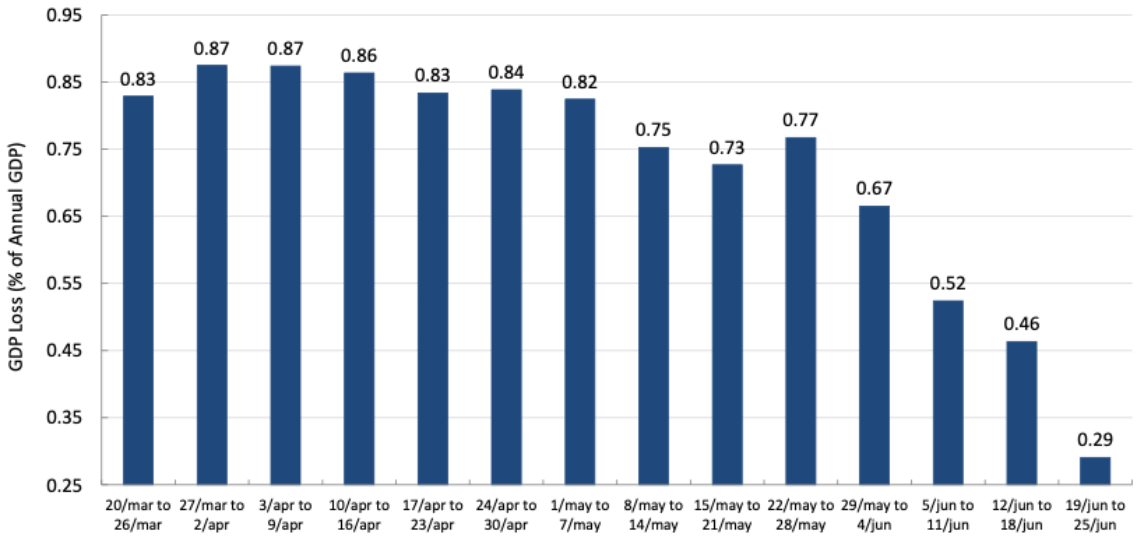
Figure 13: Impact of Mitigation Policies

	Region	GDP (in DHS millions)	GDP Loss (in DHS millions)	Transfers (in DHS millions)	A GDP (%)	B GDP Loss (%)	C Transfers (%)	(C) / (A)	(C) / (B)
R1	Tanger-Tetouan-Al Hoceima	84,369	9,588	2,959	7.95%	8.93%	11.83%	1.49	1.33
R2	Oriental	67,150	6,042	1,551	6.33%	5.62%	6.20%	0.98	1.10
R3	Fès-Meknès	104,724	8,719	3,158	9.87%	8.12%	12.63%	1.28	1.56
R4	Rabat-Salé-Kénitra	159,169	13,390	3,806	15.01%	12.46%	15.22%	1.01	1.22
R5	Béni Mellal-Khénifra	74,614	7,161	1,761	7.03%	6.67%	7.05%	1.00	1.06
R6	Grand Casablanca-Settat	312,290	37,351	5,093	29.44%	34.77%	20.37%	0.69	0.59
R7	Marrakech-Safi	118,208	12,777	3,301	11.14%	11.89%	13.20%	1.18	1.11
R8	Drâa-Tafilalet	30,996	2,804	904	2.92%	2.61%	3.62%	1.24	1.39
R9	Souss-Massa	71,277	6,963	1,772	6.72%	6.48%	7.09%	1.05	1.09
R10	Guelmim-Oued Noun	13,736	795	275	1.30%	0.74%	1.10%	0.85	1.49
R11	Laayoune-Sakia El Hamra	18,413	1,497	298	1.74%	1.39%	1.19%	0.69	0.85
R12	Dakhla-Oued Eddahab	5,728	339	122	0.54%	0.32%	0.49%	0.91	1.55
	Morocco	**1,060,672**	**107,424**	**25,000**					

Timing of the Impacts

The impact analysis should also consider time-related aspects (Figure 14). This dimension will be very helpful for the understanding of the dynamics of the economic effects associated with different degrees of lockdown. Over the fourteen weeks of restrictive measures—from March 20 to June 25 2020—the economic costs were relatively constant in the first seven weeks: around 0.8% of pre-crisis annual GDP was lost per week. As the lockdown strictness decreases, so do the GDP reductions.

Figure 14: GDP Loss per Week: Morocco, March 17-April 13



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Technical Appendix

We consider an interregional input-output flow-table for an n-sector economy with r regions (Figure A1). We separate workers into q different age groups, and identify payments by producers to wage earners in each of these groups.

Figure A1. Interregional Input-Output Flows

		Processing sectors							*Final demand*				*Total output*
		11	⋯	rn	…	$r1$	⋯	rn					
Processing sectors	11	$\mathbf{Z}_{11}^{11}$	⋯	$\mathbf{Z}_{1n}^{11}$		$\mathbf{Z}_{11}^{1r}$	⋯	$\mathbf{Z}_{1n}^{1r}$	$\mathbf{c}_1^{1\bullet}$	$\mathbf{i}_1^{1\bullet}$	$\mathbf{g}_1^{1\bullet}$	$\mathbf{e}_1^{1\bullet}$	x_1^1
	⋮	⋮	⋱	⋮	⋯	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮
	$1n$	$\mathbf{Z}_{n1}^{11}$	⋯	$\mathbf{Z}_{nn}^{11}$		$\mathbf{Z}_{n1}^{1r}$	⋯	$\mathbf{Z}_{nn}^{1r}$	$\mathbf{c}_n^{1\bullet}$	$\mathbf{i}_n^{1\bullet}$	$\mathbf{g}_n^{1\bullet}$	$\mathbf{e}_n^{1\bullet}$	x_n^1
	⋮		⋮		⋱		⋮		⋮	⋮	⋮	⋮	⋮
	$r1$	$\mathbf{Z}_{11}^{r1}$	⋯	$\mathbf{Z}_{1n}^{r1}$		$\mathbf{Z}_{11}^{rr}$	⋯	$\mathbf{Z}_{1n}^{rr}$	$\mathbf{c}_1^{r\bullet}$	$\mathbf{i}_1^{r\bullet}$	$\mathbf{g}_1^{r\bullet}$	$\mathbf{e}_1^{r\bullet}$	x_1^r
	⋮	⋮	⋱	⋮	⋯	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮
	rn	$\mathbf{Z}_{n1}^{r1}$	⋯	$\mathbf{Z}_{nn}^{r1}$		$\mathbf{Z}_{n1}^{rr}$	⋯	$\mathbf{Z}_{nn}^{rr}$	$\mathbf{c}_n^{r\bullet}$	$\mathbf{i}_n^{r\bullet}$	$\mathbf{g}_n^{r\bullet}$	$\mathbf{e}_n^{r\bullet}$	x_n^r
Imports		m_1^1	⋯	m_n^1	…	m_1^r	⋯	m_n^r	$m_c^\bullet$	$m_i^\bullet$	$m_g^\bullet$	$m_e^\bullet$	m
Indirect taxes		t_1^1	⋯	t_n^1	…	t_1^r	⋯	t_n^r	$t_c^\bullet$	$t_i^\bullet$	$t_g^\bullet$	$t_e^\bullet$	t
Labor payments	1	l_{11}^1	⋯	l_{1n}^1	…	l_{11}^r	⋯	l_{1n}^r					l_1
	⋮		⋮		…		⋮						⋮
	q	l_{q1}^1	⋯	l_{qn}^1	…	l_{q1}^r	⋯	l_{qn}^r					l_q
Other payments		n_1^1	⋯	n_n^1	…	n_1^r	⋯	n_n^r					n
Outlays		x_1^1	⋯	x_n^1	…	x_1^r	⋯	x_n^r	c	i	g	e	
Employment	1	L_{11}^1	⋯	L_{1n}^1	…	L_{11}^r	⋯	L_{1n}^r					L_1
	⋮		⋮		…		⋮						⋮
	q	L_{q1}^1	⋯	L_{qn}^1	…	L_{q1}^r	⋯	L_{qn}^r					L_q

z_{ij}^{rs} , with i, j and $r, s = 1, ..., r$ represents interindustry sales from industry i in region r to industry j in region s
t_i^s and m_i^s with $i=1, ..., n, c, i, g, e$ represent, respectively, imports and indirect taxes payments in region s
l_{ij}^s and L_{ij}^s with $i=1, ..., q$ and $j=1, ..., n$ and $s=1, ..., r$ represent, respectively, payments by sectors for labor services, and total number of workers in region s
n_j^s, with $j=1, ..., n$ and $s=1, ..., r$ represents payments by sectors for all other value-added items in region s
$c_i^{r\bullet}$, $i_i^{r\bullet}$, $g_i^{r\bullet}$, and $e_i^{r\bullet}$ with $i=1, ..., n$ and $r=1, ..., r$ represent the regional components of final demand, $f_i^{r\bullet}$, respectively, household purchases, investment purchases, government purchases, and exports from region r
x_i^r, with $i=1, ..., n$ and $r=1, ..., r$ is the total sectoral output in region r

We assume that a given lockdown strategy may initially restrict part of the labor force in performing their tasks. In the context of the COVID-19 pandemic, lockdown strategies are usually both age, sector and region-specific. Thus, we define $qxnxs$ factors $(F_{q,n}^s)$ where $0< F_{q,n}^s <1$, defining the share of non-restricted workers in each group in each sector in each region. This allows the model to be responsive to sector-labor specific characteristics. For instance, in a non-restrictive scenario for health-sector workers, we set the factor to 1; for activities that would face stronger restrictions, such as those in the entertainment sector, we set the factor closer to zero[11].

We then apply each factor $F_{q,n}^s$ to its corresponding element in both the employment matrix and the labor payments matrix. In the former case, we are able to define the number of workers facing lockdown; in the latter case, we can calculate the contribution of those workers to total labor income in each sector in each region. Once we know the aggregate income associated with restricted (and non-restricted) workers, we use its share in total labor payments by sector and region together with the sectoral labor payment coefficients, $\sum_i^q l_{ij}^s / x_j^s$. Based on the properties of the Leontief production function, we can then define a new set of sector-specific penalty factors (F_n^s), where $0< F_n^s <1$, identifying the share of output in each sector associated with non-restricted workers in each region.

This approach also allows us to assess different scenarios based on targets for compliance with the measures. Suppose we want to examine a scenario that is both consistent with the set of pre-defined factors $(F_{q,n}^s)$ and a desirable level of compliance (α). We can then find an adjustment factor or weight (ω) to be applied across all $F_{q,n}^s$ so that[12]

$$\omega F_{q,n}^s \Rightarrow \sum_i^q \sum_j^n L_{ij}^{s,restricted} / \sum_i^q \sum_j^n L_{ij}^s = \alpha \qquad (1)$$

Once we have computed the factors, F_n^s, the next step is to use this set of information to partially extract some of the sectoral flows in the interregional input-output table, considering both demand and supply reductions.

11. This procedure is applied after extracting all workers older than 60 years from all sectors to reflect age-specific control measures related to more vulnerable workers.

12. The parameters ω and α may also have a regional dimension.

Interindustry Demand:

$\forall\, z_{ij}^{rs}$, $i, j=1, \ldots, n$ and $r, s=1, \ldots, r$ we compute a corresponding restricted flow, $\overline{z_{ij}^{rs}}$, such that

$$\overline{\overline{z_{ij}^{rs}}} = \begin{cases} F_i^r z_{ij}^{rs}, \text{if } F_i^r < F_j^s \\ F_j^s z_{ij}^{rs}, \text{if } F_i^r > F_j^s \end{cases} \qquad (2)$$

Final Demand:

In addition to supply-side restrictions, associated with the factor (F_i^r), additional demand-side constraints can be added to complete the decision rule.

For each final demand user. a demand-side factor, F_u^s, $u=c, i, g, e$, and $s=1, \ldots, r$ can be specified. We define each F_u^s as follows.

F_c^s is calculated based on changes in foregone earnings by workers in region s affected by the control strategies for mitigating the effects of COVID-19. While informal workers affected by the lockdown face a full loss of income, those in the formal sector may face only a partial loss, according to a parameter (δ^s), where $o< \delta^s<1$ for $s=1, \ldots, r$. We then assume labor income changes are fully translated into household demand changes. Other possible income-related changes, such as government transfers to specific groups of workers as a measure to attenuate the effects of the crisis, would also affect F_c^s after properly mapped into household purchases.

F_i^s and F_g^s are set to unity. The implicit assumption is that investments decisions that are taking place are not affected in the very short-run, while government expenditures are kept unchanged, from the demand perspective, so that we can use government reactions for simulating policy scenarios and providing alternative values for F_g^s.

$F_g^{\bullet}$ is set to 0.75, based on the OECD projections of short-term declines in GDP for many major economies. Accordingly, in the median economy, output would decline by 25%[13].

Thus, considering each component of final demand, f_{iu}^{rs}, we apply the following rule:

$\forall\, f_{iu}^{rs}$, $i=1, \ldots, n, u=i, g, e$ and $r, s=1, \ldots, r$ we compute a corresponding restricted flow, $\overline{f_{iu}^{rs}}$, such that

$$\overline{f_{iu}^{rs}} = \begin{cases} F_i^r f_{iu}^{rs}, \text{if } F_i^r < F_u^s \\ F_u^s f_{iu}^{rs}, \text{if } F_i^r > F_u^s \end{cases} \qquad (3)$$

13. See https://www.oecd.org/coronavirus/en/.

In the case of household demand, we apply both the supply and the demand constraints, such that

$\forall f_{iu}^{rs}$, $i=1, \ldots, n, u=c$ and $r, s=1, \ldots, r$ we compute a corresponding restricted flow, $\overline{f_{iu}^{rs}}$, such that

$$\overline{f_{iu}^{rs}} = F_i^r F_u^s f_{iu}^{rs} \quad (4)$$

Using the information from the original and the diminished sectoral flows, we have now two matrices of interindustry flows, $\mathbf{Z}$ and $\overline{\mathbf{Z}}$, and two vectors of final demand, $\mathbf{f}$ and $\bar{\mathbf{f}}$. For a given vector of sectoral output, $\mathbf{x}$, we can also derive two matrices of technical coefficients, $\mathbf{A}$ and $\overline{\mathbf{A}}$.

The extraction method, initially proposed by Dietzenbacher et al (1993)[14], consists of the hypothetical extraction of a sector in the input-output matrix. The purpose is to quantify how much the total output of an economy with n sectors and r regions could change (or reduce) if a particular sector were removed from this economy. This enables the analysis of sector and regional economic relevance, within a given economic structure; given its extraction and consequent reduction in the level of activity in the economy. Note that the greater the level of interdependence of such a sector in relation to other sectors, the greater the systemic impact.

We use a variant of the extraction method. Instead of hypothetically extracting an entire sector in a specific region, we extract all sectors partially, according to the information combined in $\overline{\mathbf{Z}}$, and $\bar{\mathbf{f}}$.

In the complete interregional input-output model, with the original sectoral flows, the output of the economy is given by:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \quad (5)$$

Using $\overline{\mathbf{A}}$ as the matrix associated with restricted intersectoral trade flows due to the lockdown, and $\bar{\mathbf{f}}$, the lockdown-related final demand, gross output in the economy would be given by:

$$\bar{\mathbf{x}} = (\mathbf{I} - \overline{\mathbf{A}})^{-1}\bar{\mathbf{f}} \quad (6)$$

Therefore, after the partial extraction:

$$\mathbf{T} = \mathbf{i}'\mathbf{x} - \mathbf{i}'\bar{\mathbf{x}} \quad (7)$$

14. There are broad aspects that are studied using the extraction method such as, regional issues (Perobelli et al, 2010), emissions (Ali, 2015; Zhang et al, 2018; Zhao, 2015; Wang et al, 2013), sectoral analysis (Song et al, 2006; Temurshoev, 2010), and energy analysis (Guerra and Sancho, 2010).

where $\mathbf{T}$ is the aggregate measure of annual loss in the economy – decrease in total output if the output associated with the lockdown measures 'disappears'. In other words, it is a measure of the relative importance of activities performed by workers affected by the lockdown, or the total linkages with which such activities are associated.

We can translate sectoral gross output outcomes in other variable outcomes. To do so we multiply the vector of gross output, $\mathbf{x}$ or $\overline{\mathbf{x}}$, by a diagonal matrix, $\hat{\mathbf{v}}$, whose main diagonal contains the variable's coefficients, i.e. the ratios of the variable values by sector-region divided by the respective sectoral-regional gross output. Finally, assuming that production is continuous on weekdays, daily foregone losses can be estimated by dividing $\mathbf{T}$ (or $\hat{\mathbf{v}}\mathbf{T}$), by the number of weekdays in the benchmark year.

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