

The Effects of Entropy on Unemployment and Inflation

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Abstract

The study of economics looks at the way buyers and sellers interact to reach a set of agreements on prices and quantities of goods. It is assumed that the relationship between this set of agreements and actual transactions is noiseless, i.e. that the two sets are equal. Rathgeber studied the more general, and more realistic case, where there is an error rate which reduces agreed transactions to actual transactions. Using information theory we deduce that, at a given rate of change of output there is a linear inverse relationship between the inflation rate and the unemployment rate. This solves two fundamental problems in macroeconomic theory: the problem of reconciling the equilibrium principle with unemployment and the problem of reconciling theoretical money neutrality with empirical money non-neutrality. Working through the implications of the entropy effect, we determine how to control monetary economic systems to maintain stable inflation and full employment.

Keywords: Econophysics, Entropy, Unemployment, Inflation, Macroeconomics

1. Introduction

There are two fundamental problems in macroeconomics. The first problem is how to reconcile the equilibrium principle with unemployment. The equilibrium principle states that there is a negative feedback response of prices and quantities to excess supply and demand, so that excess supply and demand tend to zero and markets clear. The equilibrium principle is directly observable in everyday markets. We can perform a simple experiment to validate this. At some point in time, if we hold prices constant, we would observe increase in excess supply or excess demand. This has been directly observable in planned economies, for instance where queues clearly demonstrate the existence of excess demand.

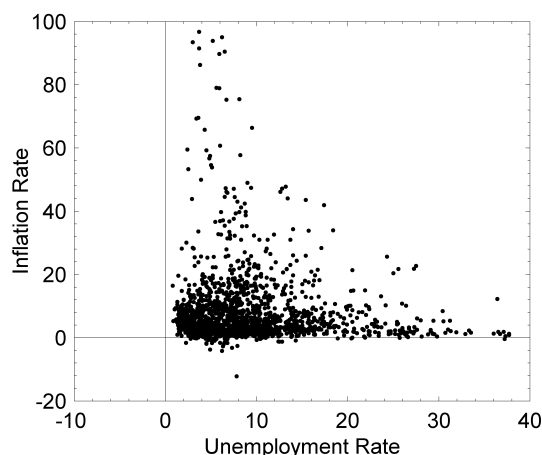


Fig. 1. Unemployment rate against inflation rate for all OECD countries 1969-2006, data from Laborsta. Historically, for these two variables, the dependent variable is plotted on the y-axis and the independent variable is plotted on the x-axis.

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The unemployment rate measures excess supply at a macroeconomic level. If the equilibrium principle holds unemployment will tend to zero. Figure 1 shows the relationship between inflation and unemployment for all OECD countries since 1969. Clearly the unemployment rate is consistently positive. Attempts to explain this mismatch between theory and data date back to at least the Ricardo-Malthus controversy [1] about 160 years ago. While Ricardo believed that the equilibrium principle held true, Malthus observed the existence of unemployment.

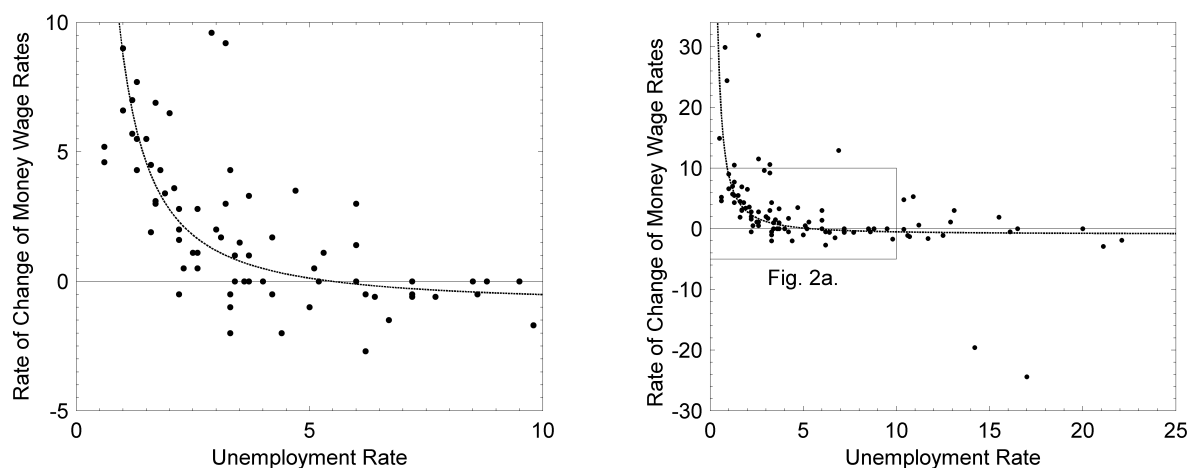


Fig. 2a. Phillips Curve for United Kingdom 1861-1957 [3]. The dotted line is the original regression curve drawn by Phillips. Fig. 2b. The same data plotted at a larger scale.



Fig. 3. Inflation rate against unemployment rate for United States 1960-1983 with sub-periods selected by Lucas [4], showing shifting inverse relationship.

The second fundamental problem was discussed by David Hume [2] about 260 years ago. He argues that theoretically since money acts only as a numeraire, increases in the quantity of money would have no real effects, resulting only in an increase in the price level. He nevertheless accepted that this did not explain why increases in nominal money quantities did in fact increase the real level of economic activity and reduce unemployment. Phillips, in his famous paper [3] argues that there exists an inverse curvilinear relationship between the rate of change of money wages and the unemployment rate for United Kingdom data spanning almost one hundred years, as shown in Figure 2. Lucas [4] presents United States data in his 1996 Nobel prize lecture showing an inverse

relationship between the inflation rate and the unemployment rate that shifts over time, as shown in Figure 3.

2. 'Natural' Rate Theory

While there is no general consensus among economists on macroeconomic theory, Milton Friedman's theory [5] stands out. His theory responds directly to the major macroeconomic problems presented above. He tries to explain the first problem by postulating, not a zero equilibrium, but a positive 'natural' rate of unemployment. He argues that this is caused by the failure of the equilibrium principle in markets at a microeconomic level. He writes that

At any moment, there is some level of unemployment which has the property that it is consistent with equilibrium in the structure of *real* wages ... The 'natural rate of unemployment' ... is the level that would be ground out by the Walrasian system of general equilibrium equations, provided there is imbedded in them the actual structural characteristics of the labor and commodity markets, including market imperfections, stochastic variability in demands and supplies, the costs of gathering information about job vacancies, and labor availabilities, the costs of mobility, and so on.

Friedman reconciles theoretical money neutrality with empirical non-neutrality by accepting that money is neutral in the long run but in the short run the slowness of quantities adjusting to changes in the price level causes an inverse relationship. Friedman's theory is represented in Figure 4.

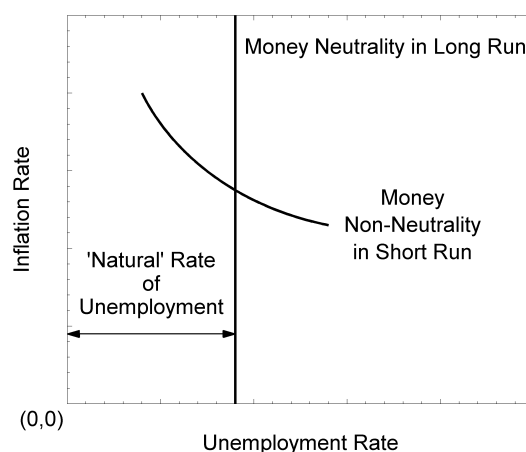


Fig. 4. Diagrammatic representation of Friedman's theory. Vertical relationship represents theoretical money-neutrality shifted the right to account for the 'natural' rate of unemployment. The oblique curve accounts for money non-neutrality.

A major difficulty is that the theory does not directly explain the causes of the 'natural' rate but passes the problem onto microeconomics. But as Robert Lucas says in his Nobel Prize lecture

So much thought has been devoted to this question and so much evidence is available that one might reasonably assume that it had been solved long ago. But this is not the case. It had not been solved in the 1970s when I began my work on it, and even now this question has not been given anything like a fully satisfactory answer.

European post-1970 increases in the unemployment rate followed by significant decreases (as we discuss later) present a very good experimental opportunity to test for causes of the 'natural' rate. Howell et. al. [6] present a careful and thorough review of econometric studies testing for possible causes of European unemployment. Table 1, simplified from Howell, who specifies the sources of econometric studies in detail, shows that cross-country econometric analysis has produced consistently contradictory results. After 40 years there is no concise explanation of the microeconomic causes of unemployment. Without an explanation of the 'natural' rate we cannot identify when the equilibrium principle holds and when it does not. It is hard to imagine how we could construct a

more fundamental contradiction in economic theory. From such a contradiction we are able to deduce any behaviour we like by arbitrarily selecting between equilibrium and non-equilibrium. We can explain anything and therefore can falsify nothing.

Table 1. Summary of implied impacts of labor market institutions on unemployment: selected studies, 1997-2005 [6].

	Employment Protection Legislation Index	Unemployment Benefit Replacement Rate	Unemployment Benefit Duration	Active Labour Market Programs	Union Density	Union Coverage	Bargaining Coordination	Taxes
Scarpetta 1996	0.37	1.3	--	insig	1.1	--	-3.07	insig
Elmeskov et al 1998	1.43	1.29	--	-1.47	insig	--	-1.48	0.94
Nickell 1997	insig	0.88	0.70	-1.92	0.96	3.60	-3.68	2.08
BGHS 2005	insig	insig	--	insig	insig	insig	insig	insig
Blanchard/Wolfers 2000	0.24	0.70	1.27	insig	0.84	insig	-1.13	0.91
Belot & Van Ours 2005	insig	-2.20	--	--	1.5	--	insig	insig
Nickell et al 2003/2005	insig	0.96	0.17	--	.30	--	-3.92	0.7
IMF 2003	0.52	0.51	--	--	2.37	--	-0.27	-0.51
BGHS 2004	insig	insig	insig	--	?	--	?	?
Baccaro & Rei 2005	insig	insig	--	--	1.02	--	insig	insig
OECD 2005	insig	1.2	--	--	insig	--	-4.97	3.00

"insig" means not statistically significant at 5% level

-- means variable not included in regression

3. Henri D. Rathgeber

In 1996 E. T. Jaynes [7] contemplated on the problems of economics. He speculates that, Millions of people combine to make a macroeconomic system whose oscillations and unstable behaviour, in defiance of equilibrium theory, leave us bewildered. ... Why is it that knowledge of microphenomena does not seem sufficient to understand macrophenomena? Is there an extra principle needed for this? Our message is that such a general principle is indeed needed and already exists, having been given by J. Willard Gibbs over 100 years ago; but it is not fully recognized in the current thinking of either statistical mechanics or economics. A macrostate has a crucially important further property (entropy) that is not determined by the microstate.

More than 20 years before Jaynes wrote these words the physicist Henri Rathgeber (1908-1995) had considered the same problem. Rathgeber's central thesis is that unemployment is caused, not by a failure of the equilibrium principle, but by noise, or increasing entropy, in the economic system. We present the economic theory of Henri Rathgeber. Rathgeber studied under Erich Regener and Paul Peter Ewald at the Stuttgart Technische Hochschule in the 1920s. He emigrated to Australia in 1939 and held the positions lecturer at Melbourne and Reader at Sydney University. He was an experimental physicist specialising in the measurement of cosmic ray intensity, with a special interest in control system design. Rathgeber was introduced to the economic writings of Silvio Gesell by his father, who was an accountant at Robert Bosch GmbH, and developed an ongoing interest in economics and in particular its connection with physics and control system design. On retirement he followed up his interest in economic research and in the early 1970s discovered his entropy explanation of unemployment. From this date he wrote extensively on the topic, engaged in correspondence and attempted to publish his results but met with considerable resistance. He unsuccessfully continued his attempts to communicate his work until his death in 1995.

4. Entropic Unemployment

The study of economics looks at the way buyers and sellers interact to reach a set of agreements on prices and quantities of goods. It is assumed that the relationship between this set of agreements and actual transactions is noiseless, i.e. that the two sets are equal. Rathgeber studied the more general, and more realistic case, where there is an error rate which reduces agreed transactions to actual transactions. We accept the equilibrium principle, at least as a first approximation, add noise or an error rate to our system, and derive an inverse linear relationship between unemployment and inflation. Given that there is an error rate, e , how can we correct for these errors?

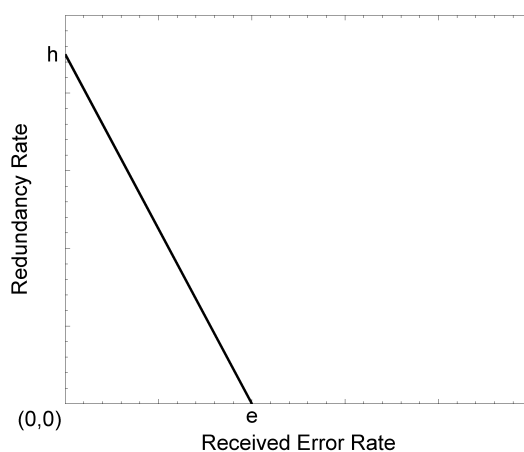


Fig. 5. Given that a message is subject to noise causing an error rate e , we can compensate for these errors by adding redundancy. It is possible to increase the redundancy rate to h so that the received message contains virtually no errors.

Shannon's information theory shows that if we want to send a message which is subject to an error rate, e , it is possible to add extra or redundant information to the message in order to reduce the received error rate. The relationship between these variables is shown in Figure 5. If we add a sufficiently high rate of redundant information, h , then it is possible to reduce the received error rate to virtually zero. If an error rate, e , reduces the set of agreed transactions to actual transactions, then given that there is some way for compensating for these errors, the received error rate determines at what rate the amount sellers agree to sell is reduced to actual sales. This is the unemployment rate. What, then, is the redundancy rate? Figure 6a shows a noiseless economy.

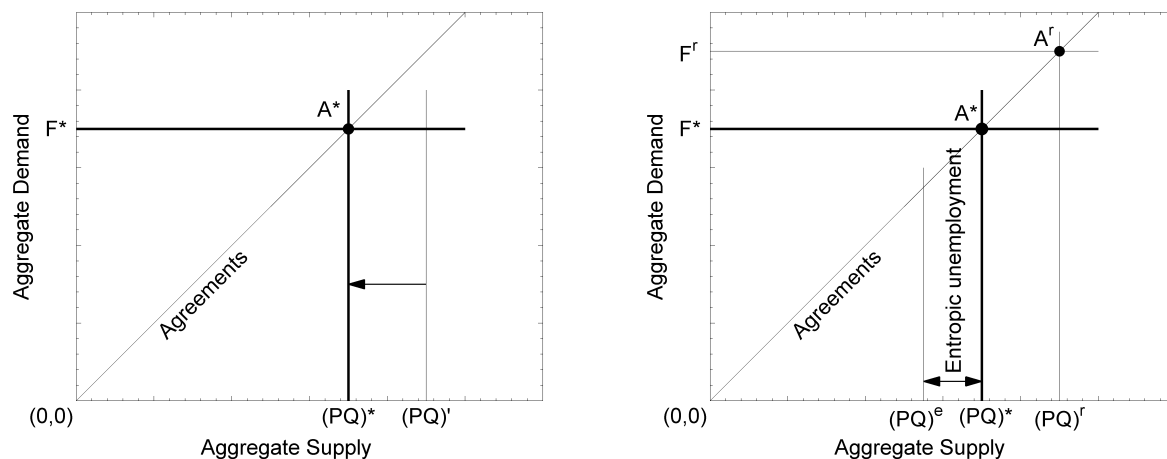


Fig. 6a. Noiseless Equilibrium. Fig. 6b. Noisy Equilibrium.

Central banks can control Aggregate Demand by changing nominal money supply, typically through open market operations, so F^* , where F stands for 'flow', is our control variable. On the horizontal axis we plot aggregate supply PQ , where P is the price level and Q is a representational basket of goods. If Aggregate Supply is at an initial position of $(PQ)'$ then there is excess Aggregate Supply and, given that the equilibrium principle holds, either P or Q or both will adjust to equilibrium where Aggregate Supply is $(PQ)^*$ and $F^* = (PQ)^*$ with agreements A^* . A similar case holds if initial Aggregate Supply is less than $(PQ)^*$. The set of agreements, A , will be the minimum of Aggregate Supply and Aggregate Demand and so will always fall on the 45 degree line. In Figure 6b, we assume that this equilibrium holds where agreements are A^* and then we add noise. $(PQ)^*$ is reduced to $(PQ)^e$ causing entropic unemployment. While sellers only want to sell $(PQ)^*$, at this level of output they face entropic unemployment. At a microeconomic level this is hidden as the failure of particular orders to result in transactions. This is adjusted for in the normal process of commerce by sellers increasing orders above the level that sellers actually want to sell, knowing that over time some orders will fail. At an aggregate level sellers can reduce this entropic unemployment by offering PQ greater than $(PQ)^*$, at say $(PQ)^r$. If these redundant transactions are agreed on by buyers, then these agreements allow for a redundancy rate in the information transmission. The rate $(PQ)^r$ is above $(PQ)^*$ is our redundancy rate. The problem is that if Aggregate Demand remains at F^* even if sellers offer redundant transactions above PQ^* the agreements will remain at A^* . The only way to increase agreements to A^r is to increase F^* to F^r . In the next time period, however, Aggregate Demand will be F^r and if the equilibrium principle holds, then aggregate supply will be $(PQ)^r$. Errors will only be compensated for with further increases in Aggregate Demand. Therefore the redundancy rate is determined by the rate of change in F . As determined previously, the unemployment rate is the received error rate. We can therefore redraw Figure 5 as Figure 8a.

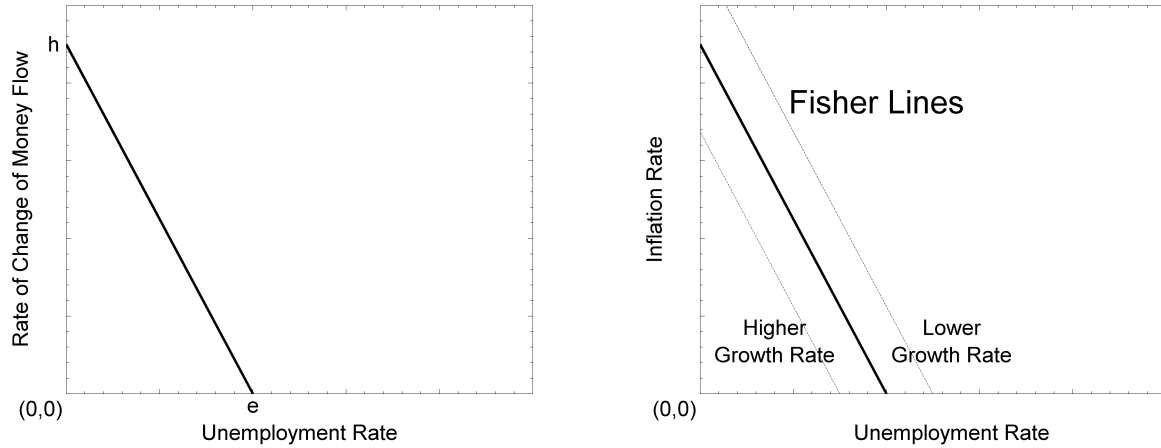


Fig. 8a. Unemployment as a function of rate of change in money flow. Fig. 8b. Unemployment as a function of inflation rate.

By considering the effects of entropy and assuming that the equilibrium principle holds, we have shown that the unemployment rate is positive even if the equilibrium principle holds, solving our first fundamental macroeconomic problem. Also, increases in the nominal flow of money result in decreases in unemployment, solving the money neutrality problem. We now reformulate the changes in flow of money in terms of the inflation rate and rate of change of output. Writing $F=PQ$ in terms of rates of change

$$\frac{1}{F} \frac{dF}{dt} = \frac{1}{P} \frac{dP}{dt} + \frac{1}{Q} \frac{dQ}{dt}$$

The rate of change of flow is equal to the sum of the inflation rate and the growth rate in output. Plotting unemployment against the inflation rate, we arrive at a series of inverse linear relationships between inflation and unemployment for given growth rates, as shown in Figure 8b. We will call these lines Fisher lines, after Irving Fisher who was the first to publish empirical evidence of this relationship in 1926 [8]. By assuming that prices and quantities adjust to macroeconomic equilibrium and introducing entropic unemployment we have solved our two fundamental problems. In a noiseless, 'perpetual motion' economy if Aggregate Demand is equal to Aggregate Supply, markets will clear. Such a system, however, does not exist and the friction in an economic system means that it is only possible for markets to clear if Aggregate Demand is sufficiently greater than Aggregate Supply. Increases in money flow increase Aggregate Demand over Aggregate Supply and compensate for the friction that causes unemployment. The cost overcoming this friction is price inflation.

5. Inflation Feedback

We now examine an instability in the position of the Fisher line. If C is firm's nominal costs, W is nominal wage costs, i the interest rate, and K nominal capital costs, then

$$C = W + iK$$

If the interest rate i is constant, an increase in the inflation rate, will cause C , W and K to rise proportionally so that there is no change in real costs. However, because a component of the interest rate compensates for the expected inflation rate, it will not remain constant but increase in response to increases in the inflation rate. An increase in the inflation rate will therefore cause capital costs to increase faster than the inflation rate, causing real costs to increase. Profits will create a constraint on this condition and at some point the growth rate must decrease as profits

fall and some production becomes unprofitable, causing a right-shift in the Fisher line such as shown in Figure 9a.

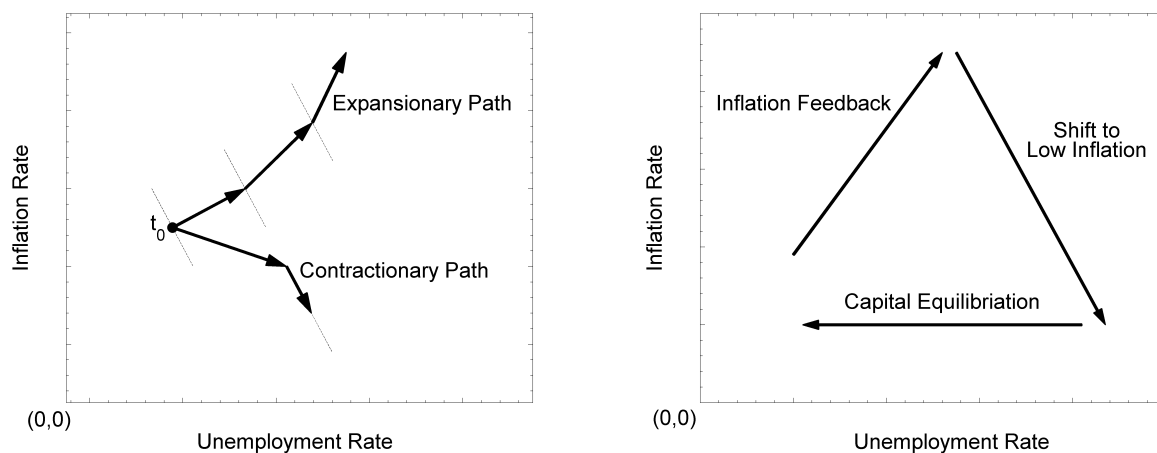


Fig. 9a.. Expansionary monetary response causing inflation feedback. Fig. 9b. Diagrammatic inflation feedback cycle.

If central banks respond with an expansionary policy this will cause further increases in the inflation rate which then feeds back into the interest rate, causing a positive feedback instability. Expansionary economic policy results in right-shifts of the Fisher line and rapid increases in both the inflation and unemployment rate, as experienced in the 1970s. A contractionary policy, with decreasing inflation rates results in a relatively stable Fisher line. Figure 9b gives a generic view of inflation-feedback and post inflation-feedback events. If central banks respond to inflation feedback with a shift to low inflation-targeting monetary policy then we see a shift along the Fisher line resulting in decreased inflation rates but further increases in the unemployment rate as seen in the 'shift to low inflation'. Firms are now locked into contracts with high interest rates, and so the return to pre-feedback growth rates will be constrained until these contracts are paid off. We see a slow increase in growth rates and decrease in the unemployment rate at low inflation rates, as shown as 'capital equilibration' until economies return to capital equilibrium in the sense that payments on contracts are close to present interest rates.

6. Evidence

We now examine the consistency of theory to evidence. The error rate, e , and the compensation rate h , should be relatively constant. If changes in the inflation rate (controlled by central banks) are sufficiently large, and the growth rate is relatively constant then we would expect to observe Fisher lines. Lucas, in his Nobel prize lecture in 1996 suggests that there are short-run inverse relationships between unemployment and inflation in the periods 1960-1969, 1970-1973, 1974-1979 and 1980-1983 in the United States. Plotting the periods Lucas selects in Figure 6, we find three Fisher lines with remarkably similar slopes. As the inflation rate increases from 1972 to 1973, inflation feedback develops and the Fisher Line shifts to the right between 1973 and 1974. The Federal Reserve reacts to increases in inflation with contractionary policy, ending the inflation feedback, however the period 1976 to 1979 sees a reversion to expansionary policy and feedback sets in again until 1980. A clockwise loop can be observed between 1974 and 1979 which can be observed across many countries, due to the connection between changes in the inflation rate and shifts of the Fisher line. From 1980, the Federal Reserve adopts a strong contractionary policy and inflation targeting, resulting in a shift along the Fisher line, causing further increases in the unemployment rate, between 1980 and 1983. After 1983 the unemployment rate slowly decreases due to capital equilibration at a low inflation rate. This shift continues to until 2000, where the United States economy returns to a stable position of low inflation and entropic unemployment.

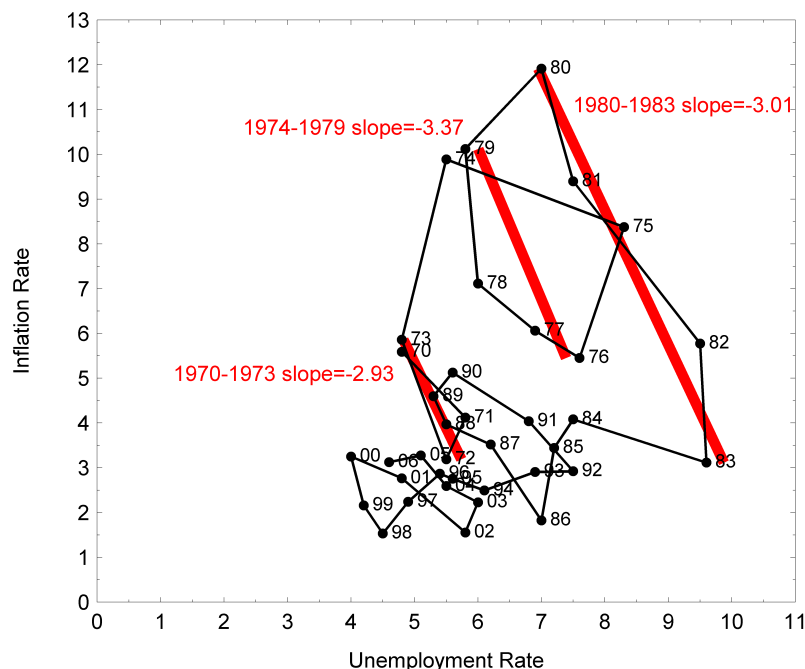


Fig. 10. Unemployment against inflation for United States 1970-2006, showing Fisher lines according to sub-periods selected by Lucas [4].

A similar picture can be observed in Australia, with inflation feedback between 1970 and 1975, decreases along the Fisher Line between 1975 and 1995, including a intermediate change in central bank policy between 1978 and 1986 until low inflation was reached in 1992. Capital equilibration causes slow decreases in unemployment until the present. Australia now remains in a relatively stable state, with unemployment and inflation similar to the United States. In Norway the central bank introduced strong contractionary policy in 1981, before Norway could experience increasing unemployment due to inflation feedback. Between 1981 and 1993 a Fisher line is observed, resulting in 1992 in an unemployment rate that was still relatively low compared to the United States and Australia. From this time a slow shift to an unemployment rate similar to United States and Australia of around 4 or 5 percent is observed. On the other hand, Figure 11 shows that Ireland experienced strong inflation feedback so that after inflation targeting was introduced, the unemployment rate was above 17 percent in 1986. Subsequent capital equilibration was correspondingly strong leading to an a similar position of low inflation and an unemployment rate of around 4 or 5 percent from 1999. Figure 13 shows the consistency in decreasing unemployment in European countries, when the time-scale is indexed to the first post-inflation feedback year. Such a consistent pattern of capital equilibration across countries, converging to a similar unemployment rate, is difficult to explain from the point of view of the natural rate hypothesis. The natural rate hypothesis explains unemployment as a function of market conditions specific to each country. Typically, explanations of changes in unemployment are explained as the result of different market conditions for each country and therefore cannot explain a general decrease across countries. Not only do decreasing unemployment rates support our theory, but also the way they have been decreasing. Countries with high initial unemployment rates have been decreasing faster than countries with initial low unemployment rates, converging to similar unemployment rates.

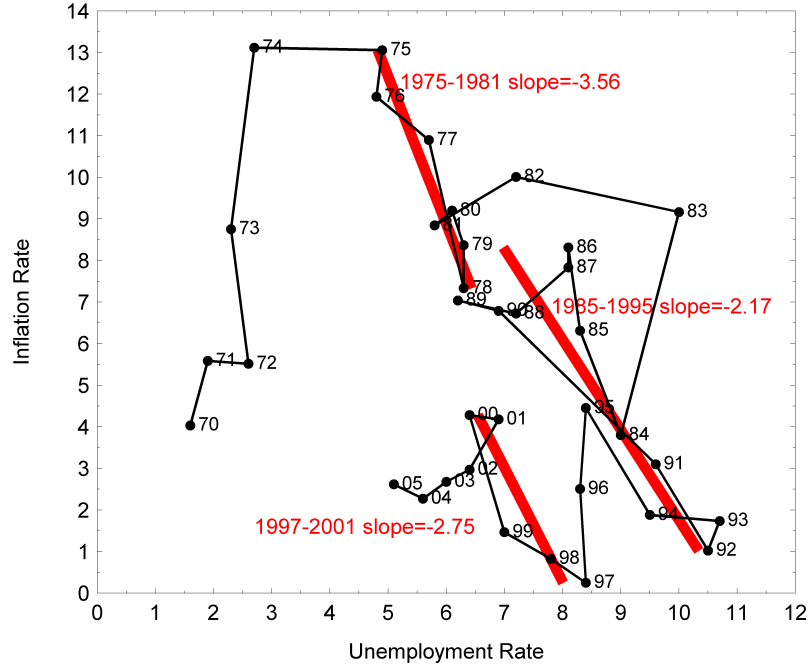


Fig. 11. Unemployment rate against inflation rate for Australia 1970-2005, showing Fisher lines.

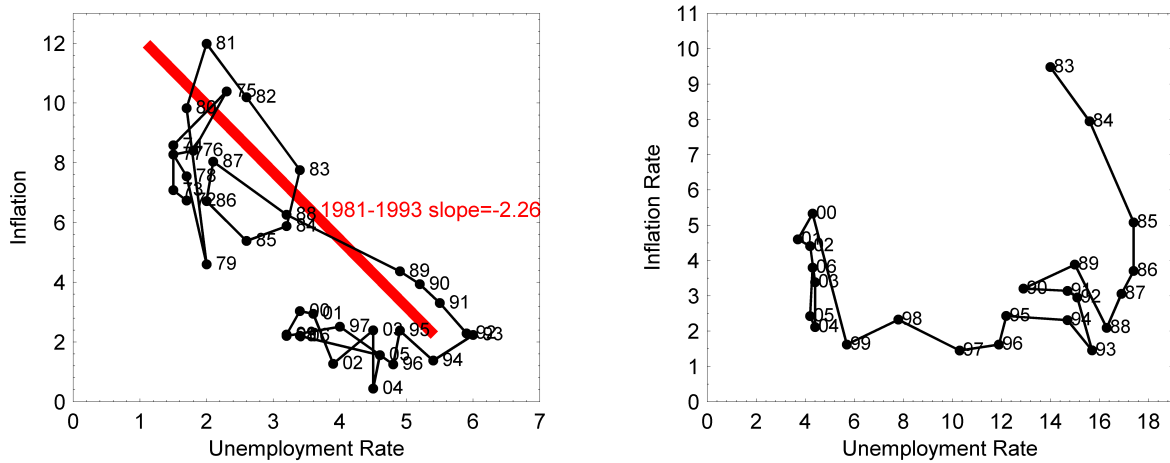


Fig. 12a. Unemployment and Inflation, Norway 1972-2006. Fig. 12b. Unemployment and Inflation, Ireland 1983-2006, showing convergence to an unemployment rate between 3 and 6 percent.

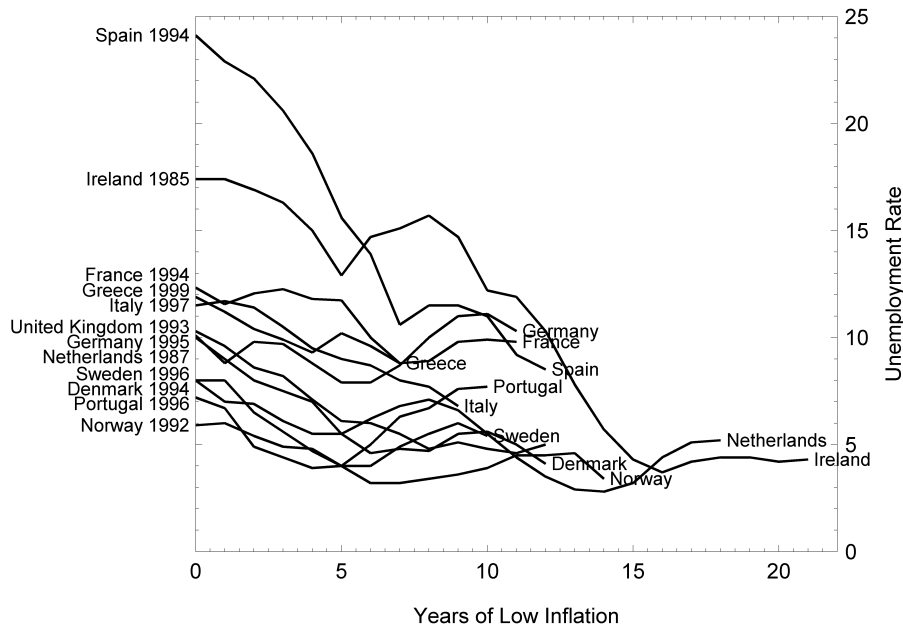


Fig. 13. European unemployment rates indexed from first post-feedback year, showing the pattern of convergence to an unemployment rate of 3-6 percent.

7. Comparison of Friedman and Rathgeber's Theory

Rathgeber's theory shows that unemployment is caused by entropy. Since a major difficulty with Friedman's theory is to explain a 'natural' rate of unemployment, can we consider Rathgeber's theory as an extension of the Friedman model? If we reconsider Figure 4, we can see that Friedman's diagram consists of three constructions. Firstly, the 'natural' rate of unemployment defines a positive unemployment rate. Secondly a vertical long-run relationship between unemployment and inflation explains theoretical money-neutrality and a short run inverse relationship between unemployment and inflation explains an empirical relationship. If we were to use Rathgeber's theory to explain the natural rate, then we would be able to dispense with the last two of Friedman's constructions which Rathgeber's theory automatically explains. Essentially Friedman explains three phenomena with three constructions, Rathgeber explains the three phenomena with one. Rathgeber's theory explains the pattern presented in the European unemployment rate, as shown in Figure 12, while a 40 year effort to explain the 'natural rate' has resulted in inconclusive if not contradictory data as shown in Table 1. The lack of a good explanation of the 'natural' rate leaves economists unable to distinguish between equilibration processes and non-equilibration processes, introducing a contradiction at the most fundamental level of macroeconomic theory.

8. Full Employment

The theory illuminates the problem in achieving full employment. We are able to select points along the Fisher line through central bank open-market-operations. Figure 14a shows that at low inflations, the selection is stable, even if the Fisher line shifts from left to right depending on variations in the growth rate. At full employment selections, however, the Fisher line consistently shifts to the right, resulting in high inflation and unemployment. A full-employment selection, if adhered to, would result in hyperinflation.

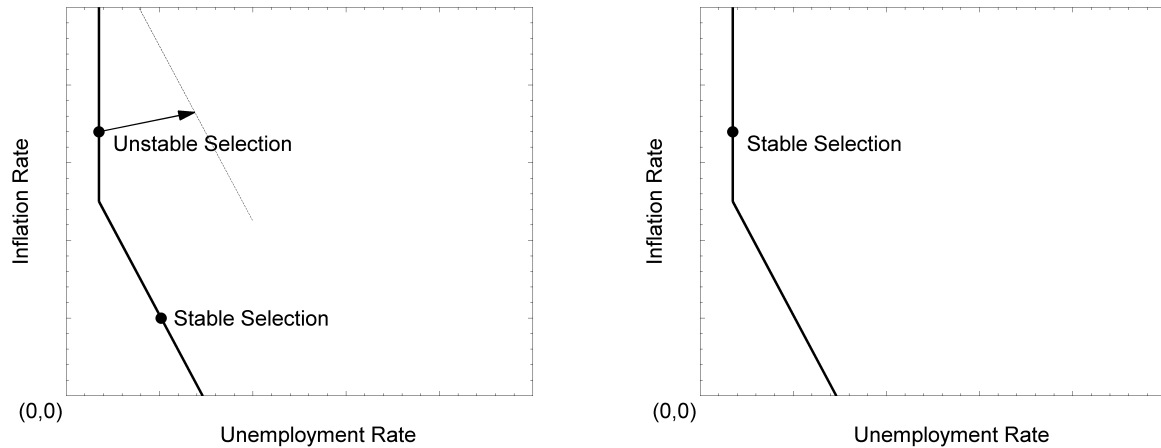


Fig. 14a. Stable and unstable unemployment/inflation choices, under non-indexed scenario. Fig. 14b. Stable unemployment/inflation choices under an indexed unit of account scenario.

Economists such as Jevons [9], Alfred Marshall [10] and more recently Robert Shiller [11] in a chapter entitled *'New Units of Measurement'* have investigated what is called an indexed unit of account. Currency is written into contracts in a unit of account so that when payments are due, the value in contracts is converted using a measure such as the CPI into a value independent of the inflation rate. In this way, the real value of payments is determined regardless of any changes in the price level. Such an arrangement is used in Chile and is called the Unidad de Fomento. If all contracts are written in an indexed unit of account, then the inflation component in the interest rate is eliminated, the inflation feedback process becomes non-existent, and it is now possible to select any points as shown in Figure 14b. The introduction of an indexed unit of account results in the possibility of central banks controlling for stable full employment. While the solution to unemployment is relatively simple, it reflects a deeper control system design problem. It is common knowledge that money performs at least two functions. It functions to organise the exchange economy as a unit of currency but also functions to organise the capital economy as a unit of account. Introducing an indexed unit of account, and thereby increasing the degree of independence between the two functions, acts to decouple the two functions and allow for the independent control.

9. Conclusion

We approximate economic social behaviour at a macro-level as conforming to the equilibrium principle. We then introduce the physical law of entropy into economics in the form of noise or an error rate. Using information theory we deduce that, at a given rate of change of output there is a linear inverse relationship between the inflation rate and the unemployment rate. This relationship gives us a foundation for further exploration. We find a positive feedback process where increases in the inflation rate, cause increases in interest rates, increases in real costs and decreases in the growth rate. If monetary authorities react to these conditions using expansionary policy this creates a positive feedback cycle through further increases in the inflation rate causing increases also in the unemployment rate. Under these conditions, high inflation rates cause further increases in inflation, meaning that the most stable policy is a low inflation target, resulting in a positive entropic unemployment. By introducing an indexed unit of account, we break the link between the exchange and capital function of money, also breaking the positive feedback cycle of increasing inflation rates and interest rates. This allows the rate of increase in money flow to be controlled in such a way as to maintain stable full employment at a stable inflation rate.

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