1 Introduction

How to organize the economy so that its environmental impact stays within the planetary boundaries is a central question of our times. A second crucial issue is how to avoid unemployment in the light of increasing labor productivity. Third, there is a debate on the merits and drawbacks of continuing economic growth in high-income countries, as empirical work shows little relation between growth and social welfare.

The main discussion, which this paper refers to, goes something like this: The economy needs to grow in order to generate a sufficient number of jobs. At the same time, growth leads to increasing environmental degradation. Hence, there is a trade-off between economic (jobs) and environmental goals.

This paper develops a model that connects the issues of environmental degradation, (un-)employment and economic growth. It uses a macroeconomic model, in which demand determines overall output and its composition. In a first step it is investigated, under which circumstances positive, zero and negative growth rates lead to decreasing environmental degradation and constant
employment. The second step examines, what conditions (particularly concerning the components of aggregate demand) need to be given for such a development.

1.1 Literature background

1.1.1 The determination of growth

The idea, that demand factors determine production in the short term is a widely accepted comprehension of the economy - which can be seen by its representation in commonly used textbooks. For example, Blanchard and Illing (2009) state “In der kurzen Frist wird die Produktion von der Nachfrage bestimmt” (p. 79). There are diverse theories of why an economy grows and what determines the size of growth in the long run though. In this paper, we follow the reasoning, that long term economic growth is a product of many (short) periods, so that short run events determine long run growth: “Trends ergeben sich nur als statistisches Resultat der vergangenen Entwicklung und folgen keiner, durch was auch immer vorgegebenen feststehenden äußeren Logik” (Heine et al., 2006, p. 20). Following this line of thought, the demand-side also determines the long run. The importance of demand-side factors has most famously been emphasized by Keynes: “the point of the aggregate demand function, where it is intersected by the aggregate supply function, will be called the effective demand” (Keynes, 2006, chapter 3, section I). Keynes argues, that aggregate supply is a function of employment. Aggregate demand is also a function of employment. If the demand is higher than current supply, firms will increase production and hence employment. This view has been further developed by a wide range of “post-Keynesian” authors. Harrod (1948) focussed on the relationship between actual and warranted growth rates. Domar (1946) developed the idea, that investments are essential for growth and that they have two effects - the capacity and the demand effect - that need to be in balance for a balanced growth path. Kaldor (e.g. Kaldor, 1957; Kaldor, 1961) elaborated in various forms on Keynesian-type growth models, in particular showing under what conditions the knife edge problem (associated with Harrod’s work) can be solved. Robinson (Robinson, 1956, ?) developed a different unique theory of growth in capitalism, also touching upon the issue of resolving the knife-edge problem. Kallecki is another author who developed growth models of similar kinds. In particular his contribution is associated with the roles of mark-up pricing and the interest rate in the growth process (??, see also Hein, 2004 for more details on Kalecki’s contributions). There are many additional authors to name and this is just a brief list of some of the important contributions to post-Keynesian growth theory, not intending to be complete.

1.1.2 Role of growth for social welfare

In economic literature, economic growth if often regarded as either a phenomena to be explained or a goal to be achieved. The reason for the desirability of economic growth depends on the particular topic at hand. It is at the very center of economic thought as well, though. Growth leads to the possibility of higher consumption and consumption is important in the determination of welfare in basically all influential welfare models. Often it is even the only determinant (see for example (Boadway and Bruce, 1984)). There are various lines of criticism on this view from other disciplines but recently it has also become an acknowledged view in the economics profession. This is mainly due to the research on subjective well-being. Many authors (e.g. Diener, 2009; Frey, 2008) come to the conclusion, that from some level of average per capita income, further growth does not increase the average welfare (or subjective well-being) of the members of the society any more. Based on these findings, in this paper, we regard economic growth solely with regard to its relation to environmental degradation and employment - and not as an end in itself.

1.1.3 Growth and environmental degradation

Decreases in environmental degradation can have three different reasons (Brock and Taylor, 2004): Changes in efficiency, scale and/or composition (of inputs or outputs). There is a vast literature on
the relationship between the scale of the economy, the environmental efficiency of the technology used and the environment. In earlier works on this issue, efficiency is due to technological developments and exogenously given (among others: AGHION et al. 1998, Brock 1977, Taylor and Copeland 1994, Forster 1973, Solow 1973, Stiglitz 1974 and many others). Another strand of literature focuses on abatement costs (Stokey 1998). Others focus on the question, what circumstances lead to technologies, that are environmentally more efficient (e.g. Acemoglu et al. 2009, Popp 2004). In this paper we focus on the composition of production and namely the composition of outputs - not of inputs.

1.1.4 Growth and employment

There are two principle factors that determine the relation between growth and employment. First, it is essential to what extend labor and other factors of production (resources, capital) are substitutable, using a given set of technologies. Here, opinions diverge. Generally speaking, neoclassically arguing models allow for substitution (Solow 1956, Acemoglu 2002, Jaffe et al. 2003, Brock and Taylor 2004) while post-Keynesian models do not (Harrod 1948, Kaldor 1957, 1961, Bhaduri and Marglin 1990, Rowthorn 1981, Dutt 1987). The second is the development and application of technology. What technology is available and what technology is applied? Different kinds of technology imply different labor coefficients (Acemoglu 2003). In many models on growth, technical change increases labor productivity. Therefore growth is needed to prevent unemployment \(^1\). In general, models mostly allow for either labor, capital and/or resource-augmenting technical change (Brock and Taylor 2005). In this paper we follow this line of argument and assume technological change, that is both labor and resource enhancing. Another interesting path of reasoning would be to open up the possibility of a different kind of technical change, that is resource-enhancing and labor-diminishing (decreases labor productivity). Such a development could be another way (contrary to the sectoral change that is used in this model), to reconcile employment, environmental sustainability and the absence of economic growth.

1.2 Reasoning of the model

1.2.1 Determination of size and composition of production

The central features of the economy are driven by the demand side. The demand side determines how much and what is produced. The components of demand are consumption, government spending and investments. The size of consumption primarily depends on households’ income. The composition of consumption is determined by consumer-decisions. It depends on consumer preferences (that can change over time) and the prices of goods. Both size and composition of government spending is regarded as an autonomous decision, made by the government. Consumption and government together determine investments. The higher consumption and government spending of a specific good, the higher the investments within this sector will be.

1.2.2 A two-sector economy

In an economy, numerous goods are produced, each with a diversity of technologies. In this paper, this complexity is simplified to two sectors with two different technologies. The sectors have different features concerning the technologies used. In one sector, production is related to a relatively high environmental impact per unit of output and high labor productivity. In the other sector, it is the other way round: production leads to relatively low environmental impact per unit of output and it has a low labor productivity. These two sectors can be interpreted in two different ways.

\(^1\)This relationship is often called Okun’s law, going back to Okun’s (Okun, 1963) analysis of the relationship between growth and unemployment. For a more recent discussion see (Knotek 2007).
• (a) In the two sectors, different goods are products. Then a shift of production from one to the other sector means a shift in what is consumed and produced. An example would be a change from the production of resource-intensive goods (such as houses, cars, electronic devices, etc.) towards services that use little resources but lots of labor (such as education, care work, art, etc.).

• (b) The two sectors stand for different modes of production, entailing different technologies. Within each sector, different goods are produced, but the production method (technology used) differs from sector to sector (but are similar within the sector). This can either take place in one part of the economy, or - as in our analysis - in all parts at the same time. This would mean, that in all parts (agriculture, industry, services, etc.), production takes place with different technologies. To make it concrete: in agriculture, there is large-scale, industrial production and small-scale, labor-intensive farming. In industry there are large factories and small workshops. In services, there are big companies with high automation and small, labor-intensive firms. Within this view, a sectoral change entails to shift from production with high labor productivity and high resource-intensity to production with low labor productivity and low resource-intensity in each sector. It is important to note, that this does not necessarily imply technological change but a different use of existing technologies.

The model works regardless of which of the two interpretations is used. In reality, it would probably be both mechanisms but for analytical simplicity, we behave as if it is only one of them.

1.2.3 Determinants of environmental degradation and employment

• Environmental degradation is determined by three factors: (1) The scale of production, (2) the environmental efficiencies in the sectors and (3) the composition of production. The idea is, that environmental degradation cannot only be reduced by increasing environmental efficiencies but also by decreasing the scale of production and/or changing from one sector to the other.

• Employment is also determined by three factors, very similar to the ones influencing environmental degradation: (1) The scale of production, (2) labor productivity and (3) the composition of production. Here the most important idea is, that employment cannot only be altered by growth and labor productivity but also by changing the sectoral composition of production. Subsequently, a stagnating or shrinking economy that goes along with a sectoral change towards labor-intensive production, can lead to constant or increasing employment.

• The connections between environmental degradation and employment: According to many models (see above), the scale of production affects both, the environment and employment. A common argument is, that economic growth generates jobs but is detrimental to the environment. The model introduces another link between (sectoral) economic growth, employment and the environment: Sectoral change also influences both, environmental degradation and employment. If one sector has a lower environmental degradation per unit of output and a lower labor productivity than the other, the growth of one sector and the shrinkage of another sector can lead to both, increasing employment and decreasing environmental degradation.

1.2.4 Intuition of the scenarios

The model depicts different scenarios, for which the conditions for decreasing environmental degradation and constant employment are investigated. In the scientific debate concerning how the economies of high-income countries can be organized so that they are environmentally sustainable and generate sufficient jobs, there are three brought perspectives. These correspond to the three scenarios below.
• Green Growth: The first is often called green growth or green new deal. It is argued, that economic growth - driven by investments in environmentally less destructive production - can lead to both, environmental sustainability and full employment. This reasoning is depicted in scenario one. In the extrem version as depicted in the model, there is no sectoral change. That means, that each sector grows with the same speed. Environmental efficiency also increases at the same speed in each sector and the same holds for labor productivity. We follow the argumentation of most authors within this strand of literature: Labor productivity increases, therefore growth is needed to obtain constant employment. In order to have decreasing environmental degradation, environmental efficiency needs to decrease faster than labor productivity increases. This story is well-known and the sectoral set up of the model does not contribute anything particularly new to it. The first scenario serves as a benchmark, against which we can investigate what changes, when we allow for sectoral change.

• Zero Growth: In the second scenario, it is investigated under which circumstances an economy with zero growth rates leads to constant employment and a decrease in environmental degradation. As in the other scenarios, increasing labor productivity and environmental efficiency are assumed in both sectors. As overall environmental degradation is the product of output (stays constant) and environmental efficiency (improves per definition), environmental degradation declines. The central issue therefore is, how constant employment can be guaranteed, under the condition of increasing labor productivity. Without sectoral change, the increasing labor productivity would lead to a decrease in employment. A gradual sectoral change from the sector with high to the sector with low labor productivity can counterweight the increases in labor productivity though. The necessary speed of this sectoral change depends on how fast labor productivity increases and how big the differences between the productivities of the two sectors are.

• Degrowth: The third scenario investigates the same question for an economy with declining production. As for zero growth, there is per definition a decrease in emissions, as production decreases and emission-intensities are assumed to improve. Regarding constant employment, there are two possibilities: (1) The overall decline in production is accompanied by a fast sectoral change. The dirty sector shrinks and the cleaner sector grows, but the shrinkage of the dirty sector is stronger than the growth of the cleaner sector. As the labor intensity of the cleaner sector is higher, this can - under specific conditions - go hand in hand with constant employment. (2) If we loosen the assumption of increasing labor productivities in both sectors, many more possible combinations of growth/shrinkage of sectors one and two can take place and lead to the targeted results.

2 Set up of the model

2.1 Definitions and assumptions

In the economy, there are two goods produced. The production of the first good has a high emissions intensity (emissions per unit of output) and a low labor intensity (hours of labor per unit of output). The production of the second good is characterized by a low emissions intensity and a high labor intensity. Emission intensities for sector one and two are given and defined as:

\[ e_1 = \frac{E}{Y_1} \]  
\[ e_2 = \frac{E}{Y_2} \]

The relation of the emissions intensities is defined as:

\[ e_1 > e_2 \]
The developments of the emissions intensities are given and defined as

\[ de_1 = de_2 = de < 0 \] (4)

Labor intensities for sector one and two are:

\[ l_1 = \frac{L}{Y_1} \] (5)

\[ l_2 = \frac{L}{Y_2} \] (6)

The relation of the labor intensities for sector one \((l_1)\) and sector two \((l_2)\) is

\[ l_1 < l_2 \] (7)

The developments of the labor intensities are given and defined as

\[ dl_1 = dl_2 = dl < 0 \] (8)

The assumption that the changes in labor intensities are smaller than zero is relaxed only in scenario 3.

Production consists of production in sector one and two

\[ Y = Y_1 + Y_2 \] (9)

### 2.2 Production

Overall production depends on the size of aggregate demand, consisting of consumption, investments and government spending.

\[ Y = AD = C + G + I \] (10)

The amount of consumption depends on the amount of income and the consumption rate. The consumption rate depends on income distribution. Government spending is autonomous. Investments depend on the size of consumption and government spending and on the capital intensity of production.

The three components of aggregate demand can all either be in good one or good two.

\[ Y = AD = C_1 + C_2 + G_1 + G_2 + I_1 + I_2 \] (11)

The division between the two goods depends on different factors for consumption, government spending and investments. The distribution of consumption between good one and two depends on preferences (that can change over time) and the relative prices of the two goods.

\[ C_{1,2} = f(P_{1,2}; preferences) \] (12)

The composition of government spending is exogenous - a political decision.

\[ G_{1,2} = f(politicaldecision) \] (13)

The division of investments depends on the respective sizes of consumption and government spending and the capital intensity of production of the good.

\[ I_{1,2} = f(C_{1,2}; G_{1,2}; k) \] (14)

with \( k_{1,2} = K_{1,2}/Y_{1,2} \)
2.3 Emissions

Emissions depend on the emissions intensities and the sizes of the two sectors

\[ E = e_1 Y_1 + e_2 Y_2 \]  
\[ (15) \]

2.3.1 Conditions for declining emissions

We start from equation \( ?? \). The total derivative shows the change of emissions \( (dE) \) due to changes in the scales of production and the emission intensities of the two sectors. Setting \( dE < 0 \) we get

\[ dE = Y_1 de_1 + e_1 dY_1 + Y_2 de_2 + e_2 dY_2 < 0 \]  
\[ (16) \]

Reformulating we get

\[ Y_1 de_1 + e_1 dY_1 < -Y_2 de_2 - e_2 dY_2 \]  
\[ (17) \]

The two sides of the equation show the changes of emissions in the two sectors. If emissions decrease in both sectors, the equation is obviously satisfied, as the left hand would be negative and the right hand positive. There are in general four factors influencing whether the condition is satisfied (the scales and emission intensities of the two sectors) and there are various possible combinations which lead to a decrease of overall emissions. In the following we investigate such relations by holding some of the factors constant.

2.3.1.1 Constant emission intensities  
With constant emission intensities, equation \( ?? \) changes to

\[ e_1 dY_1 < -e_2 dY_2 \]  
\[ (18) \]

A change in scale of one sector needs to be counteracted by a change of scale in the other sector. A change of the sector with the higher emissions intensity has a bigger impact upon employment. Hence, for example an increase of the scale of the dirty sector needs to be balanced out by stronger decrease of the scale of the cleaner sector.

2.3.1.2 Constant scales of the sectors  
With production staying the same in each sector, equation \( ?? \) changes to

\[ Y_1 de_1 < -Y_2 de_2 \]  
\[ (19) \]

An increase of one emission intensity needs to be counteracted by a decrease of emissions intensity in the other sector. The bigger the respective sector, the bigger the impact of a change of its emissions intensity.

2.3.1.3 No change in one sector  
If both factors - scale and emission intensity - in one sector stay the same, changes in the other sector determine changes in overall emissions. Equation \( ?? \) changes to

\[ Y_1 de_1 = -e_1 dY_1 \]  
\[ (20) \]

For example an increase in emission intensity needs to be counteracted by a decrease of the scale. The relative impacts of the two effects depend on the original scale and emission intensity.

2.4 Employment

The amount of employment depends on the labor intensities and the sizes of production of the two sectors.

\[ L = l_1 Y_1 + l_2 Y_2 \]  
\[ (21) \]
2.4.1 Conditions for constant employment

For employment, the basic reasoning is the same as for emissions.

We start from equation [21]. The total derivative shows the change of employment due to change in the scales of production and the labor intensities of the two sectors. Setting \( dL = 0 \) we get

\[
dL = Y_1dl_1 + l_1dY_1 + Y_2dl_2 + l_2dY_2 = 0 \tag{22}
\]

Reformulating, we get

\[
Y_1dl_1 + l_1dY_1 = -Y_2dl_2 - l_2dY_2 \tag{23}
\]

It can be seen, that the change of employment in one sector needs to counteract the change in the other sector in order to have constant employment. Changes in one of the factors can always be counteracted by changes of one of the other factors or various combinations of changes of the other factors. One example: the effect of a decrease of production in sector one (on employment) could be counteracted by an increase of the labor intensity in either of the sectors or an increase of production in sector two or a combination of such changes. The equation gets easier to interpret when holding some factors constant:

2.4.1.1 Constant labor intensities  With constant labor intensities, equation [23] changes to

\[
l_1dY_1 = -l_2dY_2 \tag{24}
\]

A change in scale of one sector needs to be counteracted by a change of scale in the other sector. A change of the sector with the higher labor intensity has a bigger impact upon employment.

2.4.1.2 Constant scales of the sectors  With scales of production staying the same in each sector, equation [23] changes to

\[
Y_1dl_1 = -Y_2dl_2 \tag{25}
\]

A change of one labor intensity needs to be counteracted by a change of labor intensity in the other sector in the opposite direction. The bigger the respective sector, the stronger the change of its labor intensity.

2.4.1.3 No change in one sector  If both factors - scale and labor intensity - in one sector stay the same, changes in the other sector need to balance each other out. Equation [23] changes to

\[
Y_1dl_1 = -l_1dY_1 \tag{26}
\]

The change in labor intensity needs to be in the opposite direction to the change in scale. The proportion depends on the sizes and labor intensity of the sector.

2.4.2 Employment with working hours

The amount of employed people \((N)\) additionally depends on the average working hours per person. We have investigated the determinants of \(L\) above (see equation [34]). We leave this part aside at this point and focus on the relationship between the development of number of people employed \((N)\), working hours \((h)\) and employment \((L)\).

\[
N = hL \tag{27}
\]

The total derivative set equal to zero gives

\[
dN = Ldh + hdL = 0 \tag{28}
\]
\[
\frac{dh}{h} = -\frac{dL}{L}
\]  \hspace{1cm} (29)

The relative change in working hours needs to be of the same size as the relative change in employment.

The (reduction of) working hours is a crucial issue, when talking about scenarios of zero or negative growth economies. In order to keep the analysis simple, it will be left out in the development of the three scenarios though. It will only be picked up again in the discussion at the end of the paper.

3 Scenarios

Based on the model as outlined above, we discuss in the following three scenarios. The first is depicted by growth in both sectors. The second has growth in one and a decline in scale in the other sector, where the growth and decline cancel each other out. The third scenario is characterized by negative growth. It is further subdivided into variation one (in which both sectors decline) and variation two (in which one sector stays the same and the other sector declines).

3.1 Scenario 1: Green Growth

Scenario 1 is a benchmark with no sectoral change, against which to compare the other scenarios. We show under what circumstances an economy with no change of the sectoral composition can develop in a manner that goes along with constant employment and a decrease of emissions. In a second step, we show how the model and the results change if we include the possibility to change average working hours.

3.1.1 Additional assumptions

As there is no sectoral change, the change of the scales of the two sectors are the same and defined as \(dY\)

\[
dY_1 = dY_2 = dY
\]  \hspace{1cm} (30)

3.1.2 Emissions

Emissions change due to changes of the scales of the two sector and the emission intensities. Recall \[31\] the change of emissions:

\[
dE = Y_1de_1 + e_1dY_1 + Y_2de_2 + e_2dY_2
\]  \hspace{1cm} (31)

Introducing the additional assumption that both sectors change with the same speed, we get

\[
(e_1 + e_2)dY < -(Y_1 + Y_2)de
\]  \hspace{1cm} (32)

Reformulating we get

\[
\frac{de}{e_1 + e_2} < -\frac{dY}{Y}
\]  \hspace{1cm} (33)

In this scenario, The change of emission intensities \(de\) is negative per definition and the sum of emission intensities \(e_1 + e_2\) is positive. Therefore the left side of the equation is negative. \(Y\) is positive. Therefore, for this equation to hold, one possible outcome would be that \(dY\) is negative. We will discuss this possibility in scenario three. Here we restrict our discussion to the case where \(dY > 0\), as that is the case of green growth. The remaining possibility is that the change of the emission intensities in each sector \((de)\) relative to the sum of the two emission intensities needs to be larger than the ratio between the change of scale of each sector and overall production.

Economic interpretation: For overall emissions to decline, emission intensities must decrease. The decrease needs to be stronger for
• higher original emission intensities.
• higher (or even negative) changes in scale of the sectors
• lower original overall production

3.1.3 Employment

Employment changes due to changes of in the scale of production and changes in the labor intensities. Assumptions are the same as before.

Equation 34 gives the change of employment

\[ dL = Y_1 dl_1 + l_1 dY_1 + Y_2 dl_2 + l_2 dY_2 = 0 \] (34)

Introducing the additional assumption we get

\[ (l_1 + l_2) dY = -(Y_1 + Y_2) dt \] (35)

Reformulating we get

\[ \frac{dl}{l_1 + l_2} = -\frac{dY}{Y} \] (36)

The denominators on both sides are positive. The change of the labor intensities is assumed to be negative (\( dl < 0 \)). Therefore, production needs to increase (\( dY \) needs to be positive) for the equation to hold. In particular, the ratio of the change in labor intensities to the sum of labor intensities needs to be the same as the ratio between the change of growth relative to overall production.

In order to keep constant employment, economic growth needs to be higher,

• for higher changes (decreases) in labor intensities.
• for lower original labor intensities.
• for higher original production levels.

3.1.4 Emissions and employment

Combining equations [33] and [36], we get

\[ \frac{de}{e_1 + e_2} < \frac{dl}{l_1 + l_2} \] (37)

In order to have full employment and at the same time a decrease of emissions, proportional change of the emission intensities need to be smaller than the proportional changes of the labor intensities. It should be remembered here, that both rates are assumed to be negative (\( de < 0, dl < 0 \)). Therefore, equation [37] infers that efficiency gains concerning emissions are faster than the gains concerning labor. Equation [36] additionally says, that labor intensity needs to change at the same speed as output changes.

Overall the following picture appears: With a given rate of change of labor intensity, output needs to rise with the same proportional speed, in order to keep the employment constant. The rate of change of emissions intensity needs to be higher than the changes of labor intensity and output in order to result at decreasing levels of emissions.

3.2 Scenario II: Zero Growth

The second scenario illustrates under what conditions a zero growth environment can be combined with constant employment and decreasing emissions.

\[ ^2 \text{We relax this assumption in scenario three, below.} \]
3.2.0.1 Additional assumptions and definitions

There is one additional assumption related to the zero growth environment. In order to achieve zero growth, the growth of one of the sectors needs to equal the shrinkage of the other sector. Therefore
\[ dY_1 = -dY_2 \]  

Additionally we define the difference between the two emissions intensities as \( e_d \)
\[ e_d = e_1 - e_2 \]  

with \( e_d > 0 \), as \( e_1 > e_2 \)

3.2.1 Emissions

Equations 31 keeps the same. Introducing the new assumption and definition, we get
\[ \frac{de}{e_d} < -\frac{dY_1}{Y} \]  

The left side is negative. \( Y \) is positive. Therefore, if \( dY_1 \) is negative, the condition is definitely given. If \( dY_1 \) is positive, it depends on the ratio between the changes in emissions intensity to the difference in emission intensities and the ratio between the change of the scale of sector one and the overall production, whether overall emissions decrease.

3.2.1.1 The real issue with emissions

As explained above, the actual goal is not to have stagnating emissions (or emissions just slightly declining) but a decrease in emissions as big as possible. Therefore, it makes sense to look at the overall development of emissions. Introducing the assumptions into equation 31 we get
\[ E_d = Yde + e_dY_1 \]  

Therefore, overall emissions decline the faster, the

- bigger \( de \) is
- the bigger the difference between the emission intensities of the sectors is
- the faster the sectoral change takes place (the faster sector 1 decreases)

3.2.2 Employment

34 stays the same, so that when introducing the additional assumption and definition we get
\[ \frac{dl}{l_d} = -\frac{dY_1}{Y} \]  

This equation is central to the second scenario. It says, that the ratio between the change of the labor intensities and the difference between the labor intensities needs to be the same as the ratio between the change of the scale of the first sector and overall production. For our scenario this means: If we have a negative development of the labor intensities (as assumed), sector one needs to shrink. The shrinkage has to be faster, the

- faster is the decline of labor intensities
- smaller the difference between the labor intensities of the two sectors
- the bigger is overall production
3.2.3 Emissions and employment

Combining equations 40 and 42 we get

\[ \frac{de}{e_d} < \frac{dl}{l_d} \quad (43) \]

Interpretation:

- in 40 the left hand side is negative but has probably a small value. in order for the equation to hold, the right hand side therefore needs to be positive or have a negative value that is even smaller than the left hand side. That means, that the scale of sector one needs to decrease or, for fast improvements in emissions intensities and/or big differences of emission intensities, may increase very little.

- looking at 42 we get clear outcomes. the left hand side is positive, so that the right hand side also needs to be positive, therefore, \( dY_1 \) needs to be smaller than zero. The higher the \( dl \) and the smaller \( l_d \) are, the faster \( Y_1 \) needs to decrease (and \( Y_2 \) needs to increase, as \( Y_1 = -Y_2 \)). In economic terms: The faster labor intensities decrease, the faster the sectoral change has to take place. If labor intensities in sector two are much bigger than the ones in sector one, the sectoral change does not need to be as fast.

- in 43 the ratio between the change of emission intensity and the difference of emissions intensities between the sectors needs to be smaller than the relation between the change of labor intensity and the difference between the labor intensities of the two sectors. that means: as the right hand side is per definition positive, this condition is always given, as long as \( de \) is negative (and \( e_d \) is positive). If \( de \) was positive, the relation between \( de \) and \( e_d \) needs to be smaller than the relation between \( dl \) and \( l_d \).

Overall economic interpretation: Given the zero growth, and decreasing \( l_1 \) and \( l_2 \), sector 1 needs to decline and sector 2 needs to grow. The faster the labor intensities decrease, the faster this change needs to take place. The sectoral change needs to be slower for bigger differences of labor intensities between the sectors. The faster the sectoral change takes place, the smaller the decreases in emissions intensities need to be in order to get declining emissions - although a higher decrease is of course still desirable. Overall emissions decline the faster, the

- bigger \( de \) is
- the bigger the difference between the emission intensities of the sectors is
- the faster the sectoral change takes place (the faster sector 1 decreases)

3.3 Scenario III: Degrowth

In scenario three we look at scenarios with negative growth rates. The scenario is further divided into two variations. In the first, both sectors decline with the same speed. In the second, one sector declines and the other keeps the same size.

3.3.0.1 Additional assumptions Overall production decreases. Therefore,

\[ dY_1 + dY_2 < 0 \quad (44) \]

3.3.1 Emissions

Using equation 31 we get

\[ (Y_1 + Y_2)de + e_1dY_1 + e_2dY_2 < 0 \quad (45) \]
3.3.1.1 Variation 1 If both sectors decline with the same speed \((dY_1 = dY_2 = dY)\), we get
\[
\frac{de}{e_1 + e_2} < -\frac{dY}{Y} \tag{46}
\]
Interpretation: If both sectors decline, the emissions intensities can actually increase and at the same time have a decrease in total emissions. Of course - as the goal is to decrease emissions as much as possible - a decrease in emission intensities is preferable.

3.3.1.2 Variation 2 If sector one declines \((dY_1 < 0)\) and sector two stays the same \((dY_2 = 0)\), we get
\[
\frac{de}{e_1} < -\frac{dY_1}{Y} \tag{47}
\]
The result is similar as before. Only that the relation between the decline of scale and the possible increase in emissions intensities (to hold total emissions constant) does not depend on the sum of the emissions intensities but the difference between them.
As we have assumed negative changes in emission intensities and scenario 3 assumes an overall shrinkage of the economy, environmental degradation will be reduced in any case.

3.3.2 Employment
Starting point is again equation \([34]\) By introducing the additional assumption, we get
\[
(Y_1 + Y_2)dl + l_1dY_1 + l_2dY_2 = 0 \tag{48}
\]
3.3.2.1 Variation 1 If both sectors decline with the same speed \((dY_1 = dY_2 = dY)\) we get
\[
\frac{dl}{l_1 + l_2} = -\frac{dY}{Y_1 + Y_2} \tag{49}
\]
This is the same outcome as scenario 1, only that here, we assume a decline and not an incline of production in both sectors. Consequently, the labor intensities in both sectors need to increase in order to keep full employment.

3.3.2.2 Variation 2 Now to the variation that one sector declines and the other stays the same. With \(dY_1 < 0\) and \(dY_2 = 0\), we get
\[
\frac{dl}{l_1} = -\frac{dY_1}{Y_1 + Y_2} \tag{50}
\]
As we assumed that sector one declines \((dY_1 < 0)\), \(dl\) needs to be positive. Therefore, also in this scenario we need an increase in labor intensities.
One can also loosen the assumption, that \(dl_1 = dl_2 = dl\). If for example, only the labor intensity in the declining sector one can change and the labor intensity in the other sector is given \((dl_2 = 0)\), we get
\[
\frac{dl_1}{l_1} = -\frac{dY_1}{Y_1} \tag{51}
\]
In this scenario, all changes take place in sector 1. The labor intensity needs to increase proportional to the decrease of production in that sector.
3.3.3 Emissions and employment

Variation one Recall equations \textsuperscript{46} and \textsuperscript{49}

We get

\[
\frac{de}{e_1 + e_2} < \frac{dl}{l_1 + l_2}
\]  

(52)

This is the same as scenario 1.

Variation 2 Recall equations \textsuperscript{47} and \textsuperscript{50}

We get

\[
\frac{de}{e_1} < \frac{dl}{l_1}
\]  

(53)

that's different! new interpretation possible!

4 Determination which scenario takes place

4.1 Scenario 1: Green Growth

Still to be written

4.2 Scenario 2: Zero Growth

The question is, under what conditions scenario two takes place. That means, how consumption, government spending and investments need to behave, in order to realize scenario two. The first and central condition for scenario two is, that \(dY_1 = -dY_2\). Therefore, we first look at, what determines \(dY_1\).

Recall \textsuperscript{11}

\[Y = AD = C_1 + C_2 + G_1 + G_2 + I_1 + I_2\]

Hence,

\[Y_1 = C_1 + G_1 + I_1\]  

(54)

and

\[dY_1 = dC_1 + dG_1 + dI_1\]  

(55)

In order to understand the role of investments, it is best to start thinking from a situation with constant production. Here, investments are exactly equal to capital depreciation. A negative change in investments therefore means, that the capital stock declines as depreciation is higher than investments. A positive change of investments means, that production and production capacity increase. Investments in sector 1 are determined by the demand for goods in sector 1, multiplied by the investment multiplier \((r)\).

\[I_1 = f(C_1, G_1)\]  

(56)

\[dI_1 = r(dC_1 + dG_1)\]  

(57)

Hence

\[dY_1 = dC_1 + dG_1 + r_1(dC_1 + dG_1) = (1 + r_1)(dC_1 + dG_1)\]  

(58)

One central condition for scenario two (as derived above) has been developed in equation \textsuperscript{42}

\[\frac{dl}{l_d} = -\frac{dY}{Y}\]

Putting \textsuperscript{65} into \textsuperscript{12} we get

\[\frac{dl}{l_d} = -\frac{(1 + r_1)(dC_1 + dG_1)}{Y}\]  

(59)
Referring back to the reasoning in scenario two (see above), we can now make more concrete statements concerning what needs to happen to achieve the zero growth scenario: Consumption and/or government expenditures in sector one need to decrease. The amount it needs to decrease depend on

- the change of labor intensities.
- the difference between labor intensities in the sectors.
- the investment multiplier.
- the overall production level.

In order to investigate how exactly consumption and government spending would need to change in order for the scenario to take place, it is most illustrative to separate the effects. Therefore we look at each factor separately (holding the other factors constant) in turn.

4.2.0.1 Sectoral change due to changes in government spending  The case of government spending is rather trivial. The change of government spending is exogenously given. Equation 59 changes to

\[
\frac{dl}{ld} = -\frac{(1 + r_1)dG_1}{Y}
\]  

(60)

All the factors that determine how much government spending needs to change have been elaborated above. Government spending needs to change according to following equation:

\[-\frac{dY}{ld(1 + r_1)} = dG_1\]  

(61)

Additionally, the change of government spending in sector one needs to be compensated by a counter-directional change in sector two. As \(dY_1 = -dY_2\), we get

\[(1 + r_1)dG_1 = (1 + r_2)dG_2\]  

(62)

An example can best explain this result: Let us assume that the investment multiplier is higher for sector one than for sector two. If government spending in sector one decreases, the counteracting increase of spending in sector two needs to bigger (\(|dG_2| > |dG_1|\)).

4.2.0.2 Sectoral change due to changes in consumption  The change of consumption is due to changes in preferences and changes in price. As changes in preferences are very difficult to include in a formal model, they are not included in the following formal analysis. I come back to the issue of changing preferences in the discussion in the conclusion though.

Let us look at the effect of one price change and under what circumstances it would lead to scenario two. If the price of goods increases, this should crowd out consumption in sector one. At the same time, it is likely to increase consumption in sector two (as there are only two sectors). The effect in sector one is described by the price elasticity of sector one and the effect in sector two is its cross price elasticity.

Sector one

\[\varepsilon_1 = \frac{dC_1}{dP_1} \]  

(63)

\[dC_1 = \varepsilon_1 \frac{dP_1}{P_1}C_1\]  

(64)

Therefore, keeping government spending constant, aggregated demand changes as

\[dY_1 = (1 + r_1)dC_1 = (1 + r_1)\varepsilon_1 \frac{dP_1}{P_1}C_1\]  

(65)
Giving us

\[ - \frac{dY_1 P_1}{l(d(1 + r_1)e_1C_1)} = dP_1 \]  

(66)

We get further detail when including the other sectors behaviour. As the price of good one increases, consumption in sector two increases. This effect is covered by the price cross elasticity \( \varepsilon_{c2} \)

\[ \varepsilon_{c2} = \frac{dC_2}{C_2} \frac{dP_1}{P_1} \]  

(67)

\[ dC_2 = \varepsilon_{c2} \frac{dP_1}{P_1} C_2 \]  

(68)

As \( dY_1 = -dY_2 \), we get

\[ (1 + r_1)dC_1 = (1 + r_2)dC_2 \]  

(69)

Putting equation 64 and equation 68 in, we get

\[ \frac{(1 + r_1) C_2}{(1 + r_2) C_1} = \frac{\varepsilon_1}{\varepsilon_{c2}} \]  

(70)

Interpretation...

4.3 Scenario 3: Degrowth

Still to be written

5 Conclusion

Major findings and conclusions

- It has been analyzed, under which circumstances economies with positive, zero or negative growth rates can have both constant employment and decreasing environmental degradation.

- The model has illustrated, that economies with zero or negative growth rates can lead to both, constant employment and decreasing environmental degradation. In order to obtain constant employment under zero or negative growth, it is necessary to have a significant sectoral change from the sector with high labor productivity to the sector with low labor productivity (or to have decreasing overall labor productivity).

- If the sector with lower labor productivity is also featured by lower emissions intensity, such a sectoral change can also support the decrease of emissions.

- For such a sectoral change to take place, in the model, either consumption or government spending needs to shift from the sector with high and to the sector with low labor productivity. Regarding consumption, this can either be due to changes in prices (which is also possible to influence by economic policy) or by a change in preferences. Government spending is a political decision. The conditions for government spending to shift are not part of the present analytical framework.
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