

## Hypothèses de formalisation et choix optimaux de l'Autorité publique dans l'urgence de la pandémie de COVID19

Cécile Bastidon<sup>1,3</sup> Antoine Parent<sup>2,3</sup>

<sup>1</sup> Université de Toulon, LEAD

<sup>2</sup> LED, Université Paris 8, et OFCE-Sciences Po,

<sup>3</sup> CAC-IXXI, Institut des Systèmes Complexes, ENS Lyon, France

La covid-19: regards et questions interdisciplinaires  
Institut Rhônalpin des Systèmes Complexes  
7 mai 2021



# Introduction

World Economic Outlook, January 2021 Update

**Figure 2. Contributions of Consumption and Investment to Global GDP Growth**

(Percentage points, year over year)

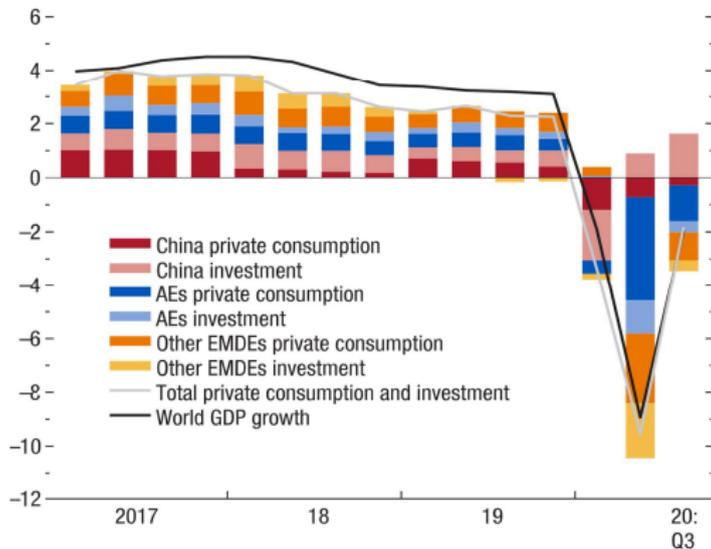


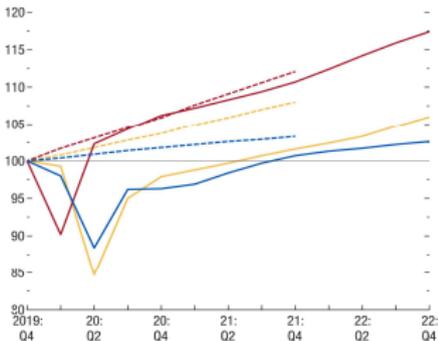
Figure 1: Contributions de la consommation et de l'investissement à la croissance globale (source FMI)

# Introduction

World Economic Outlook, January 2021 Update

**Figure 1. Divergent Recoveries: WEO Forecast for Advanced Economies and Emerging Market and Developing Economies**  
(Index, 2019:Q4 = 100)

— China (Jan. 2021 WEO Update)    - - - China (Jan. 2020 WEO Update)  
 — AEs (Jan. 2021 WEO Update)    - - - AEs (Jan. 2020 WEO Update)  
 — EMDEs excluding China (Jan. 2021 WEO Update)    - - - EMDEs excluding China (Jan. 2020 WEO Update)



Source: IMF staff estimates.

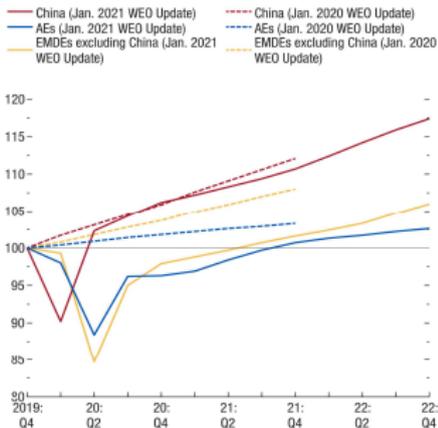
Note: AEs = advanced economies; EMDEs = emerging market and developing economies; WEO = World Economic Outlook.

**Figure 2: (a) Scenarios de sortie de crise ; (b) Faillites d'entreprises : comparaison avec la crise financière globale et un échantillon historique récent de récessions (source FMI)**

# Introduction

World Economic Outlook, January 2021 Update

**Figure 1. Divergent Recoveries: WEO Forecast for Advanced Economies and Emerging Market and Developing Economies**  
(Index, 2019:Q4 = 100)

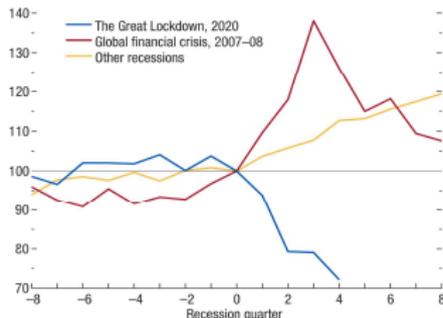


Source: IMF staff estimates.

Note: AEs = advanced economies; EMDEs = emerging market and developing economies; WEO = World Economic Outlook.

World Economic Outlook, January 2021 Update

**Figure 6. Bankruptcies**  
(Index, last prerecession quarter = 100)



Sources: CEIC; national authorities; and IMF staff calculations.

Note: Data are from 13 countries with varying coverage during 1990:Q1–2020:Q3. Lines are averages across recession types, with quarter 0 the last prerecession quarter. For the Great Lockdown, quarter 0 is 2019:Q4 for all countries. For the global financial crisis, quarter 0 is the country-specific date of peak real GDP during 2007–08. Other recessions are country-specific and identified by two consecutive quarters of negative growth during 1990–2006 and 2009–19.

**Figure 2: (a) Scenarios de sortie de crise ; (b) Faillites d'entreprises : comparaison avec la crise financière globale et un échantillon historique récent de récessions (source FMI)**





# Introduction

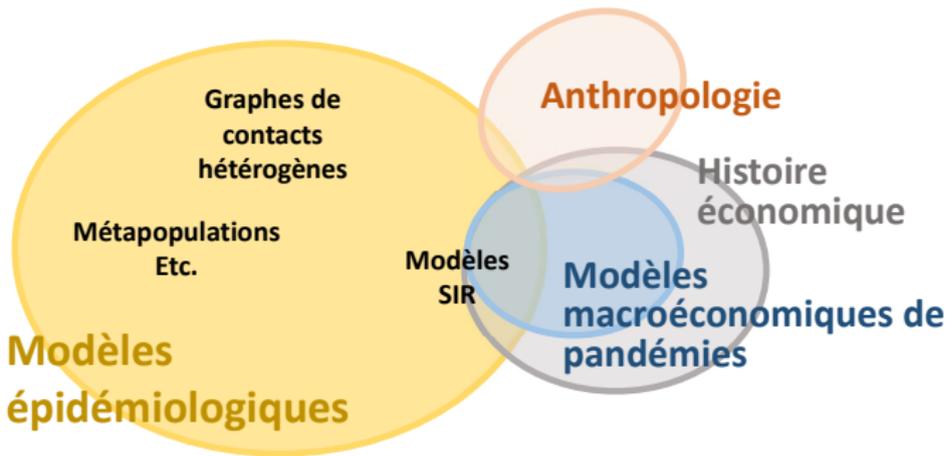


Figure 5: Recouplement des littératures passées en revue : épidémiologie, approches mixtes, macroéconomie, histoire économique, anthropologie, etc.





## Les modèles SIR/SEIR : le socle

### *A Contribution to the Mathematical Theory of Epidemics.*

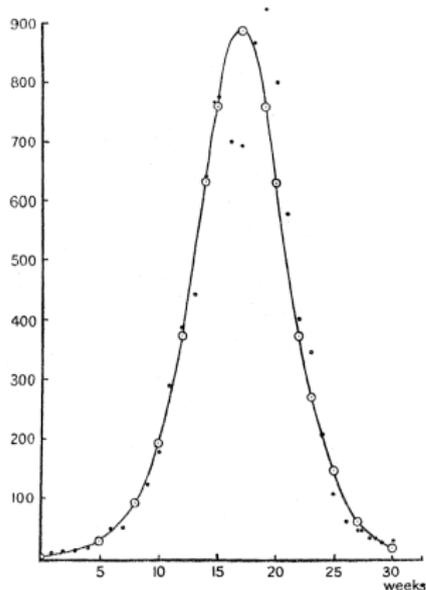
By W. O. KERMACK and A. G. MCKENDRICK.

(Communicated by Sir Gilbert Walker, F.R.S.—Received May 13, 1927.)

(From the Laboratory of the Royal College of Physicians, Edinburgh.)

#### *Introduction.*

(1) One of the most striking features in the study of epidemics is the difficulty of finding a causal factor which appears to be adequate to account for the magnitude of the frequent epidemics of disease which visit almost every population. It was with a view to obtaining more insight regarding the effects of the various factors which govern the spread of contagious epidemics that the present investigation was undertaken. Reference may here be made to the work of Ross the affected to the unaffected by contact infection. Each infected person runs through the course of his sickness, and finally is removed from the number of those who are sick, by recovery or by death. The chances of recovery or death vary from day to day during the course of his illness. The chances that the affected may convey infection to the unaffected are likewise dependent upon the stage of the sickness. As the epidemic spreads, the number of unaffected members of the community becomes reduced. Since the course of an epidemic is short compared with the life of an individual, the population may be considered as remaining constant, except in as far as it is modified by deaths due to the epidemic disease itself. In the course of time the epidemic may come to an end. One of the most important problems in epidemiology is to ascertain whether this termination occurs only when no susceptible individuals are left, or whether the interplay of the various factors of infectivity, recovery and mortality, may result in termination, whilst many susceptible individuals are still present in the unaffected population.



The accompanying chart is based upon figures of deaths from plague in the island of Bombay over the period December 17, 1905, to July 21, 1906. The ordinate represents the number of deaths per week, and the abscissa denotes the time in weeks.

Figure 6: Dynamique épidémique dans [Kermack and McKendrick \[1927\]](#)

# Les modèles SIR/SEIR : le socle

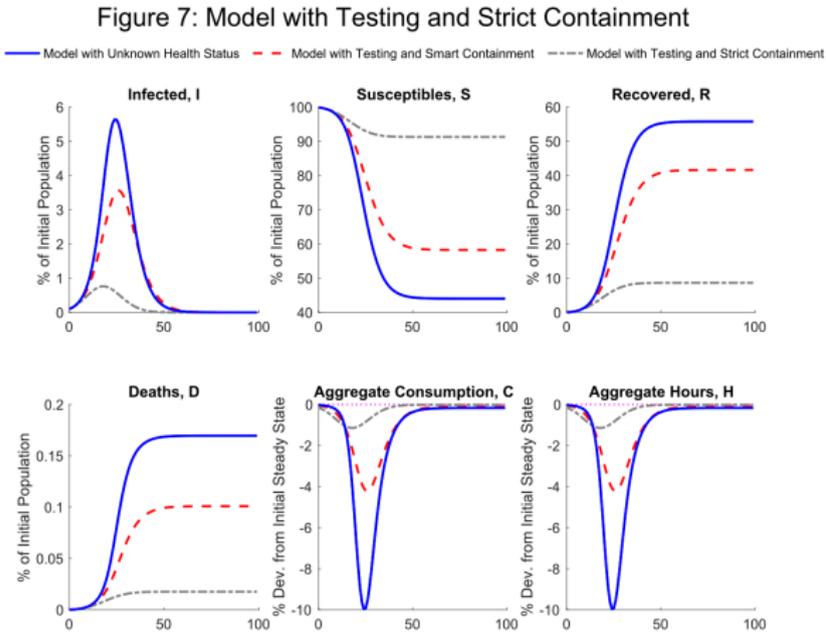


Figure 7: Dynamique épidémique et décisions économiques dans [Eichenbaum et al. \[2020a\]](#)

# Modèles épidémiologiques à changements d'états non observés et degrés de sévérité

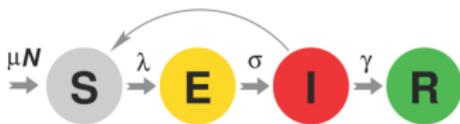


Figure 8: Structure des changements d'états de trois modèles épidémiologiques. (a) Modèle SEIR à la [Kermack and McKendrick \[1927\]](#) (source : [Koop and Kutcha \[2020\]](#)) ; (b) Modèle à états multiples non observés (source : [Giordano et al. \[2020\]](#)) ; (c) Modèle ICL (source : [\[ICL\]](#)).

# Modèles épidémiologiques à changements d'états non observés et degrés de sévérité

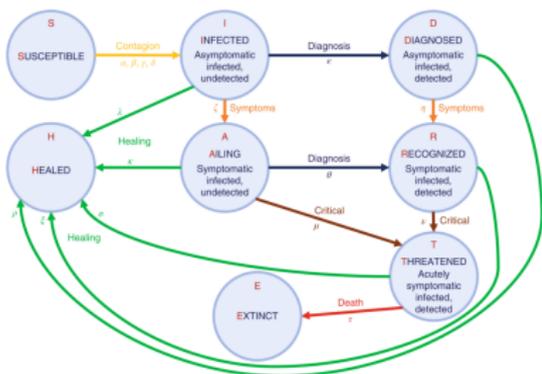
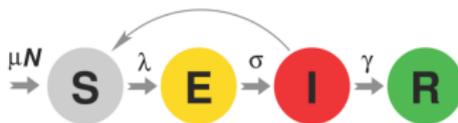


Figure 8: Structure des changements d'états de trois modèles épidémiologiques. (a) Modèle SEIR à la [Kermack and McKendrick \[1927\]](#) (source : [Koop and Kutcha \[2020\]](#)) ; (b) Modèle à états multiples non observés (source : [Giordano et al. \[2020\]](#)) ; (c) Modèle ICL (source : [\[ICL\]](#)).

# Modèles épidémiologiques à changements d'états non observés et degrés de sévérité

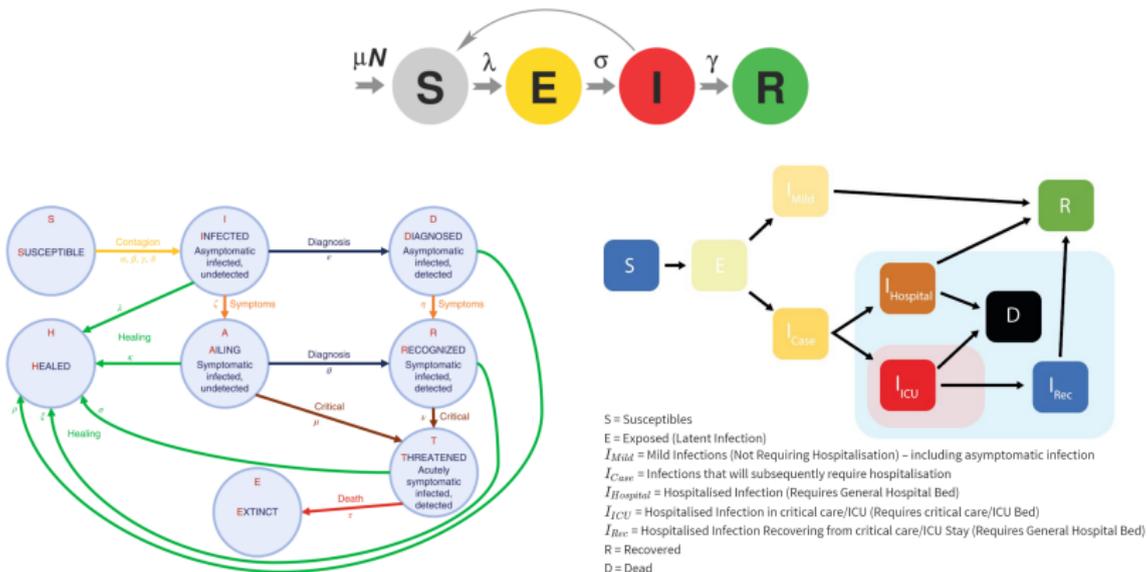


Figure 8: Structure des changements d'états de trois modèles épidémiologiques. (a) Modèle SEIR à la Kermack and McKendrick [1927] (source : Koop and Kutcha [2020]) ; (b) Modèle à états multiples non observés (source : Giordano et al. [2020]) ; (c) Modèle ICL (source : [ICL]).



## Un exemple de modèle épidémiologique global : le modèle ICL

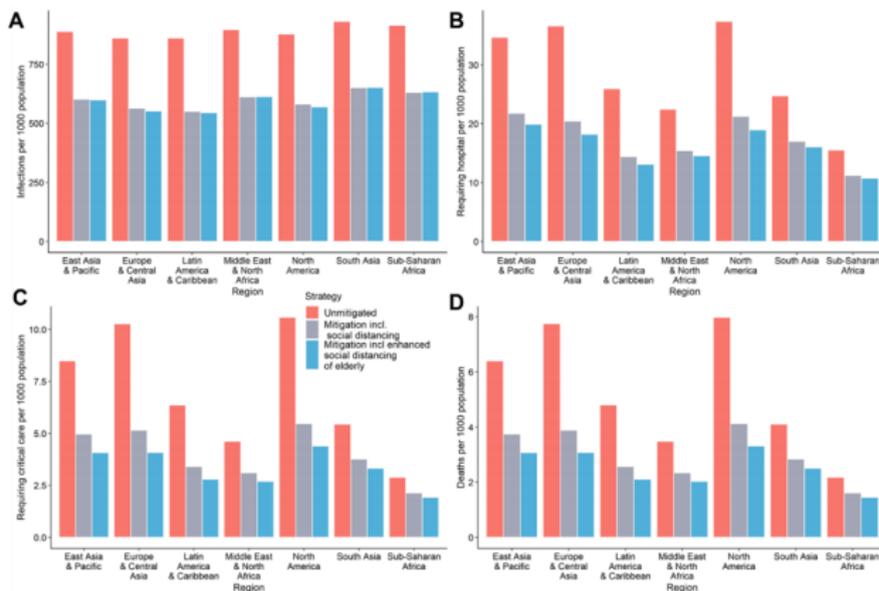
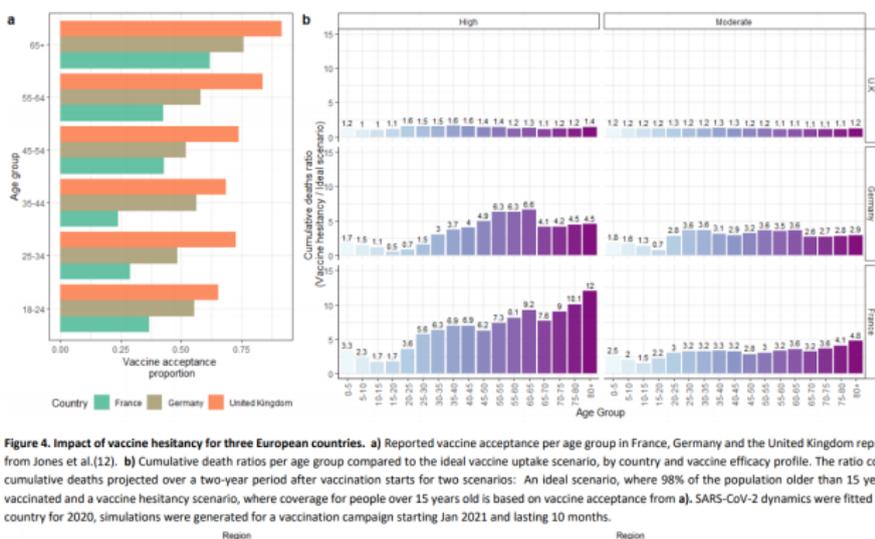


Figure 4. Estimated total number of infections (A), individuals requiring hospitalisation (B) and critical care (c) and deaths (D) in unmitigated and mitigated scenarios by World Bank region.

Figure 9: Prévisions d'infections, hospitalisations, soins intensifs et décès associées à différents niveaux de contrainte des mesures restrictives, mars 2020. Source : [ICL](#)



## Un exemple de modèle épidémiologique global : le modèle ICL



**Figure 4.** Impact of vaccine hesitancy for three European countries. **a**) Reported vaccine acceptance per age group in France, Germany and the United Kingdom reproduced from Jones et al.(12). **b**) Cumulative death ratios per age group compared to the ideal vaccine uptake scenario, by country and vaccine efficacy profile. The ratio compares cumulative deaths projected over a two-year period after vaccination starts for two scenarios: An ideal scenario, where 98% of the population older than 15 years gets vaccinated and a vaccine hesitancy scenario, where coverage for people over 15 years old is based on vaccine acceptance from **a**). SARS-CoV-2 dynamics were fitted for each country for 2020, simulations were generated for a vaccination campaign starting Jan 2021 and lasting 10 months.

**Figure 4.** Estimated total number of infections (A), individuals requiring hospitalisation (B) and critical care (c) and deaths (D) in unmitigated and mitigated scenarios by World Bank region.

**Figure 10:** Prévisions de surmortalité par tranche d'âge et par pays associées à l'acceptation de la vaccination, avril 2021. Source : [ICL].

# Outline

- 1 Introduction
- 2 Modèles épidémiologiques de référence
  - Les modèles SIR/SEIR
  - Changements d'états non observés et degrés de sévérité
  - Le modèle global ICL
- 3 Modèles épidémiologiques et graphes de contacts
  - Graphes de contacts hétérogènes
  - Graphes de contacts et modèles de métapopulations
  - Transitions épidémiologiques
- 4 L'arbitrage épidémiologique vs. macroéconomique dans les modèles mixtes
  - Interactions et modèles mixtes de pandémies
  - Architecture générale des modèles mixtes
  - Externalités des choix décentralisés et frontière de Pareto
  - Chocs d'offre, effets d'amplifications, etc.
- 5 Le coût de la pandémie dans la littérature macroéconomique
  - Scenarios à partir de données historiques
  - Modèles sectoriels et d'équilibre partiel
  - Modèles sectoriels et d'équilibre partiel
  - Statistiques en période de pandémie
- 6 Conclusion

## Graphes de contacts hétérogènes

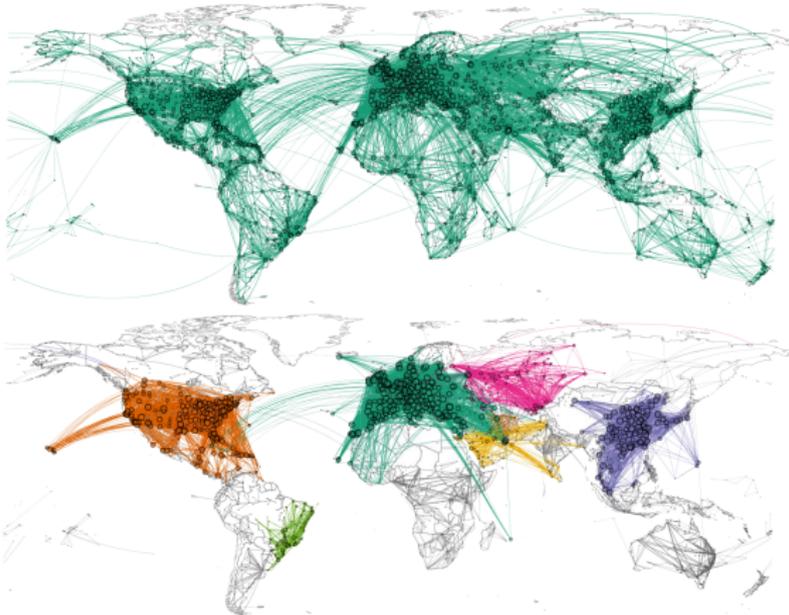


Figure 11: Réseaux de transport aériens sous hypothèse de retrait du tiers des liaisons : (a) Critère des liens épidémiologiques ; (b) Critère de la centralité d'intermédiarité. Source : Matamalas et al. [2018]

# Graphes de contacts et modèles de métapopulations

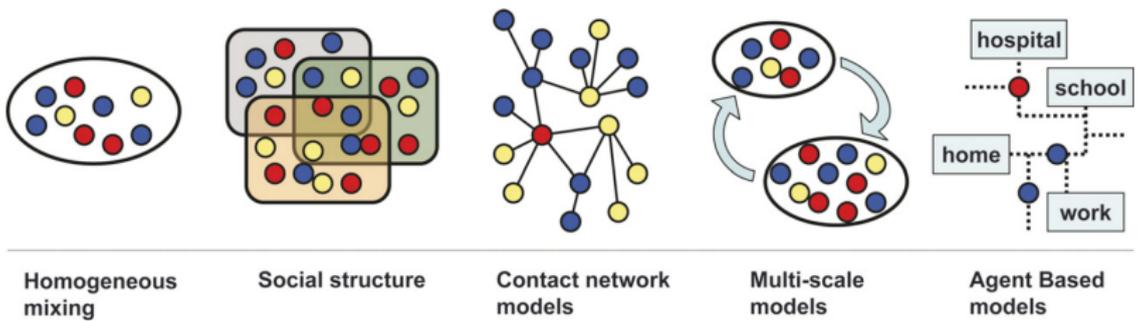


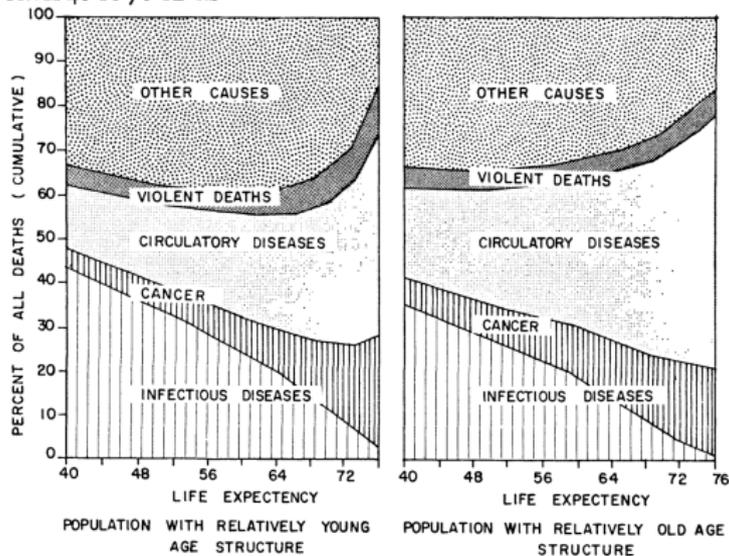
Fig. 1. Different scales structure used in epidemic modelling. Circles represent individuals and each colour corresponds to a specific stage of the disease. From left to right: homogeneous mixing, in which individuals are assumed to homogeneously interact with each other at random; social structure, where people are classified according to demographic information (age, gender, etc.); contact network models, in which the detailed network of social interactions between individuals provide the possible virus propagation paths; multi-scale models, which consider sub-population coupled by movements of individuals, while homogeneous mixing is assumed on the lower scale; agent-based models, which recreate the movements and interactions of any single individual on a very detailed scale (a schematic representation of a city is shown).

**Figure 12: Echelles de formalisation des modèles épidémiologiques :** contacts homogènes, classifications démographiques (âge, genre, etc.), réseaux sociaux de contacts, modèles multi-échelles (homogènes à l'échelle inférieure), modèles multi-agents. Source : [Colizza et al. \[2007\]](#)



## Graphes de contacts et transitions épidémiologiques

FIGURE 3. PATTERN OF MORTALITY TRENDS (STANDARDIZED MORTALITY) BY CAUSE-OF-DEATH GROUPS FOR EXPECTATION OF LIFE AT BIRTH FROM 40 TO 76 YEARS



Source: Department of Economic and Social Affairs, *Population Bulletin of the United Nations*, 6, 110-112, 1962.

Figure 13: Mortalité, par groupes de causes de décès, en fonction des espérances de vie à la naissance, de 40 à 76 ans. Source : [Omran \[1971\]](#)

## Outline

- 1 Introduction
- 2 Modèles épidémiologiques de référence
  - Les modèles SIR/SEIR
  - Changements d'états non observés et degrés de sévérité
  - Le modèle global ICL
- 3 Modèles épidémiologiques et graphes de contacts
  - Graphes de contacts hétérogènes
  - Graphes de contacts et modèles de métapopulations
  - Transitions épidémiologiques
- 4 L'arbitrage épidémiologique vs. macroéconomique dans les modèles mixtes
  - Interactions et modèles mixtes de pandémies
  - Architecture générale des modèles mixtes
  - Externalités des choix décentralisés et frontière de Pareto
  - Chocs d'offre, effets d'amplifications, etc.
- 5 Le coût de la pandémie dans la littérature macroéconomique
  - Scenarios à partir de données historiques
  - Modèles sectoriels et d'équilibre partiel
  - Modèles sectoriels et d'équilibre partiel
  - Statistiques en période de pandémie
- 6 Conclusion

## Mécanismes d'interactions et modèles mixtes de pandémies

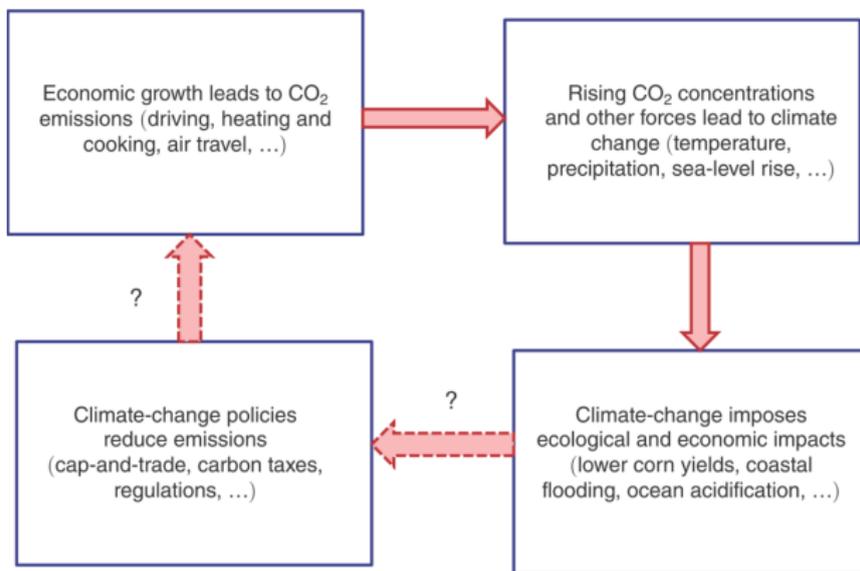


FIGURE 2. THE CIRCULAR FLOW OF GLOBAL WARMING SCIENCE, IMPACTS, AND POLICY

Figure 14: Schéma d'ensemble des modèles d'évaluation intégrés du changement climatique (IAMs, *Integrated Assessment Models*, source : Nordhaus [2019]).

# Architecture générale des modèles mixtes

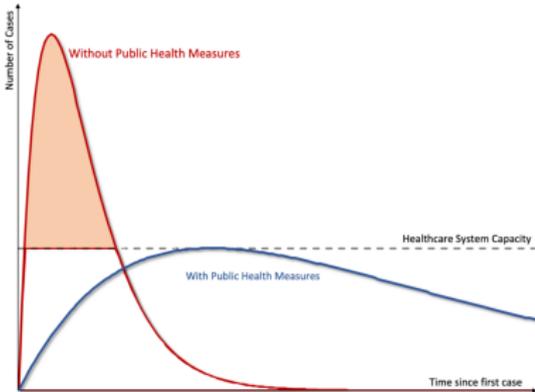


Figure 1: Flattening the Pandemic Curve

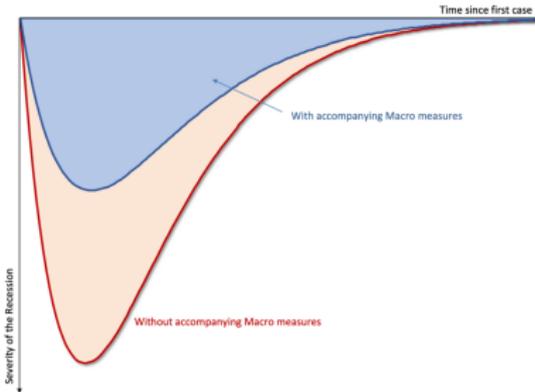


Figure 2: Flattening the Recession Curve

Figure 15: "Applatis les courbes": (a) Courbe de la pandémie ; (b) Courbe de la récession.  
 Source : [Gourinchas \[2020\]](#)

← Littératures

# Externalités des choix décentralisés et frontière de Pareto

Figure 3: Basic SIR-Macro Model With and Without Containment

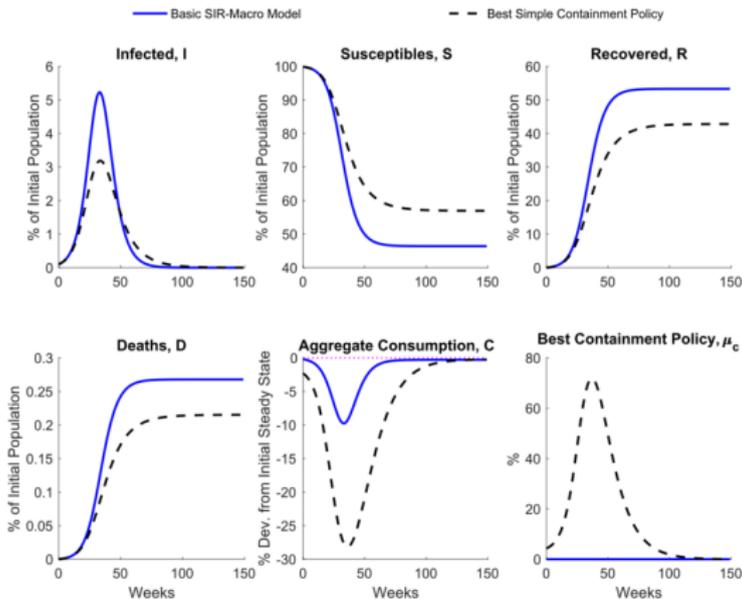


Figure 16: Décisions décentralisées, décisions collectives : variables épidémiologiques et économiques. Source : [Eichenbaum et al. \[2020b\]](#)

## Externalités des choix décentralisés et frontière de Pareto

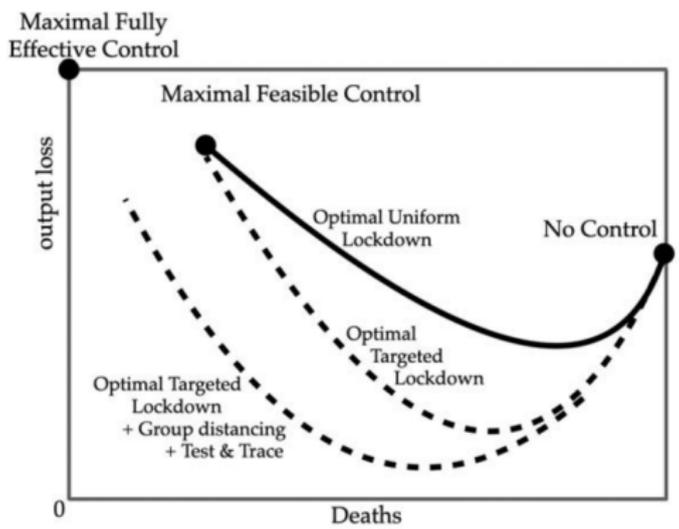
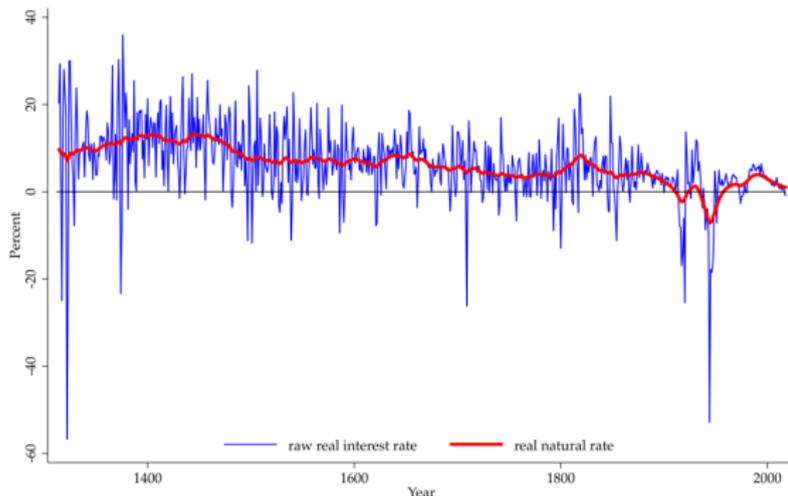


Figure 1.2: Frontière: économique vs. lives lost with additional policies.

Figure 17: Frontières : critère économique vs. vies humaines dans différentes hypothèses de mesures contraignantes. Source : Acemoglu et al. [2020]

## Chocs d'offre, effets d'amplifications, etc.

**Figure 1:** *The European real natural rate of interest, 1315–2018*

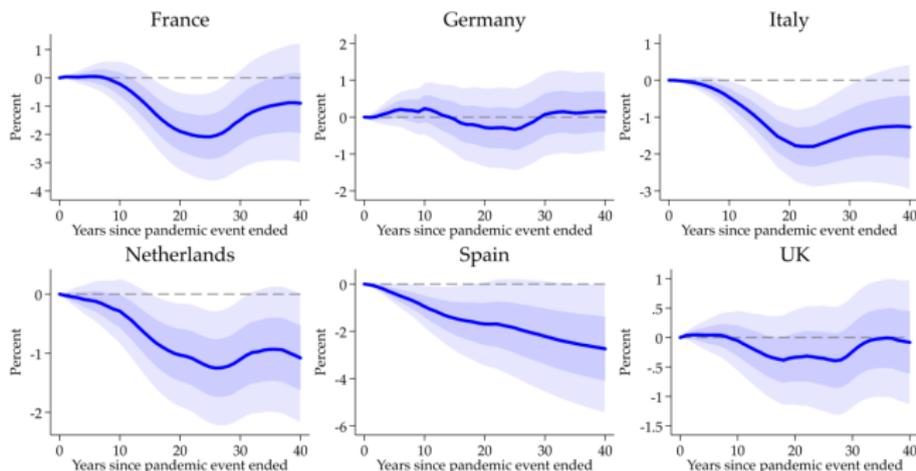


Notes: Raw interest data from Schmelzing (2020). The real rate is based on the model in Equation 3. See text.

**Figure 18:** Réponses historiques des taux d'intérêts aux pandémies, 1300-2020 : Taux d'intérêts réels brut et naturel. Source : Jordà et al. [2020]

## Chocs d'offre, effets d'amplifications, etc.

Figure 3: Country-specific response of the real natural rate of interest following pandemics



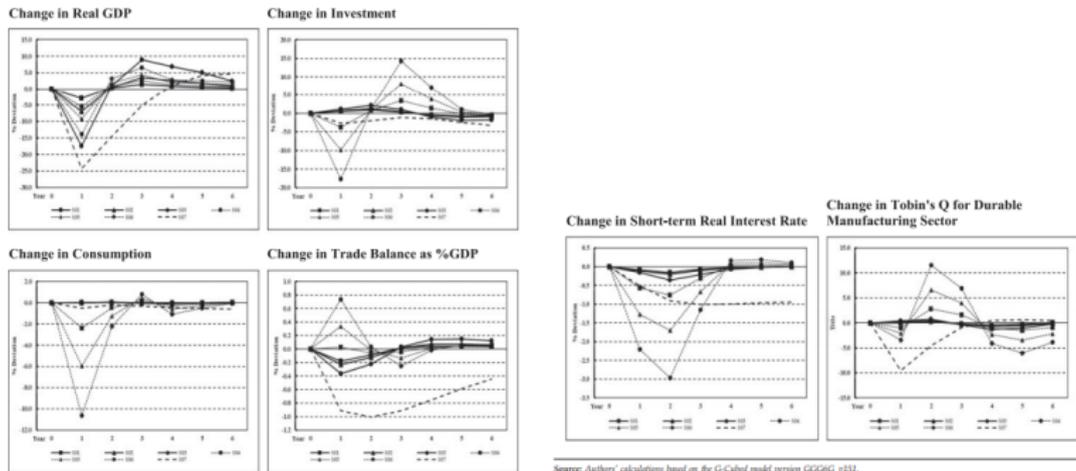
Notes: Responses calculated using Equation 2. Shaded areas are 1 and 2 s.e. bands around response estimates. See text.

Figure 19: Réponses historiques des taux d'intérêts aux pandémies, 1300-2020 : Réponses nationales du taux réel naturel. Source : Jordà et al. [2020]



## Scenarios épidémiologiques et macroéconomiques élaborés à partir de données historiques

Figure 9. Dynamic results for the United States



Source: Authors' calculations based on the G-Cubed model version GGGGc\_p15f.

Figure 20: Prévisions de PIB, investissement, consommation, balance commerciale, taux d'intérêts à court terme, et Q de Tobin élaborées à partir de données épidémiologiques historiques. Source : McKibbin and Fernando [2020]

## Modèles sectoriels et d'équilibre partiel

Tableau 3. L'approche par la production des branches : illustration simplifiée de la table entrées-sorties mondiale du point de vue du pays domestique

		CONSOMMATION INTERMÉDIAIRES (par branche)	
		PAYS DOMESTIQUE	RESTE DU MONDE
PRODUCTION (par produit)	MONDE	$CI^{dom}$  Consommations intermédiaires domestiques de produits domestiques (17 x 17)	$CI^{exp}$  Consommations intermédiaires étrangères de produits domestiques (17 x (17 x 11))
		$CI^{imp}$  Consommations intermédiaires de produits importés ((17x11) x 17)	$CI^{râm}$  Consommations intermédiaires du reste du monde ((17 x 11) x (17 x 11))
	VALEUR AJOUTÉE		
	Impôts nets subv.	$VA_{pb}^{dom}$	$VA_{pb}^{râm}$
	Marges de transports		
	PRODUCTION (par produit)	$p^{dom}$	$p^{rdm}$

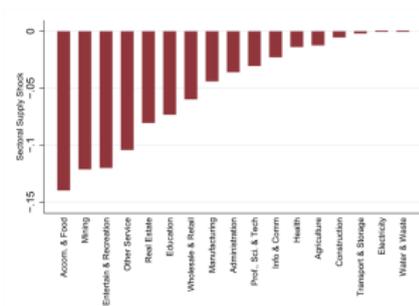
Source : OFCE.

Figure 21: Représentation de la production des branches par le tableau entrées-sorties, distinguant les consommations intermédiaires domestiques et importées. Source : [Dauvin et al. \(2020\)](#)



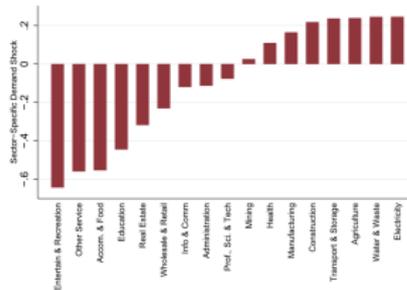
## Modèles sectoriels et d'équilibre partiel

Figure 2: Supply Shock by Sector



Notes: Depicts the COVID-19 demand shock by 1-digit NACE sector, as the percent change relative to the non-COVID scenario. Supply shocks are first aggregated from the 4-digit NACE to 1-digit NACE by taking a simple average across 4-digit sectors within each country. The gross value added sector share of each country is used to aggregate 1-digit sector shocks across countries. The countries used in aggregation are the high coverage group, which includes Belgium, Czech Republic, Finland, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain.

Figure 3: Demand Shock by Sector



Notes: Depicts the COVID-19 demand shock by 1-digit NACE sector, as the percent change relative to the non-COVID scenario. Demand shocks are first aggregated from the 4-digit NACE to 1-digit NACE by taking a simple average across 4-digit sectors within each country. The gross value added sector share of each country is used to aggregate 1-digit sector shocks across countries. The countries used in aggregation are the high coverage group, which includes Belgium, Czech Republic, Finland, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain.

Figure 22: Chocs sectoriels. (a) Chocs d'offre ; (b) Chocs et de demande, échantillon de 14 économies émergentes et avancées. Source : Gourinchas et al. [2020]

# Modèles sectoriels et d'équilibre partiel

Figure 4: Weekly Evolution (Sector)

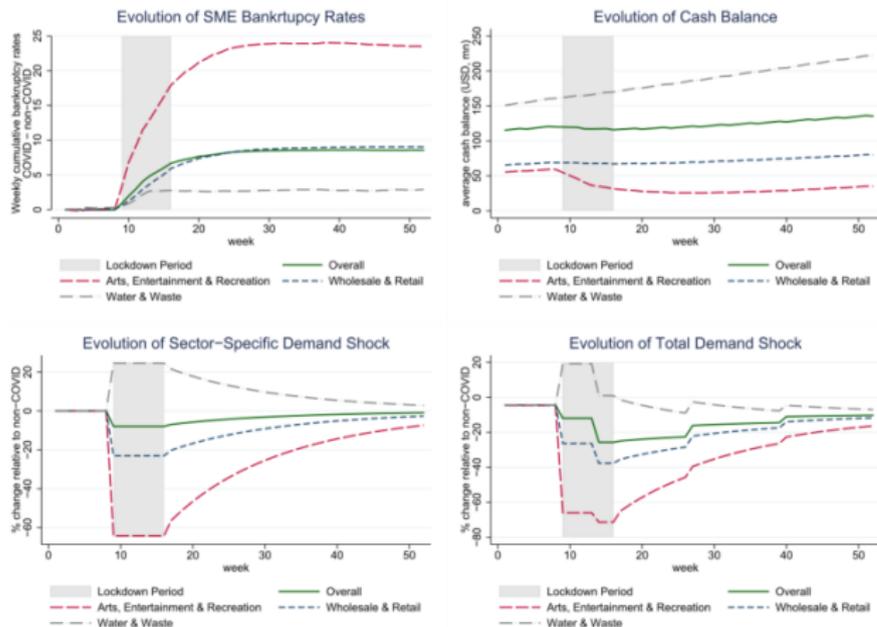


Figure 23:  
Dynamique hebdomadaire de variables relatives aux PME, par secteur d'activité.  
Source : Gourinchas et al. [2020]

## Méthodologie de la production de statistiques en période de pandémie



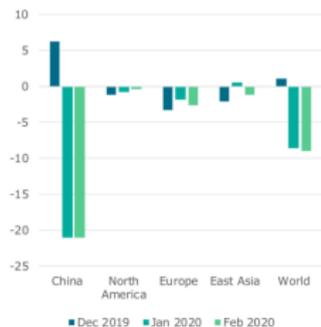
### Contributing organisations

Asian Development Bank (ADB)  
 Bank for International Settlements (BIS)  
 Cooperation Council for the Arab Countries of the Gulf (GCC)  
 European Central Bank (ECB)  
 Eurostat  
 Food and Agriculture Organization of the United Nations (FAO)  
 International Civil Aviation Organization (ICAO)  
 International Labour Organization (ILO)  
 International Monetary Fund (IMF)  
 International Organization for Migration (IOM)  
 International Telecommunication Union (ITU)  
 Office of the United Nations High Commissioner for Human Rights (OHCHR)  
 Organisation for Economic Co-operation and Development (OECD)  
 Partnership in Statistics for Development in the 21st Century (PARIS21)  
 United Nations Children's Fund (UNICEF)  
 United Nations Conference on Trade and Development (UNCTAD)  
 United Nations Development Programme (UNDP)  
 United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP)  
 United Nations Economic and Social Commission for West Asia (ESCWA)  
 United Nations Economic Commission for Africa (UNECA)  
 United Nations Economic Commission for Latin America and the Caribbean (ECLAC)  
 United Nations Educational, Scientific and Cultural Organization (UNESCO)  
 United Nations Entity for Gender Equality and the Empowerment of Women (UN Women)  
 United Nations Environment Programme (UNEP)  
 United Nations High Commissioner for Refugees (UNHCR)  
 United Nations Human Settlement Programme (UN Habitat)  
 United Nations Industrial Development Organization (UNIDO)  
 United Nations Office for the Coordination of Humanitarian Affairs (OCHA)  
 United Nations Office on Drugs and Crime (UNODC)  
 United Nations Population Fund (UNFPA)  
 United Nations Statistics Division (UNSD)  
 United Nations World Tourism Organization (UNWTO)  
 Universal Postal Union (UPU)  
 World Bank (WB)  
 World Health Organization (WHO)  
 World Trade Organization (WTO)

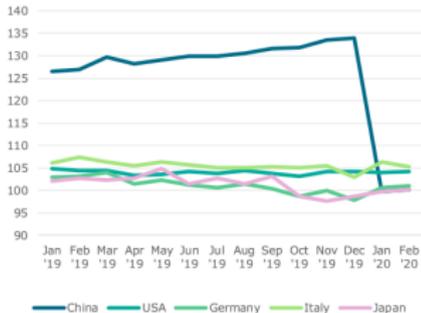
# Méthodologie de la production de statistiques en période de pandémie

Monthly growth rates of Manufacturing

Output compared to previous year



Production output of countries with the highest shares



For more information, see World Manufacturing Production (Report): <https://stat.unido.org/content/publications/world-manufacturing-production>

Methodology: [https://www.unido.org/sites/default/files/2017-06/Methodology\\_of\\_the\\_Quarterly\\_Report\\_0.pdf](https://www.unido.org/sites/default/files/2017-06/Methodology_of_the_Quarterly_Report_0.pdf)

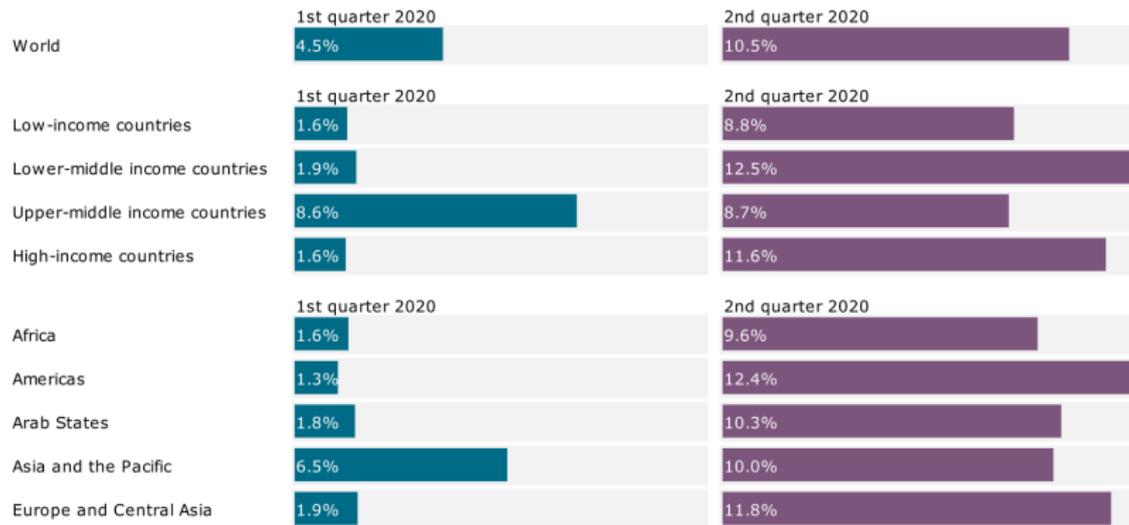
Preliminary data on index numbers (base 2015) are derived from national statistical sources. In case of missing seasonal adjusted data, UNIDO conducts seasonal adjustment where appropriate. Seasonal adjustments are made to filter out any fluctuations or calendar effects within time series shifts.

The aggregates for World, North America, Europe and East Asia are calculated with weights referring to the base year 2015. Furthermore, only available country data is taken into account for calculating the aggregates. The aggregate for the world manufacturing output considers a share of 78 per cent of all countries due to data availability. The dataset will be regularly updated if further information will become available.

Figure 24: Exemple de données macroéconomiques du rapport CCSA : production manufacturière et production totale. Source : CCSA [2020]

## Méthodologie de la production de statistiques en période de pandémie

### Estimated drop in aggregate working hours

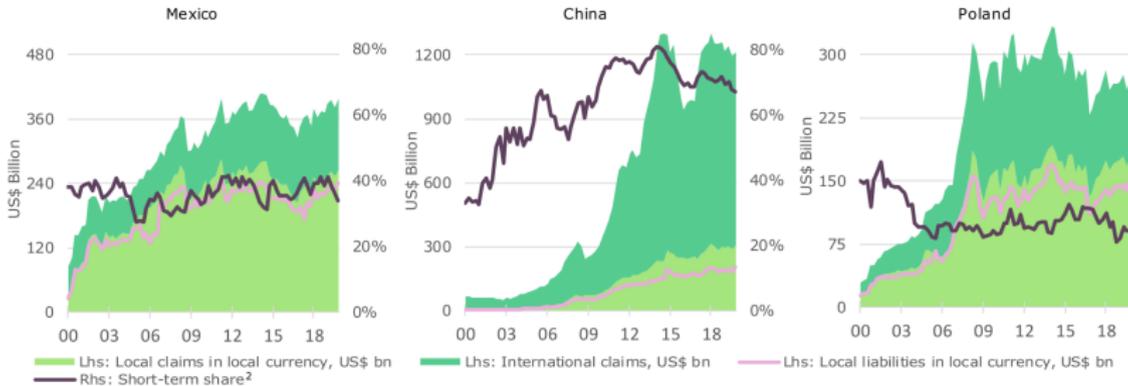


Source: ILO now casting model.

Figure 25: Exemple de données macroéconomiques du rapport CCSA : recul des heures travaillées. Source : [CCSA \[2020\]](#)

# Méthodologie de la production de statistiques en période de pandémie

Figure 1 - Foreign claims<sup>1</sup> on selected emerging markets



<sup>1</sup> Foreign claims is the sum of international claims (cross-border claims in all currencies and foreign currency claims extended local foreign offices) and locally extended claims in local currency.  
<sup>2</sup> Share of short-term claims (maturity up to and including one year) in total international claims.  
 Source: BIS consolidated banking statistics on an immediate counterparty basis (Table B4).

Figure 26: Exemple de données financières du rapport CCSA : Créances sur les économies émergentes. Source : CCSA [2020]

# Méthodologie de la production de statistiques en période de pandémie

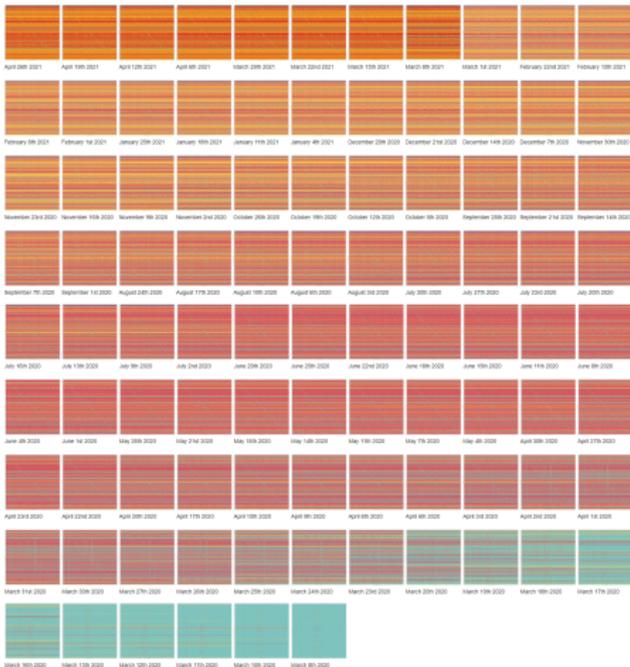


Figure 27: Exemple de données sur la mobilité du rapport CCSA : carte thermique internationale des restrictions de déplacement, fréquence hebdomadaire du 8 mars 2020 au 26 avril 2021. En vert : absence de restriction, en jaune : restriction partielle, en rouge : restriction totale. Source : [CCSA \[2020\]](#)







## References II

- Joan T Matamalas, Alex Arenas, and Sergio Gómez. Effective approach to epidemic containment using link equations in complex networks. *Science advances*, 4(12): eaau4212, 2018.
- Vittoria Colizza, Marc Barthélemy, Alain Barrat, and Alessandro Vespignani. Epidemic modeling in complex realities. *Comptes rendus biologies*, 330(4):364–374, 2007.
- Abdel R. Omran. The epidemiologic transition: A theory of the epidemiology of population change. *The Milbank Memorial Fund Quarterly*, 49(4):509–538, 1971. ISSN 00263745. URL <http://www.jstor.org/stable/3349375>.
- William Nordhaus. Climate change: the ultimate challenge for economics. *American Economic Review*, 109(6):1991–2014, 2019.
- Pierre-Olivier Gourinchas. Flattening the pandemic and recession curves. *Mitigating the COVID Economic Crisis: Act Fast and Do Whatever*, page 31, 2020.
- Martin S Eichenbaum, Sergio Rebelo, and Mathias Trabandt. The macroeconomics of epidemics. *NBER Working Paper Series*, (26882), April 2020b.
- Daron Acemoglu, Victor Chernozhukov, Iván Werning, and Michael D Whinston. A multi-risk sir model with optimally targeted lockdown. *NBER Working Paper Series*, (27102), May 2020.

