GDP growth: an inevitable lock-in?

Simone D’Alessandro, Tommaso Luzzati, Mario Morroni

Dipartimento di Scienze Economiche – Università di Pisa
tluzzati@ec.unipi.it

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Dou we need GDP growth? Alleged reasons

1) An increase of income per capita is regarded as a **widening of the set of choices available to individuals**. Therefore it is seen as an increase in individual freedom of choice.

2) **Equity**: a) **intragenerational**: increasing GDP reduces conflicts in income distribution, facilitates redistribution policies and the provision of public goods. b) **intergenerational**: how to cope with population ageing and the provision of pensions and social services for the elderly.

3) **Unemployment**:
   
   a) to contrast a **labour saving technical change** and avoid decreasing employment levels. If GDP increases less than productivity, the number of employees decreases possibly increasing unemployment.
   
   b) the main **Keynesian recipe for decreasing unemployment** has been the increase in the equilibrium level of income. In fact demand for labour derives from the demand for goods and services. An increase in the demand for goods and services determines a rise in employment and a consequent decrease in unemployment (if the elasticity of employment in relation to output is positive).

4) **Dynamic efficiency**: firms tend to invest in technical change, which enhances competitiveness, if they forecast an increase in demand of the goods and service they supply. GDP growth provides resources for basic research and R&D.
Non perché la crescita economica consenta di raggiungere, di per se stessa, gli obiettivi di benessere, giustizia ed equità che i politici affermano di perseguire. Ma perché, senza una crescita più sostenuta, è difficile che quegli obiettivi possano essere raggiunti in condizioni di consenso sociale ed elettorale.
No need for telling here reasons against GDP growth (after a given threshold?)!

Social costs of GDP and the breaking up of the relation between GDP & welfare

Against GDP?
Against growth?
Against growthmania?
"We will find neither national purpose nor personal satisfaction in a mere continuation of economic progress, in an endless amassing of worldly goods. We cannot measure national spirit by the Dow Jones Average, nor national achievement by the gross national product. For the gross national product includes air pollution and advertising for cigarettes, and ambulances to clear our highway carnage. It counts special locks for our doors, and jails for the people who break them. The gross national product includes the destruction of the redwoods, and the death of Lake Superior. It grows with the production of napalm and missiles and nuclear warheads . . . It includes Whitman's rifle and Speck's knife, and the broadcasting of television programs which glorify violence to sell goods to our country."

"And if the gross national product includes all this, there is much that it does not comprehend. It does not allow for the health of our families, the quality of their education or the joy of their play. It is indifferent to the decency of our factories and the safety of our streets alike. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of public officials . . . the gross national product measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country. It measures everything, in short, except that which makes life worthwhile; and it can tell us everything about America -- except whether we are proud to be Americans.
Main arguments

We model an economy that produces with funds and flows which are complementary.

(1) \( Y(t) = \min ( AK(t), e(t)E(t) ) \)

\( K \equiv \text{capital stock} \quad A > 0 \)

\( E \equiv \text{energy flow} \),

\( e \equiv \text{energy efficiency} \)

\( e > 0, \quad e \in [e_0, e_M) \), \quad e' > 0 \)
Main arguments

Our exercise starts (t=0) when the issue of exhaustion of fossil fuels enter the agenda.
Before t=0 non-renewables energy sources were largely abundant; renewables were biomasses harvested at a rate higher than the regeneration rate since the stock was large. The economy, GDP, consumption and investment, grew at positive rates, i.e. exponentially.
At t=0 our society would like to invest in renewable energy sources, both in terms of research and development and of installation of renewable energy capacity≡R.
The reason is to start replacing fossil fuels so to avoid, if possible, energy shortages when, at time t, the production of non-renewable energy will stop to have positive net energetic yield («accessible » in Georgescu terms).
How should our society invest in R?
Two polar cases, either the society takes the resources from the investment in capital (included human capital, knowledge,...) or from consumption.

**FIRST:** part of the investments in capital are diverted towards renewables.

\[ IR(t) = (1 - \phi(t)) (Y(t) - C(t)) \]

\( \phi(t) \equiv \text{quota of investments diverted to renewables.} \)

How much has to be diverted? What will be the consequences?
Since the investment in capital affects the economy growth rate, the quota destined to investments in capital should be rather high: a relatively high growth rate, will make the absolute amount of investment in R high even if this is small in relative terms, i.e., as compared to total investments.

$$\text{IR}(t) = (1- \phi(t)) (Y(t) - C(t))$$

$\phi(t) = \text{quota of investments diverted to renewables}.$

At the same time higher rates of growth will make more rapid the fossil fuel extraction, so that our society will have less time to accumulate R.

In synthesis

higher $\phi(t) \rightarrow$ higher growth in R however and $t$ close
lower $\phi(t) \rightarrow$ lower growth in R however $t$ far away
This suggests that the range of available choices of $f(t)$ is tiny, or even void.
As a consequence it might be difficult to induce investments to make the accumulated $R$ at $t$ to be enough to avoid energy shortage.
If this condition is not met, capital would become unemployed and income drop.
The amount of the energy shortage affects the long run outcome.
if the gap is small enough to make the economy to be able to replace most/all of the depreciated investments, without squeezing too much consumption, then the economy could enter a path that goes to a relatively high level of income in the long run or even enter a path of constant growth; otherwise the economy will start to decumulate and enter a path leading to a low level income in the long run.
This suggests that the range of available choices of \( f(t) \) is tiny, or even void. As a consequence it might be difficult to induce investments to make the accumulated \( R \) at \( t \) to be enough to avoid energy shortage. If this condition is not met, capital would become unemployed and income drop. The amount of the energy shortage affects the long run outcome. If the gap is small enough to make the economy to be able to replace most/all of the depreciated investments, without squeezing too much consumption, then the economy could enter a path that goes to a relatively high level of income in the long run or even enter a path of constant growth; otherwise the economy will start to decumulate and enter a path leading to a low level income in the long run.
"Installed" Capacity of Renewable Resources

% GDP in Renewables
4% GDP in Renewables
6% GDP in Renewables
2% GDP in Renewables
Why the path to sustainability is so narrow, or even non-existent?

Just because our economy choose to let the macroeconomic aggregates to grow at a constant rate in the period from 0 to t. Consumption has grown exponentially until non-renewables “end”.

Therefore, let us consider an alternative strategy, a strategy that considers consumption at t=0 as satisficing so that income growth goes entirely to finance investment in capital and in renewables. Obviously the path towards sustainability is much more wider so that it is easier to enter the path towards steady states with relatively high consumptions.
Three Different Strategies

From 2% to 10% in Few Years

Stop Growth

4% of GDP
Further specifications of our model

We assume that:

a) a **logistic learning curve exists for accumulating in R**. In other words, for low levels of accumulated investments investment in R causes low increases of R; for R sufficiently high, the return of investment increases quickly with R leading to a mature stage in which the return tends to an upper bound.

b) the accumulated investments in R depreciate at a lower rate than ordinary capital.

c) that **energy efficiency improves with time according to an exogenous logistic process**.

Under these assumptions, which are made merely because the seem plausible, the « end » of non-renewables should not be too early in order to exploit progress in energy efficiency. At the same time it is important to invest quickly enough in R in order to enter the **take off stage in R technology** before the « end » of non-renewables. For this purpose growth is important since it makes resources available for investment in R technology.

For the sake of simplicity, we assumed that exponential growth is impossible and that in the long run income converges to a **steady state** values.

Parameters used to simulate our model are set accordingly, that is, by imposing that:

a) the energy(material) efficiency is limited from above, in other words, a unit of energy cannot « produce » more than a maximum amount of GDP.

b) the investment in renewable energy has decreasing returns in its accumulation process \( f( )<1 \) in eq. 6).

Both conditions seems to us plausible.
This paper does not tackle the welfare effects of GDP growth.

Of course we are conscious that sever limits to the working of our society come from the waste-side of the story. We are at risk of poisoning ourselves in a process where consumption is not anymore welfare enhancing.

This can be used as a sound reason for policies favouring substitution of growth in consumptions with growing investments in renewables as suggested above. This would widen the narrow path towards sustainability.
THE MODEL

Goods production

(1) \( Y(t) = \min \left( AK(t), \varepsilon(t)E(t) \right) \)

\( K \equiv \text{capital stock} \quad A > 0 \)
\( E \equiv \text{energy flow}, \quad \varepsilon \equiv \text{energy efficiency} \quad \varepsilon > 0, \quad \varepsilon \in [\varepsilon_o, \varepsilon_M) , \varepsilon' > 0 \)

Capital accumulation

(2) \( \Delta K = I^K(t) - \delta^K K(t) \quad I^K \equiv \text{investment in Capital} \delta^K = \text{capital depreciation rate} \)

Energy

(3) \( E(t) = Q(t) + H(t) \)

\( Q \equiv \text{use/production of non renewable energy sources} \)
\( H \equiv \text{use/production of renewable energy sources} \)
Non renewable extraction

(4) \( Q(t) = -\Delta X(1-\alpha/X(t)) \)
where \( \alpha > 0 \) and \( \alpha/X = \) unitary physical extraction cost

\( X \equiv \) NonRenewable stock

\( Q(t) > 0 \) iff \( \alpha/X(t) < 1 \)

i.e. energy cost < energy production

from (4) \( \rightarrow \)

(4bis) \( \Delta X = -Q(t) [1+\alpha/(X(t)-\alpha)] \)

Use of renewables

(5) \( H(t) = hR(t) \) \( h > 0 \) \( R \equiv \) stock of installed capacity

(6) \( \Delta R = I^R(t) f(R(t)) - \delta^R [R(t)-R(0)] \)
\( I^R \equiv \) investment in renewables \( \delta^R \equiv \) renewables depreciation rate

(7) \( f(R(t)) = \beta + \theta / [1+ e^{\eta-R(t)}] \) \( \beta, \theta, \rho, \eta > 0 \)

\( f(R(t)) \) is a logistic function: the productivity of the investment in renewables increases logistically with the accumulated stock. The initial level of stock \( R(0) \) does not deteriorate due to the natural reproduction processes \( (R(0) \equiv \) biomass)
Behaviour

Consumption and investment:

Decision variables:

$C(t) \equiv \text{consumption}$, $\phi(t) \equiv \text{proportion of savings invested in capital}$

(8) $C(t) \leq Y(t)$

(9) $I^K(t) = \phi(t)(Y(t)-C(t))$

(10) $I^R(t) = (1- \phi(t)) (Y(t)-C(t))$

$(Y=C+ I^K + I^R)$
Production:

Technical efficiency: \( \varepsilon(t)E(t) = AK(t) \)

Efficiency attained

A) through the control of non-renewable energy FLOWS (*Short-term/myopic efficiency*), i.e.

*the economy extracts exactly the needed amount of non renewable energy, provided the stock of NRs is enough.*

\[ Q(t) = \frac{AK(t)}{\varepsilon(t)} - H(t) \quad \text{if} \quad \frac{AK(t)}{\varepsilon(t)} > H(t), \quad \text{else} \quad Q(t) = 0 \ (\text{no NRs needed}) \]

and if \( -\Delta X \leq X \), that is if \( Q < (X^{-\alpha}) \) (from eq. 4),

otherwise efficiency cannot be attained since accessible NRs are exhausted

\[ Q(t): X(t+1) = \alpha, \ i.e. \ Q = (X-\alpha)^2/X < Q_{desired} \rightarrow AK > \varepsilon E \]

B) (*long-term efficiency*) through the control of the accumulation process of both Capital and Renewable capacity (i.e. the choice of Investments and their ripartition \( \phi \)) so that

\( \varepsilon(t)E(t) = AK(t) \ \forall \ t \ (\text{even if} \ X = 0) \)
Some related references


Some related references

• GDP Growth


THANKS FOR YOUR PATIENCE!
Growth Rates for Different Investment in Renewables

Rate of Growth

Time

2% of GDP

4% of GDP

6% of GDP

7% of GDP