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Incidence of Climate on Emerging Economies: Lessons from English's Past*

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Abstract

Evidence from English real wages and real land rents for the period 1500-1800 are used to evaluate the impact of temperature and precipitations on under-developed economies. Estimating key parameters of an AK-growth model, we extract Total Factor Productivity (TFP hereafter) shocks and estimate the impact of temperature and extreme precipitation events (droughts and and flood) on TFP. We produce evidence that a two degree reduction of temperature lowers TFP by 0.1 (one standard deviation of TFP shocks). We also show that, conditionally on temperatures, the impact of floods on TFP is statistically significant while the impact of droughts is not. We consider these results as a useful benchmark to measure the impact of global warming and/or measures intended to contain it on developing economies.

Keywords: Economic growth, Climate, Real wages, Land rents.
JEL Classification: C22, N13, O41, O47, Q54.

1 Introduction

Widespread poverty severely limits the capabilities to adapt global warming. It is then highly probable that the poorest regions of the World (in particular in Africa and Asia) will be among the first to suffer from global climatic change. The shortage in data makes a precise evaluation of economic impact a challenging task.

This problem resembles the questions raised in the late 60's by economic growth strategies. Many theoretical studies claimed that investment in (human and physical) capital,

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together with drastic modifications of demographic patterns, trade openness and possibly liberally-oriented political and fiscal reforms have played a major role in the uprising of currently developed countries. Historical data on US, England, France, Germany and Japan have been patiently gathered to provide sound quantitative supports for these theoretical claims (see for instance Maddison (2000)). The aim of this note is to use a similar idea to obtain reliable evaluations of the impact of climate change on macroeconomic series.

To this end, we propose a simple AK-growth model and confronts its main conclusions to long historical time series of real wages and real land rents in England. We focus on pre-industrial time where English economy displays patterns close to emerging countries (namely prevalence of agricultural sector, slow technological innovations, narrow ways to mutualized individual risks, political instability, major impact of diseases and climate on demographic evolution). We use real wages and land rents to extract a (model-consistent) measure of TFP shocks and estimate the impact of two climatic factors (temperature and precipitations) using long series provided by IPCC (Intergovernmental Panel on Climate Change) experts.

The rest of the note is as follows. Section 2 contains a brief description of the data we use. Section 3 sets up the model and presents the main econometric results. A brief section concludes.

2 Data

We collect three different types of data. The first one is an annual sequence of English real wages starting in 1264.[1]

The second source of data comes from the site of Gregory Clark. We gather all the 4,983 rents of the Charity Commission Land Rents data set from 1502 to 1800.[2] We use the estimated annual rental value of land in pounds (including land tax if paid by the tenant). To obtain a comparable index we simply divide this estimated rent by the total surface.[3] To mitigate the amount of heterogeneity, we only consider the years for which

[1] This exceptionally long sequence is available at http://www.measuringworth.org.

[2] The data set extends to 1912 but we concentrate on pre-industrial period. There is also an anecdotic record in 1394, but there is no data form this date on to 1502.

[3] We did try to use more information. Although the data set contains many details regarding the type

we have a sufficiently large amount of data (namely 10 per year, which leave us with 172 different dates from 1606 to 1800). A real rent annual index is obtained by averaging rental values and by dividing by the real price index (see measuringworth.org for the real price index).

The last source of data we use concern the climate. It has been kindly provided by Juerg Luterbacher. We have the annual mean temperatures for an area around London (average of 4 grid points which is around 5000 km^2) and the annual precipitation sum from 1500 to 2000 (again we only use the first part of the data until 1800).

The following table gives a brief description of the series we use.

Table 1: Descriptive Statistics

Serie	Min	Q_1	Med.	Q_3	Max	Aver.	Std. Err.	Kurt.
Real wages	9.15	37.24	43.78	53.19	284.69	53.58	38.71	11.33
Real rents	0.14	0.428	0.527	0.663	1.297	0.556	0.198	1.19
Precipitation (mm *per* year)	318.93	620.06	688.35	737.31	964.99	682.56	93.41	0.609
Temperatures (Celsius)	7.29	9.14	9.49	9.89	11.11	9.48	0.59	0.469

3 Stochastic fluctuations and impact of climate

We first state a model with infinitely lived price-taker agents (a variation of the well-known AK-growth model). We then use our data to infer the impact of climatic variations.

3.1 Model

We assume the representative agent maximizes

$$E_0\left[\sum_{t=0}^{+\infty}\beta^t \log\left(C_t - hN_t^{1+\mu}\right)\right]$$

of land, its usage, its owner, very few observations are directly comparable.

with respect to consumption (C_t) and labor (N_t) paths, subject to the following constraints

$$C_t + I_t = W_t N_t + R_t K_{t-1} + \pi_t$$
$$K_t = A_K K_{t-1}^{\delta} I_t^{1-\delta}$$

where π_t is the representative firms' profit $Y_t - W_t N_t - R_t K_{t-1}$ with $Y_t = A_t K_{t-1}^{\alpha} N_t^{1-\alpha} \overline{K}_{t-1}^{\gamma}$ the production level.

The first equation is the budget constraint (where W_t and R_t stand respectively for real wage and real rate) whereas the second equation reflects the accumulation of capital K_t.[4] This equation which is a slight variation of the usual linear case has been proposed by Lucas and Prescott (1971) (see also Hercowitz and Sampson (1991)). The parameter $0 < \delta < 1$ may be interpreted as a quality of installed capital (see above references for details). The production function is of the standard Cobb-Douglas form with A_t the Solow residual, except for the presence of the term $\overline{K}_{t-1}$. It represents the average stock of capital available at the beginning of period t. It is considered as fixed by individual agents.

Equality between marginal (dis)-utility and marginal productivity of labor gives

$$h(1+\mu) N_t^{1+\mu} = (1-\alpha) Y_t.$$

Incorporating this into the production function gives

$$Y_t = \left(\frac{1-\alpha}{h(1+\mu)} \right)^{\frac{1-\alpha}{\alpha+\mu}} \left(A_t K_{t-1}^{\alpha} \overline{K}_{t-1}^{\gamma} \right)^{\frac{1+\mu}{\alpha+\mu}} . \qquad (1)$$

We then recognize the well-known AK model. The term $\overline{K}$ plays a crucial role in the dynamic of growth. It creates a positive externality. Several justifications have been proposed including, learning-by-doing (see Lucas (1993) and Stokey (1988), among others), human capital (see Becker, Murphy and Tamura (1990) and Stokey (1991), among others).

An adaptation of Hercowitz and Sampson (1991) arguments shows that a possible solution is given by $Y_t = S I_t$ where $S = \alpha\beta(1-\delta)/(1-\delta/\beta)$. Using the convention $x_t = \log(X_t)$ for every a.s. positive sequence X_t, the law of motion for (the logarithm of) capital at the

[4]We assimilate capital as land hence real rate and real rent coincide.

symmetric equilibrium is given by[5]

$$k_t = a_K + (1-\delta)s + \rho k_{t-1} + (1-\delta)\frac{1+\mu}{\alpha+\mu}a_t \tag{2}$$

where $\rho = \delta + \frac{(1-\delta)(1+\mu)}{\alpha+\mu}(\alpha+\gamma)$. Notice that the importance of externality may be tailored by the value of γ.

3.2 TFP shock extraction

We now derive the process a_t as a function of the bivariate stochastic process (r_t, w_t). The model implies the following system of equations

$$\begin{aligned}
r_t &= \ln(\alpha) + y_t - k_{t-1} && (i)\\
w_t &= \ln(1-\alpha) + y_t - n_t && (ii)\\
(1+\mu)n_t &= \ln(1-\alpha) - \ln(h(1+\mu)) + y_t && (iii)\\
k_t &= a_k + (1-\delta)s + \delta k_{t-1} + (1-\delta)y_t && (iv)
\end{aligned}$$

where the two first equations derive from the maximization of private profits. Equations (ii) and (iii) implies that y_t equals $\frac{1+\mu}{\mu}w_t$ up to some constant term. Taking this into account in (i) implies that k_{t-1} equals $\frac{1+\mu}{\mu}w_t - r_t$ up to some constant term. Finally, plugging this into (iv) implies that $\frac{1+\mu}{\mu}(w_{t+1} - w_t) - r_{t+1} + \delta r_t$ is a constant term. Minimizing the variance of $\lambda(w_{t+1} - w_t) - r_{t+1} + \psi r_t$ with respect to λ and ψ gives $\hat{\mu} = 5.992$ and $\hat{\delta} = 0.117$. The estimate for δ is consistent very a low quality of installed capital (relative to actual standard).[6]

These estimates may now be used to infer the sequences $\hat{y}_t$ and $\hat{k}_t$ up to some insignificant constants. Finally Equation (1) implies $\frac{\alpha+\mu}{1+\mu}y_t - (\alpha+\gamma)k_{t-1}$ equals a_t up to a constant term. Regressing the infer sequence $\hat{y}_t$ on $\hat{k}_{t-1}$ and extracting the noise using the Cochran Orcutt correction for AR(1) dependency we obtain an estimated sequence for TFP $(\hat{a}_t)$. The autocorrelation coefficient for this sequence is 0.12.

[5] We assume $log(\overline{K}_t) = k_t$ which amounts to say that the externality arises from the un-weighted geometric average of individual stocks of capital. The only restriction here is that all individual stocks of capital must be strictly positive. It may not be very attractive an assumption if agents were heterogenous but it is harmless in the symmetric case.

[6] As a rough comparison, remark that when $\delta = 0.95$ the depreciation is 42 times slower.

3.3 Impact evaluation

Using the innovations of $\hat{a}_t$ as a measure of TFP shocks, we perform an ARMAX estimation with temperature and indications of extreme precipitation events as exogenous effects. We define drought (resp. floods) as an abnormal low (resp. high) level of precipitation conditionally on temperature levels.[7]

Table 2: ARMAX estimation

	coef.	std. err.	Student-t	p. value
const	-2.68	1.13	-2.36	0.02 **
ϕ_1	-0.06	0,38	-0.16	0.87
θ_1	0.18	0.38	0.49	0.62
Temp.	0.55	0.24	2.27	0.02 **
$(\text{Temp.})^2$	-0.03	0.01	-2.18	0.02**
drought	0.01	0.03	0.25	0.79
flood	-0.08	0.04	-2.02	0.04**

First notice that once climatic conditions have been filtered out, the TFP process no longer display any inner dynamic features (order-1 autocorrelation and moving average parameters ϕ_1, θ_1 are not different from zero). This backs our prior that TFP fluctuations in England before the Industrial Revolution are largely due to climatic variations.

Second temperature levels and flood episodes do affect productivity. Notice that both abnormally high and low temperatures lower production level. The model may be used to compute the level of temperature for which the expected TFP level is the highest (*ceteris paribus*). This "optimal" temperature is 9.67 degrees Celsius which correspond to the 65%-quantile of the distribution of temperatures over the period 1500-1800. This may be related to the well-known Little Ice Age (a term coined by Matthes (1939)). The model is also able to forecast the impact of a two degree Celsius rise above the average temperature.[8] The model forecasts that such a rise induces a 0.1 decrease in the TFP level, which is exactly

[7]Precipitations and average annual temperatures are strongly related in the Northern-West part of Europe. To avoid multicolinearity problems, we first perform an estimation of precipitations as function of current and three previous temperatures. The dummy variable 'drought' (resp. 'flood') is set to 1 whenever the residual of this estimation is below its 5%-quantile (resp. above its 95%-quantile).

[8]A two degree rise on global warming by the end of XX–first century corresponds to the lower bound of the rise induced by the actual climatic change according to the IPCC.

the estimated standard error of the innovations of the process $\hat{a}_t$. Notice that droughts do not have much influence on TFP but floods have. A flood induces an adverse shock similar to a one degree Celsius deviation from the optimal level of temperature.

4 Conclusion

This paper evaluates the economic impact of temperature and/or precipitation variations in England between 1500 and 1800. Estimating an AK-growth model, we show that climatic fluctuations adversely affect TFP of a pre-industrial economy. A two degrees rise in the temperature induces a decrease in the Total Factor Productivity similar to a one standard error (TFP) shock. Flood episodes also lower productivity, though to a lesser extent.

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