Climate, technology, family size; on the crossroad between two ultimate externalities

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Contribution 1

Build an analytic climate-economy model with

- closed-form solutions (GHKT 2014)
- endogenous growth (variety expansion Romer 1986)
- endogenous family planning (Becker 1989)
- endogenous human capital (MRW 1992)

calibrate and assess the SCC when global warming reduces growth (Dell et all 2012, Burke et al 2015)

closed-form Social Costs of Carbon

- $SCC_t = \frac{\delta\theta}{1-\beta} Y_t$
  - GHKT2014 rewrite the DICE model in Brock-Mirman 1972 format;
  - solution in finite steps no need to run infinite horizon model.
- vdBGL2016, RvdP2016: closed-form analytical solutions can be generalized to SCC formulas that proxy IAMs (e.g. DICE) very well

Contribution 2

Calibrate model and re-estimate SCC using new Empirical Climate-Growth literature (summary)

Table: Dependent variable: economic growth

	(1)	(2)
Temperature	0.261	1.27***
Temp. × Poor	-1.66***	
Temp. sq.		-0.05***
Country FE	YES	YES
Year FE	YES	YES
N	4924	6584

Sources: (1) Dell, Jones & Olken, AEJmacro 2012, Table 2. (2) Burke, Hsiang & Miguel, Nature 2015, Table 1 (x100). Various controls, lags, and FEs included.

Estimate uses panel data with annual variation in weather and growth between countries. Interpreting as sensitivity to climate..

Contribution 3

Use the model to structure thinking about family planning as the ultimate externality.

- Hardin 1968: "To couple the concept of freedom to breed with the belief that everyone born has an equal right to the commons is to lock the world into a tragic course of action."
- Kuznets 1960: "[we should view] human beings not as producers of commodities and services, but as producers of new knowledge"
- support a structured discussion on (more) people as the source, or solution, for scarcity of natural resources (specifically climate change).
- Reason to worry or to celebrate the future 10-12bn world population?
  - Do more people increase or reduce environmental damages and welfare?
  - do not expect a simple answer, or a number ...

Method

Basis: Brock Mirman model (1972): Ramsey-Cass-Koopmans with discrete time, stochastic TFP, full capital depreciation, log-utility $\rightarrow$ closed-form solution for all decision variables (investment in capital).

Climate extension:

- emissions as production factor + higher temperatures decreases TFP
- higher temperatures decreases innovation

Endogenous population extension:

- human capital
- endogenous fertility

Semi-endogenous growth extension:

- variety expansion with standing on shoulders & toes

Scope: limitations

- World model
  - no heterogeneous regions
  - no migration
- Dynasties as units of decision making
  - no value of individual life / optimal population size
  - externalities between dynasties (cf. aggregate versus average welfare)
  - Interpretation: Am I ok with my neighbor's third child?
- Undirected technical change
  - No renewables versus fossil fuels (no fossil fuel markets)
- Social/congestion population externalities, and thus optimal population, remain unobservable

Summary of agents

- Households choose consumption and savings (c_t, s_t), human capital and fertility (f_t, h_t), that maximize welfare, given wages (w_t), interest (r_t), lump-sum transfers $(\tau_{n,t})$, fertility taxes $(\tau_{f,t})$.
- Final sector produces final good (Y_t) using intermediates $(y_{i,t})$, implying demand function for intermediates.
- Intermediates sector sets prices (p_t) that maximize profits given wages (w_t), interests (r_t), prices for emissions and renewables $(\tau_{f,t}, \tau_{z,t})$, royalties for blueprints $(\pi_{i,t})$
- Innovators produce varieties (a_t), choosing capital, labor, emissions (k_t, l_t, e_t) that maximize profits given royalties for blueprints $(\pi_{i,t})$, wages (w_t), interests (r_t), prices for emissions and renewables $(\tau_{f,t}, \tau_{z,t})$.
- Government may maximize welfare or use fiscal rule of thumb. Sets carbon taxes $(\tau_{e,t})$, fertility taxes $(\tau_{f,t})$, and lump-sum transfers $(\tau_{n,t})$ and maintains closed budget.

Aggregate Economy

$$W_t = \sum_{j=0}^{\infty} \beta^j \left[\ln(C_{t+j}/N_{t+j}) + \gamma \ln(f_{t+j}) + u(N_t)\right] \quad (1)$$

$$C_t + K_{t+1} = e^{-\delta_Y T_t} A_t^{\frac{1}{\varepsilon-1}} (1 - s_A) X_t(.) \quad (2)$$

$$A_{t+1} = e^{-\delta_A(\varepsilon-1)T_t} (s_A X_t(.))^{1-\psi} A_t^{\varphi} \quad (3)$$

$$N_{t+1} = (1 + f_t - \delta_N) N_t \quad (4)$$

$$h_{t+1} = {x_t}^{\eta_s} h_t^{\eta_h} \quad (5)$$

$$R_{t+1} = R_t - E_t \quad (6)$$

$$T_t = \sum_i \theta_i E_{t-i} \quad (7)$$

with $X_t(.) = K_t^{\alpha} [q_t(E_t, Z_t)]^{\kappa} (h_t(1 - \phi f_t - x_t f_t) N_t)^{1-\alpha-\kappa}$ total effort

Control variables: investment share of output $s_{K,t}$, share of effort into innovation $s_{A,t}$, share of time into education x_t, fertility f_t, emissions E_t

Note that h_t is an intensive state variable, while K_t, A_t, N_t are aggregate stocks.

Investment shares

$$s_K^* = \alpha\beta\left[1 + \frac{\beta(1-\psi)}{(\varepsilon-1)(1-\beta\varphi)}\right] \tag{8}$$

$$s_A^* = \frac{\beta(1-\psi)}{(\varepsilon-1)(1-\beta\varphi)+\beta(1-\psi)} \tag{9}$$

- interpretation s_K^*: BM72 has $s_K^* = \alpha\beta$. Here we have additional value of capital as it also produces knowledge. In blue the share of the value of produced knowledge relative to produced final goods.

Social costs of carbon has 2 parts

- GHKT14: closed-form Social Cost of Carbon

$$SCC_t = g^* Y_t \tag{10}$$

$$g^* = \delta_Y \sum_{i=1}^{\infty} \beta^i \theta_i \tag{11}$$

- This model: growth reduction, has more persistent effects

$$g^* = \left[\delta_Y + \frac{\beta \delta_A}{1 - \beta \varphi} \right] \sum_{i=1}^{\infty} \beta^i \theta_i \tag{12}$$

The term $1/(1-\beta\varphi)$ measures the persistence of a growth-reducing negative shock.
If conditional convergence is 2%/yr, and pure discounting is 2%/yr, then any growth reduction shock is valued at $1/(0.02+0.02) = 25$ times the one-year damage.

Calibration: all parameters

Table: Parameters and Macro Targets

Parameter	Description	Value	Source / Targeted Moment
α	Capital-output elasticity	(0.12,0.26,0.39)	Savings share
β	Pure discount	(0.74,0.82,0.90)	Return on capital
δ_Y	Climate damage for output [/K]	(0.005,0.01,0.015)	Hsiang et al. 2017
δ_A	Climate damage for growth [/K]	(0.01,0.03,0.05)	Dell et al. 2012,Burke et al. 2015
ε	Elasticity of demand	(3,5,7)	Industry mark up
φ	Standing on shoulders	(0.71,0.79,0.88)	Convergence of 1-3% p.y.
κ	Natural resource share in output	(0.05,0.1,0.15)	Resource shares
ψ	Standing on toes	(0.49,0.80,0.93)	Income growth, $g_Y/g_L = 1.2 - 1.6$
θ_i	Climate sensitivity [K/TtCO2]	(0.4,0.7,1.0)	Climate literature

The triples for $\beta, \delta_Y, \delta_A, \varepsilon, \kappa, \theta$ present the lower bound, median, and upper bound for chosen uniform distributions, while the triples for α, φ, ψ present 5,50,95 percentiles that come out of the calibration process.

First quantitative results, carbon prices

We do not need to simulate (!), but can calibrate to long-run economic behavior (population and economic growth)

Table: Outcomes for calibrated model

Variable	Description	Value
s_K	Capital Investment share	$(0.12, 0.24, 0.34)$
s_A	Research share	$(0.06, 0.11, 0.18)$
τ_E	SCC [€/tCO2]	$(11, 20, 38) + (54, 144, 300)$

The triples present 5,50,95 percentiles. The Social Cost of Carbon is partitioned in its two components

Discussion: Our interpretation of Dell et al (2012) and Burke et al (2015) results in very high Social Costs of Carbon related to growth damages (144 vs 20).

SCC:growth versus level effects

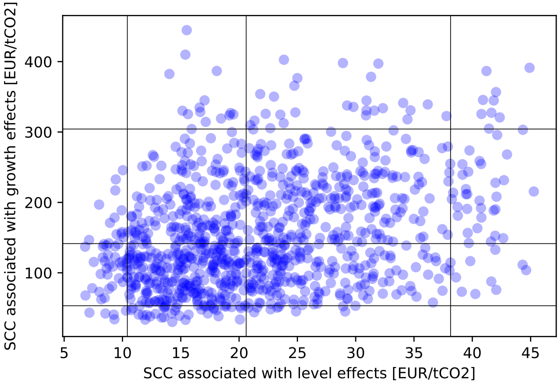

Figure: SCC estimates, decomposed in level and growth effects, for Monte Carlo set of parameters. (sample size=1000)

Part 2. Population and Welfare

Should we worry about too many children (up to 11bn)? Which measure?

1. effect of additional child on welfare (short run)
2. effect of population size on welfare in balanced growth (long run)
3. effect of additional child in one family on welfare in other family
4. optimal number of children according to max welfare

1^{st} perspective: Welfare

Lemma (separable log-linear welfare)

Welfare depends on the state variables log-linearly:

$$V_t = \zeta_K \ln(K_t) + \zeta_A \ln(A_t) - \sum_{i=1}^{\infty} \Theta_i E_{t-i} + \overline{V}_t(R_t, N_t, h_t).$$

For $u(.) = 0$: population-permanent income elasticity $= (1-\beta)\zeta_N$: $(-0.18, -0.05, 0.09)$

- population $\nearrow$ 10% $\Rightarrow$ permanent income $\searrow$ 0.5%

2^{nd} perspective: returns to scale

Negative welfare effect of population is short-run: fixed capital and technology.

Long-run: in any semi-endogenous growth: larger population increases long-run per capita income. Resource scarcity is too small to counter (by the rules of calibration, Jones 2020).

$$\frac{\widehat{Y}}{\widehat{L}} = \frac{-\kappa(\varepsilon-1)(1-\varphi)+(1-\kappa)(1-\psi)}{(1-\alpha)(\varepsilon-1)(1-\varphi)-\alpha(1-\psi)}\widehat{L} = 0.22\widehat{L} \tag{13}$$

3^{rd} perspective: birth externality

Birth externality: parents internalize the dilution of their savings with the increase in number of children. They do not internalize the other positive innovation + climate + per capita pseudo-property rights effects.

Proposition (optimal fertility tax)

$$\tau^*_{f,t} N_{t+1} = -(\zeta_K + (1-\psi)\zeta_A + \zeta_{R,t+1} + \zeta_{N,t+1}) C_t \tag{14}$$

- A positive birth externality in most cases: $\tau_{f,t} = (-69, -22, 21)$.
- Positive innovation externality > negative climate externality

4^{th} perspective: optimal growth

Whether population growth is optimal or not, does not depend only on returns to scale effects...

A preference for many children γ results in

- positive balanced growth, $f^* > \delta_N$ for $u(.) = 0$
- a larger steady state N^{**} for $u(0) = \infty, \lim_{N \to \infty} u(N) < 0$

Population and Welfare

Should we worry about too many children (up to 11bn)? Our model collects various mechanisms:

1. additional child reduces short-run welfare (capital/capita ↘)
   Standard neo-classical capital-per-capita argument
2. long-run welfare p.c. increases with population size (innovation ↗)
   Kuznets 1960, Simon 1981, Bretscher 2020)
3. or decreases (resources p.c. ↘, Hardin 1968)
4. family externality depends on existing (other) market failures
   Harford (1998), Schou (ITPF 2002), Gerlagh, Lupi, Galeotti (WP 2018), Kruse-Andersen (WP 2019)
5. optimal number of children or of population depends on 'love for large family'
   but also opportunity costs of children may change with economic structure: Peretto and Valente (2015), Brunschweiler et al. (2020)

But we cannot calibrate $u(.)$?

Research answers 1 (Innovation & SCC)

1 Climate change and endogenous growth

   a If climate change affects growth, as estimated in recent empirical literature, does that increase the social costs of carbon (carbon tax) substantially?

After you understand the model, the results become obvious.

- Yes and substantially so, due to slow recovery of lost TFP
- Provided a simple intuitive closed-form solution

Research answers 2 (Climate and population)

2 Reason to worry or to celebrate the future 10-12bn world population?
   a Do more people increase or reduce environmental damages and welfare?

Social Optimum

- More people means more man-made varieties, a positive externality.
- More people means less space, less nature, a negative externality.
- In social optimum, positive exceeds negative externality, when measured in per capita consumption.

But empirically

- History shows that pollution increases with population, and space for nature decreases with population
- Policy does not adapt optimally.
- Our models structurally omit physical needs and social preferences for friends & living space; what data to calibrate?

Thank You

Comments appreciated