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The macroeconomics of Trygve Haavelmo

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Halvor Mehlum and Jon Vislie

Introduction

In December 2011 the Department of Economics, University of Oslo, hosted a symposium to commemorate Nobel Laureate Trygve Haavelmo, on the occasion of the centennial of his birth. The program was made up of eminent scholars giving presentations related to Trygve Haavelmo's contributions to econometrics and economic theory.

Trygve Haavelmo was awarded the Nobel memorial Prize in Economics in 1989 for his seminal contributions to the foundation of modern econometric theory. His numerous publications on econometrics from 1930-40's are well known to the international community. A selection of the symposium presentations on econometrics and econometric methodology will appear in a special issue of Econometric Theory. Beyond econometrics, Haavelmo made a lot of interesting contributions to economic theory. The present volume of Nordic Journal of Political Economy contains the symposium contribution related to these other contributions.

Well known to the profession is his book "A Study in the Theory of Economic Evolution", from 1954. This was a predecessor on neoclassical growth theory, rent seeking, international inequality and migration. Kalle Moene in his contribution to the present volume combines some of Haavelmo's ideas related to rent seeking and institutional quality, and their consequence for uneven development. In his other well-known book from 1960, "A Study in the Theory of Investment", Haavelmo builds a complete investment theory, from basic principles and distinguishing between flow and stock variables, incorporating not only demand for capital, but also the supply of investment goods. In this book he outlines some important consequences for the macroeconomy and macroeconomic modelling, inpsired by both Wicksell and Keynes. In fact, macroeconomic theory caught Haavelmo's attention and thinking during all the years he was teaching at the University of Oslo. Some of these ideas are unfortunately not well known because they appeared in lecture notes in Norwegian. Therefore we decided to publish a translated version of a paper by Haavelmo, published in 1956 in a Festschrift in honor to Erik Lindahl, so as to give some flavour of Haavelmo's ideas. In the present volume some of the macro material of Haavelmo is further elaborated in one article by André K. Anundsen, Tord S. Krogh, Ragnar Nymoen and Jon Vislie, and one by Sheetal Chand. These papers are mainly discussing the interaction between monetary policy and the business cycle.

The year before Haavelmo went to USA, was spent in Århus, Denmark, in 1938-39. Niels Kærgård tells a story about the economic profession in Scandinavia at that time, and especially the influence Haavelmo had on macroeconomic thinking at the University of Århus, and perhaps vice versa.

Another issue occupying Haavelmo's mind for years, until his death in 1999, was the tension between population growth, economic progress and environmental quality. It is no exaggeration to say that Haavelmo was very pessimistic as to the future development. Rapid population growth and too high rate of growth in consumption per capita and energy consumption, would lead to environmental degradation and severe welfare loss. This issue is further discussed by Michael Hoel and Bjart Holtsmark.

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The macroeconomics of Trygve Haavelmo*

Abstract

Haavelmo's "A study in the theory of investment" from 1960 is a tour de force in macroeconomic theorising. His later offerings in this area are less known outside Norway. In this paper, we present his models of business cycles (crises) and inflation dynamics. The business cycle model generates cycles as an endogenous outcome of the mismatch between the return to capital and investors' required rate. Haavelmo approached inflation dynamics from two different perspectives: First, in the spirit of Knut Wicksell, he included a "cumulative process" into his business cycle model. His second formulation is related to conflict theories of inflation.

Keywords: *Haavelmo, Business Cycles; Inflation; Investments; Monetary Policy.*

JEL classification: *E22, E31, E32, E44.*

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1 Introduction

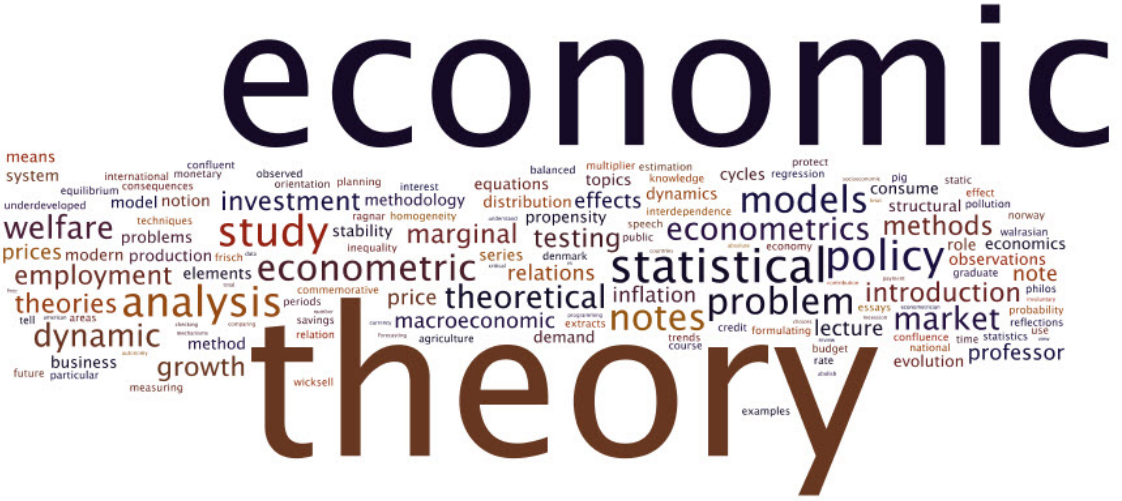
The recent financial crisis has lead to a debate about the limitations of current macroeconomic models. Some will also claim that it is time to reconsider our perception of "macroeconomics and reality". In this paper, we present some of Trygve Haavelmo's macroeconomic theories, which we believe provide several insights that can be a useful reference point for a discussion of what type of changes may be needed to redevelop macroeconomics as a discipline focusing on what seems to be an inherently unstable economy.

Trygve Haavelmo is widely known for his contributions to econometric theory, for which he was also awarded the Nobel Memorial Prize in Economic Sciences in 1989. What is less known, especially to the international audience, is his contributions to economic theory, and in particular his macroeconomic theorising. As Figure 1 illustrates, economic theory was indeed a dominant topic in Haavelmo's research output. In this figure, the size of each word is proportional to the frequency of its use in the titles of Haavelmo's publications in English and Norwegian. The impression we get is that, even though econometrics and statistics make up a very important part of Haavelmo's research output, the two words *economic* and *theory* are the most frequently used words in the titles of his publications. One reason why many of his contributions to economic theory is less known internationally is that much of this work was only published in Norwegian – important exceptions are of course his work on growth and evolution (Haavelmo, 1954) and investment theory (Haavelmo, 1960). With interest to the intellectual history of economics, this is in itself a good reason to make his theoretical insights accessible in English. That said, it is part of our motivation that his work in macroeconomics has more than just a pure historical interest. Our study complements the excellent paper by Moene and Rødseth (1991), which surveys Haavelmo's non-econometric work more broadly.

Haavelmo wrote at the high tide of Keynesian fiscal policy activism and he lived in a country known for economic planning and strictly regulated credit markets. Against this background, it may seem surprising that we claim that Haavelmo wrote anything of interest for today's macro economists. The reason why we still think his work has relevance for the modern economist, stems from the fact that Haavelmo studied the role of monetary policy in models where markets are assumed to be completely liberalised and where firms and households in important respects behave in accordance with the classical theoretical paradigm. Thus, even though Haavelmo formulated theories that may have seemed farfetched and of little relevance for the practically oriented economists of his day, his macroeconomic theory now represents a perspective that is surprisingly relevant for modern capitalist economies. In particular, it questions the possibility of stabilising economies with liberalised credit markets – a question that mainstream macro economists hardly asked before the financial crisis. As the following quote by Robert Lucas demonstrates, there was instead a renewed confidence that – thanks to the progress in macroeconomic research – business cycles of any seriousness was a thing of the past:

> [M]acroeconomics [...] has succeeded: Its central problem of depres-

Figure 1: A word cloud of the titles of all published papers and lectures of Trygve Haavelmo



Source: http://www.sv.uio.no/econ/om/tall-og-fakta/nobelprisvinnere/haavelmo/Published%20Works2/ and www.wordle.net

> sion prevention has been solved, for all practical purposes, and has in fact been solved for many decades. Lucas (2003, 1)

The interaction between financial markets and the real economy was of particular concern to Haavelmo, who considered a hypothetical world in which market forces were allowed to operate freely. Because this hypothetical alternative has become a realistic description of the way most modern economies are organised today, Haavelmo's theories are more relevant today than at the time when they were presented. In addition, the fact that Haavelmo was theorising with this hypothetical world in mind, makes it easier to compare his theories to modern developments in theoretical macroeconomics.

Haavelmo's understanding of the linkages between the real economy and the financial markets was inspired by the writings of Knut Wicksell, see Wicksell (1898, 1906). His analysis of monetary theory can be seen as complementary to the arguments made by Wicksell, that led to his famous cumulative process. This is concisely presented in Chapter 33 of the book "A Study in the Theory of Investment" (Haavelmo, 1960). In addition to his book on investment theory, the best source to Haavelmo's business cycle model is "Orientering i makro-økonomisk teori" ("A Study in Macroeconomic Theory "), Haavelmo (1969), henceforth SMT. This book was on the reading list for several generations of Norwegian economists, but was unfortunately never completed as a textbook in English.

By taking into account the dual role of capital as both a factor of production and an investment object in the financial markets, Haavelmo showed how a *fundamental overdeterminacy* will arise if the monetary authorities choose to use the rate of interest as a policy instrument. This overdeterminacy is due to the properties of standard arbitrage conditions for the agents' portfolio decisions.

Equilibrium in the financial market requires that the real interest rate and the rate of return on capital satisfies Haavelmo's "law of indifference in the capital market". However, capital is also used in the production process. Equilibrium in the capital market requires that the actual and required return coincide. Thus, if the central bank interferes in the interest rate determination and sets an interest rate that does not lead to equality between the actual and required return to capital, the model does not have a unique solution. Thus, an autonomously set interest rate will make the model logically inconsistent (overdetermined).

Haavelmo formulated a logically coherent model by assuming that private sector investment behaviour depends on the discrepancy between the required return to capital in the financial market and the actual return in production. When this investment response is integrated into a macroeconomic model, abrupt endogenous cycles with deep recessions and booming periods are generated. Thus, Haavelmo's model has as an inherent feature that economic cycles arise endogenously from a mismatch between the two rates of return, which is in contrasts to modern macro models, which rely on exogenous shocks to create business cycles.

As we shall see, the price level is assumed fixed in his business cycle model, but Haavelmo was also concerned with how the inflation process is generated, and provided several interesting insights on this topic in a series of lectures he held in the 1950s and the 1970s. After the Second World War, price stability was put up as one of the main policy targets in Norway, along with full employment. During this period, there were both price and wage controls, and rationing of most commodities. Because Norway had a fixed exchange rate regime, full employment could be achieved only by controlling prices and wages. During the 1950s, the system with rationing was gradually abandoned and price controls were relaxed, but in order to reach full employment, price stability (or low inflation) was still deemed necessary.

After being employed as a Professor of Economics at the University of Oslo in 1948, Haavelmo was asked by Ragnar Frisch to take responsibility for the advanced teaching in economic theory. Upon this request, Haavelmo initiated a teaching-program that for years was strongly influenced by the economic challenges related to the Norwegian economy. His lectures in 1951-52 on "Dynamic Price Theory" can be seen as a response to the policy issues mentioned above. Later – in the 1970s – when "stagflation" was the big challenge, he returned to this topic in his lectures. The lectures he held in the 1950's are summarised in Thalberg (1952), while Qvigstad (1975) covers his later lectures on the same topics. To the modern reader, it is evident that he sketched a conflict theory of inflation, which preceded econometric models built around the concepts of monopolistic competition, wage bargaining, equilibrium correction and cointegration (see Bårdsen et al. (2005) and Bårdsen and Nymoen (2009) for an operational model of this kind).

We continue our journey into Haavelmo's macroeconomic theorising in the following way: The next section defines "the law of indifference in the capital markets", which is an equilibrium condition between the rate of return to capital in the financial markets and the money market interest rate. We follow up with a discussion of Haavelmo's concept of a fundamental overdeterminacy that arises

if the money market interest rate is set autonomously. Thereafter, we present his business cycle model, which generates endogenous cycles driven by a mismatch between the two rates of return to capital. His theoretical contributions to the understanding of inflation dynamics are then discussed, while the final section concludes.

2 The Law of Indifference in the Capital Market

A recurrent issue in Haavelmo's work is how an unregulated capital market will affect private investment activity and macroeconomic stability. As was the case in most Western economies, the Norwegian capital market was heavily regulated for a long period of time after the Second World War.[1] Even long before full deregulation had taken place, Haavelmo outlined a monetary theory and its policy implications within a deregulated and decentralised context. Most intriguing is his fundamental overdeterminacy arising in a model where a monetary authority imposes additional constraints on the money market rate of interest. To see more closely what Haavelmo had in mind when he referred to this fundamental overdeterminacy, we present what Haavelmo would have referred to as a "skeleton" model; a model that is simplified to concentrate on the basic logic of the main argument.[2]

Consider a closed economy with a private sector and a monetary authority (representing the entire banking industry as well as the Central Bank). The private sector consists of households and capital owners that rent real capital to producing firms. At any point in time, the private sector has a given nominal wealth, W, and has borrowed an amount, L. The sum of available resources ($W + L$) can be held in cash (as deposits, M, in the banking sector) or invested in real capital, with a nominal value pK.[3] During a short time span, the stock of capital is large relative to the flow of new investments, and is therefore regarded as fixed in the short run. The banking sector's balance sheet requires loans (L) to be fully backed by deposits (M), and the following relations have to be satisfied:

$$W = pK + M - L \tag{1}$$

$$M = L \tag{2}$$

We treat the private sector as one agent with well-defined preferences over different portfolio profiles. Real capital earns a return r_K when capital owners are renting equipment to private firms. Money holdings in the form of deposits give a return equal to the money market rate of interest, i. We introduce real money holdings, $\frac{M}{P}$, along with an aggregate measure of the general level of activity in the economy, Y, which can be interpreted as a measure of GDP. The preference function is assumed to be:

[1] For a description of the deregulation process in Norway, see Krogh (2010).

[2] The model presented in this section is based on Chapter 23 in SMT.

[3] K is a physical measure of the stock of real capital at some point in time, while p is a measure of the price level.

$$V\left(K, \frac{M}{p}, \frac{L}{p}; \frac{W}{p}, r_K, i, Y\right) \tag{3}$$

where the choice variables are $\left(K, \frac{M}{p}, \frac{L}{p}\right)$, and the exogenous variables are given by $\left(\frac{W}{p}, r_K, i, Y\right)$.[4] The private sector maximises (3) given the wealth constraint represented by equation (1). For given values of the four-tuple $\left(\frac{W}{P}, r_k, i, Y\right)$, the solution to the optimisation problem results in standard demand functions for capital, loans and deposits of the following kind:

$$K^* = k\left(\frac{W}{p}, r_K, i, Y\right) \tag{4}$$

$$\left(\frac{L}{p}\right)^* = l\left(\frac{W}{p}, r_K, i, Y\right) \tag{5}$$

$$\left(\frac{M}{p}\right)^* = m\left(\frac{W}{p}, r_K, i, Y\right) \tag{6}$$

In equilibrium, with Y and p given, and (1) and (2) satisfied, we automatically have $pK = W$. Hence, we end up with a single equilibrium condition, which can be expressed as:

$$m(K, r_K, i, Y) = l(K, r_K, i, Y) \tag{7}$$

This condition defines an equilibrium relationship between the two rates of return, which Haavelmo refers to as the law of indifference in the capital markets. Consider first the case where – using Haavelmo's formulation – the monetary policy is *passive*, i.e. no attempt is made by the monetary authorities to use the interest rate as a policy instrument. In this case, the money market rate of interest, i, is endogenously determined, so that (7) is satisfied.

Alternatively, consider the case of an *active* monetary policy, e.g. when i is used by the monetary authorities to achieve some nominal target. For a given money market interest rate, equation (7) defines a particular value of r_K, denoted r^*. This is the rate of return required by capital owners to be willing to hold the existing stock of real capital at the prevailing interest rate level. In the case of an active monetary policy, it is convenient to let (7) define r^* as:

$$r^* = f(i; K, Y) \tag{8}$$

[4] Patinkin (1956) formalised similar preferences by incorporating real money balances in the preference function. One might say that (3) captures the Pigou and Fisher effects, as discussed by Tobin (1980).

3 Fundamental Overdeterminacy

Will the required rate of return, r^*, defined by (8) be compatible with macroeconomic stability, i.e. a stable flow of private investments, smooth private consumption and high employment? To realise that the answer is "No" is crucial to the understanding of Haavelmo's ideas. The heart of the matter is how the various interest rates are determined. When considering a classical model, where agents make portfolio decisions according to the description in the previous section, Haavelmo focused on a simple, yet crucial point. Equilibrium in the asset market requires (7) to hold. At the same time, capital equipment, K, is owned by households and rented by firms to produce output according to an aggregate macro production function $\phi(K,N)$, where N is aggregate employment. With a depreciation rate, δ, a wage level, w, and a price of renting one unit of capital, r_K, profits are given by:

$$\phi(K,N) - (\delta + r_K)K - wN$$

Maximising profits with respect to capital, we find that:

$$r_K = \phi'_K(K,N) - \delta \tag{9}$$

where the right hand side of (9) is the net marginal return to capital. Given this marginal return to capital, the law of indifference dictates the equilibrium money market rate of interest (confer equation (7)).[5]

If instead the interest rate is used as a policy instrument, the required rate of return, r^*, is given by (8). In this case, there is no reason to expect r^* to coincide with the actual return to capital, $\phi'_K(K,N) - \delta$. This causes capital owners to receive either more or less from renting out capital than what is required for equilibrium in the asset market. If we require that an economic explanation should be based on a determined mathematical model, we have a puzzle: The model we have formulated cannot explain how the economy operates in the case of an active monetary policy – the model is fundamentally overdetermined.

One way of reading this result is that it is an argument against active monetary policy. This would be to push the logic of the argument a bit too far. The overdeterminacy is only a feature of an economic model, not of the real world. Hence, the only mistake we can make is to use a wrong – or irrelevant model – to aid monetary policy decisions. Specifically, models that implicitly or explicitly assume that the capital markets are in joint equilibrium have low relevance for monetary policy in Haavelmo's view:[6]

> It is obvious what an actual economy does under such circumstances: It operates under a different model that does have a solution. Why, then, should we take even the slightest interest in an overdetermined

[5] This level corresponds to what Wicksell (1898) called the normal rate of interest.

[6] Haavelmo (1960, 200–201).

> model? If we do, the only acceptable reason would seem to be that we believe that, somehow, the economy first "tries out" the hopeless model, and then *derives* a practicable alternative *in a way which could be predicted by studying the overdetermined model.*

Haavelmo pointed out that one possible solution would be to add a Wicksellian cumulative process, a route he followed in his inflation theories, which we return to in a later section. In his business cycle model, he instead excluded $\phi'_K(K,N) - \delta = r^*$ as a condition to be satisfied at any point in time, and at the same time sketched a theory of investment behaviour when this equality does not to hold. This was a natural way to attack the issue, since a state of disequilibrium plays an important role in explaining investment behaviour in his 1960-treatise.[7] A point that Haavelmo stressed was that in a classical model there is no way to derive the demand for investment from the first-order condition with respect to capital. The theorist therefore has to look for reasons outside the classical profit motive to get a formal theory of investment, this being for instance supply side constraints or time-lags in the production of capital goods.[8] The way of avoiding the overdeterminacy problem, as Haavelmo does in SMT, can be viewed as a short-cut to the more complicated job of modeling supply side constraints.

To see the point, focus on the source of the "problem", namely that the exogenously determined interest rate level under an active monetary policy interferes with equilibrium in the capital market. When the required rate of return in (8) corresponds to the actual rate of return given by (9), the households (which are the investors) have an implicit demand for investment, passively investing their savings. On the other hand, when r^* fails to match the actual return to capital, other investment responses become relevant. The theory Haavelmo proposed was:

$$\text{Investment demand} = \begin{cases} \infty & \text{if } \phi'_K(K,N) - \delta > r^* \\ \text{Passive} & \text{if } \phi'_K(K,N) - \delta = r^* \\ 0 & \text{if } \phi'_K(K,N) - \delta < r^* \end{cases}$$

This is only a formal way of saying that when the interest rate is set too low, investors will try to purchase as much capital equipment as possible. When it is too high, they will not invest at all.

Clearly, infinite demand cannot be be an equilibrium outcome. Because we have a one-sector economy, there is no way for investors to signal their desire for more capital, and no reason for consumers to cut back on consumption to make a larger piece of the pie available for investments.

The theory of optimising behaviour cannot be used to determine how total production will be allocated between consumption and investment. Haavelmo's solution was to impose rationing of investors. This implies that the model can

[7] See Boianovsky (2002) for comments on how this influenced, and was influenced by, the unemployment theories of Don Patinkin.

[8] Several authors have recognised these insights, see e.g. Nickell (1978, 12).

have a solution with excess demand, where Haavelmo assumed that consumption has priority over investments, which are residually determined. This will put an upper bound on the maximum supply of capital goods equal to full employment GDP less consumption.

We next follow Haavelmo and show how these different theory elements can be used to formulate a short-run macroeconomic model which is logically consistent, regime dependent, and generates interesting dynamics.

4 A Business Cycle Model

In Part VI of SMT, the implications of the fundamental overdeterminacy and the possible investment responses are analysed in a dynamic macroeconomic model. It is a Keynesian type macro model for a closed economy, where the investment response of firms in the economy plays a fundamental role. Haavelmo included a brief presentation of this model in his article on business cycles in the International Encyclopedia of the Social Sciences, see Haavelmo (1968). But the only complete presentation is found in SMT.

Momentary equilibrium

Assume that the production sector can be described by a representative firm that produces aggregate output (Y) at every instant according to a standard macro production function:

$$Y(t) = \phi(N(t), K(t)) \tag{10}$$

where $N(t)$ denotes labour input and $K(t)$ is capital input.[9] As noted above, in any period t, the capital stock is a predetermined variable. The firm can hire one unit of labour or capital at prices $w(t)$ and $r_K(t)$, respectively.

For the supply of labour, we assume that the entire labour force, $H(t)$, is willing to work as long the wage they receive exceeds some reservation level $\underline{w}$. During periods of unemployment, competition on the *supply* side drives the wage down to the reservation level. Under full employment, competition on the *demand* side will push the wage up to the marginal productivity of labour.[10] The labour market can be summarised by the following conditions:

$$N(t) \leq H(t) \tag{11}$$

[9] The function in (10) is assumed to be constant returns to scale, strictly increasing and concave in both arguments. This implies that the inputs are technical complementarities.

[10] Implicitly, this is equivalent to assuming that the representative firm adopts different strategies during a recession than in a boom. In a boom, the firm acts as a price-taking profit maximiser, while it produces only what it is demanded during a recession. If this assumption is relaxed, so that the firm is assumed to be a price-taking profit maximiser also in the recession, real wages would in fact have to increase for the representative firm to hire as few workers as it does in recessions, i.e. when equation (11) is not binding.

$$w(t) = \begin{cases} \dfrac{\partial \phi}{\partial N} & \text{when } N(t) = H(t) \quad (12a) \\ \underline{w}(t) & \text{when } N(t) < H(t) \quad (12b) \end{cases}$$

It is assumed that $\underline{w}(t)$ corresponds to a minimum wage set by the government at a "reasonable" level.[11]

As explained above, the household sector seeks to hold an optimal portfolio, investing its wealth either in physical capital or as deposits in the banking sector. For an exogenously given money market interest rate, we find the investors' required rate of return from the law of indifference in the capital markets. Taking (8) and simplifying by assuming that $f'_Y = f'_K = 0$, we get the law of indifference in a simplified form:

$$r^*(t) = f(i(t)) \tag{13}$$

The household sector is willing to hold the existing capital stock as long as the return from doing so does not fall below r^* as defined by (13). The actual return to capital, r_K, is found from the firm's optimisation problem:

$$r_K = \phi'_K(K, N) - \delta \tag{14}$$

If $r_K > r^*$, the household sector earns more from holding capital than what they require, given the money market rate of interest, i. They will invest as much as possible in order to increase their stock of capital. Since the productive capacity of the economy is momentarily fixed, the entire GDP can end up as investments, which is unrealistic. In order to keep the model simple, Haavelmo assumed that investors become subject to rationing and that investments in this case are determined by full capacity GDP less consumption. When $r_K < r^*$, we are in the opposite situation – investors do not receive their required return and would, if they could, get rid of capital. Of course, gross investments cannot fall below zero, but this will at least result in negative net investments (given sufficient depreciation). We then have the following discontinuous relation for private investments, I_p:

$$I_p(t) = \begin{cases} \phi(H(t), K(t)) - g(R(t)) - C_g(t) - I_g & \text{when } r_K(t) \geq r^*(t) \quad (15a) \\ 0 & \text{when } r_K(t) < r^*(t) \quad (15b) \end{cases}$$

where the first case represents *maximum* investments and the second is *minimum* investments, bounded below at zero.

To complete the description of the demand side, we assume that private consumption, C_p, is given by the standard Keynesian consumption function $g(R)$,

[11] It should be noted that these labour-market assumptions are not identical to those in SMT, but rather a special case of equation (26.8) in SMT, where the only wage-requirement is that the entire labour force is always willing to work for a wage not exceeding the marginal productivity of the representative firm.

where R is after-tax income. Government consumption, C_g, and investments, I_g, are taken to be exogenous. We have the following definitions of aggregate consumption, investments, income, and a condition for clearing of the goods market:

$$C(t) = g(R(t)) + C_g(t) \tag{16}$$
$$I(t) = I_p(t) + I_g(t) \tag{17}$$
$$R(t) = Y(t) - \delta K(t) - T(t) \tag{18}$$
$$Y(t) = C(t) + I(t) \tag{19}$$

where T is the amount of taxes collected by the government.

Multiple regimes

A solution to equations (10) - (19) is a momentary equilibrium of the model. At first sight, it seems that we have too many conditions – 10 equations and only 9 endogenous variables. However, by inspecting these equations in more detail, we observe that not all will hold simultaneously. As noted above, if $r_K \geq r^*$, firms invest as much as possible and equation (15) then satisfies (19), which becomes redundant. In that case, the entire labour force is employed, $N(t) = H(t)$, and the wage is equal to its marginal product, i.e. equation (11) is binding and the wage is determined by equation (12a). In the opposite case, $r_K < r^*$, firms invest nothing and equation (15) and (19) represent independent relationships. Since the economy is operating below full capacity, equation (11) can be ignored and the wage is set to satisfy the minimum wage as given by (12b). Hence the model does not have one unique momentary equilibrium. Instead there are *two* possible equilibria, or regimes. In summary, letting A and B label the two regimes, we have:

Regime A: A "high activity" state (boom), characterised by capacity constraints on the supply side. This occurs when investments are given by (15a) – as much as possible is invested. As a result of this, there is full employment with (11) binding and (12a) determining the wage.

Regime B: A "low activity" state (bust) which is demand constrained. This occurs when investments are given by (15b) – as little as possible is invested. The result is unemployment [(11) is not binding] and wages are fixed at the level in (12b). Employment, $N(t)$, follows from (10).[12]

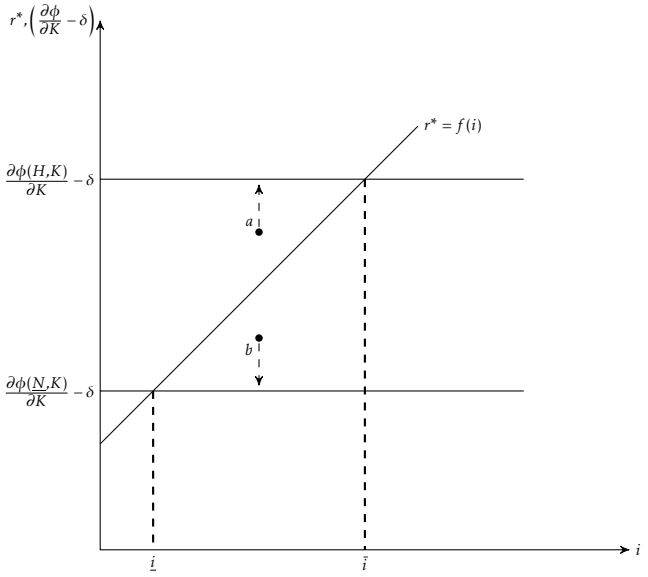
Two factors are important in determining which regime will be active: The initial situation – including "initial" employment – and the current rate of interest i. Let $\underline{N}$ be the level of employment arising under regime B (whereas H is the level under regime A), and define $\bar{i} = f^{-1}(\frac{\partial \phi(H,K)}{\partial K} - \delta)$ and $\underline{i} = f^{-1}(\frac{\partial \phi(\underline{N},K)}{\partial K} - \delta)$, which

[12] With fully flexible wages, the drop in output would be smaller, but it would not change the qualitative picture.

are – as will soon become evident – two critical levels of the interest rate. Figure 2 shows how the momentary equilibrium is determined.

Suppose we start out with an interest rate $i \in [\ \underline{i}, \bar{i}\ ]$ and a given initial employment level $N \in (\underline{N}, H)$. The corresponding marginal productivity of capital is given by point a in Figure 2. In this situation, capital owners will recognise that the marginal return to capital is higher than the required return r^*, and their response will be to invest as much as possible. Employment jumps to H and – as a result of that – the actual return to capital jumps to the regime A level, $\frac{\partial \phi(H,K)}{\partial K} - \delta$. What if employment had started at a lower level, making the marginal return to capital corresponding to point b? In this case, capital owners would want to invest as *little as possible*, since the actual return is less than the required return. Employment would fall to $\underline{N}$, while r_K would jump down to $\frac{\partial \phi(\underline{N},K)}{\partial K} - \delta$. Hence, neither a nor b can constitute equilibrium combinations of the marginal productivity of capital and employment – equilibrium employment is either H or $\underline{N}$.

Figure 2: Two alternative regimes. Replication of Figure (26.12) in SMT



The effect of monetary policy will therefore depend on the initial situation. If employment is at H and the interest rate at any level $i \in [\ \underline{i}, \bar{i}\ ]$, the economy remains in a high activity state. However, if the interest rate is increased to a level marginally above $\bar{i}$, investments will immediately fall to its minimum level and the economy enters a recession. Employment falls to $\underline{N}$, causing the marginal productivity of capital to drop further below r^*, and we enter regime B.

What if $i \in [\ \underline{i}, \bar{i}\ ]$ and we are in regime B initially? Then we can see from Figure 2 that the economy will remain in this recessionary regime – even if the interest rate is initially very close to $\bar{i}$ and then reduced to a level just above $\underline{i}$. To initiate a regime shift, the interest rate must be reduced to a level below $\underline{i}$, making it sufficiently profitable to invest in new capital goods. If that happens, employment will jump to H and we switch to regime A.

At this point, two central conclusions can be drawn: If the economy is initially characterised by the high activity state, then any interest rate below $\bar{i}$ will

sustain high activity. However, if the economy is in the low activity state, then any interest rate exceeding $\underline{i}$ will keep the economy in a depression.

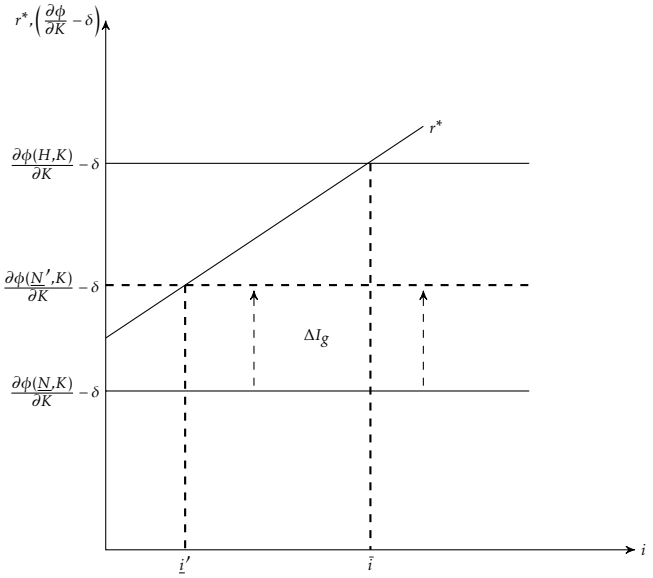
As we have seen, Haavelmo included a very stylised story about how wages adjust in his business cycle model. Apart from that, price movements play no role. Apparently, Haavelmo's position was that the main argument was robust to this simplification. Indeed, at the level of abstraction he used, and as long as the full employment ceiling has not been reached (as in Regime B), the change in the general price level can safely be regarded as adaptive in nature and subordinate to fluctuations in real output.

'Liquidity trap'

Note that there might well be a big discrepancy between the interest rate level required to push the economy out of the low activity state and the interest rate that moves the economy from the high activity state to the low activity state.[13] An implication of this is that it might be easier to use the interest rate to dampen activity than as a stimulus to speed up recovery.

In this spirit, Haavelmo provides an alternative explanation of the Keynesian liquidity trap. His point is that it can happen that, as is the case in Figure 3, the actual return to capital in the low activity state is below the required return for *any* money market interest rate. An expansionary monetary policy will by itself not be sufficient to move the economy out of recession. The reason is that the investors are unwilling to invest more in capital, no matter how low their alternative return is.

Figure 3: Potential liquidity trap. Replication of Figure (26.15) in SMT



Although the prescribed cure is the same as that recommended by Keynes and others, namely supplementing monetary policy by a fiscal expansion, the mech-

[13] The same point is stressed in Haavelmo (1968), where a similar model is very briefly discussed.

anism is quite different. Consider the case where no investments are carried out by existing firms because the return to capital is less than the required rate from the law of indifference (the lower line in Figure 3). Monetary stimulus is not sufficient to generate a recovery. However, assume that the government increases public investments by an amount ΔI_g. This fiscal expansion will increase employment in the low activity state to a level $\underline{N}'$, leading to an increase in the marginal productivity of capital due to technical complementarities in production. This is illustrated by shifting the lower line in Figure 3 upwards. If the interest rate is kept low enough (at least lower than $\underline{i}'$), the combination of expansionary fiscal and monetary policy may be sufficient to push the economy into the high activity state.

Endogenous cycles

In the previous section, we showed how the model operates *at any given point in time*, and we saw that two possible regimes can prevail. We now consider the dynamic implications of the model. It will become evident that the model has a typical solution with switching between the two regimes, creating *endogenous cycles*.

In a dynamic context we need, in addition to (10)-(19), equations for how the stocks of labour and capital evolve over time. We therefore define:

$$\dot{K}(t) = I(t) - \delta K(t) \tag{20}$$

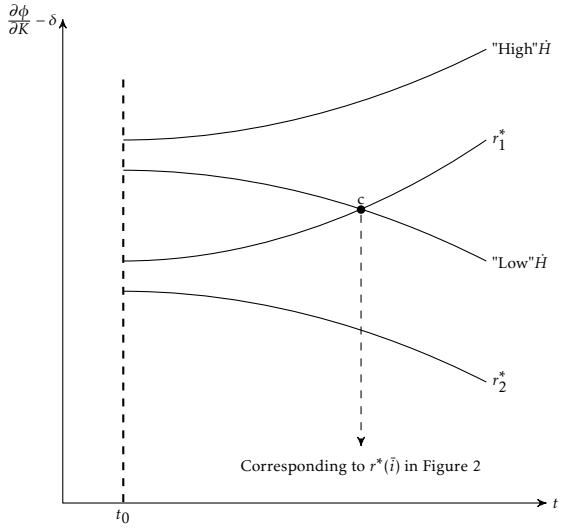
$$\dot{H}(t) = \text{Some function of time} \tag{21}$$

As we saw in the description of the alternative regimes, a central variable in the model is the marginal productivity of capital. When the capital stock and the population change over time, so will the marginal productivity of capital. For instance, let us consider the development if we are initially in regime A. Assume that both the capital stock and the labour stock are growing, but that the growth in the labour stock is low relative to the growth in the capital stock. In this case, the marginal productivity of capital will decrease over time because the capital intensity increases. Alternatively, if population growth is high relative to the the growth in capital, then we might have an increasing marginal productivity if investments are insufficient to stop the capital intensity from decreasing. Figure 4 illustrates two alternative paths: "Low" $\dot{H}$ and "High" $\dot{H}$.

Interestingly, what matters is not really the exact time-profile for the marginal productivity of capital, but how it matches the path of r^*, the required rate of interest, determined by the path of the policy instrument $i(t)$. In Figure 4, two possible interest rate trajectories, r_1^* and r_2^*, are drawn. If the relevant development for $\frac{\partial \phi}{\partial K} - \delta$ is that of "High" $\dot{H}$, we see that the economy is on a sustainable full employment path independent of the chosen policy path, i.e. whether r_1^* or r_2^* is chosen.[14] However, if we consider the case where population growth is low, an interest rate path such as r_1^* will not sustain high activity forever, since as soon

[14] At least within the horizon shown in the figure.

Figure 4: Marginal return dynamics under regime A. Replication of Figure (27.11) in SMT



as point c is reached, we will shift to regime B. This implies that the model can create endogenous switching between the two regimes.

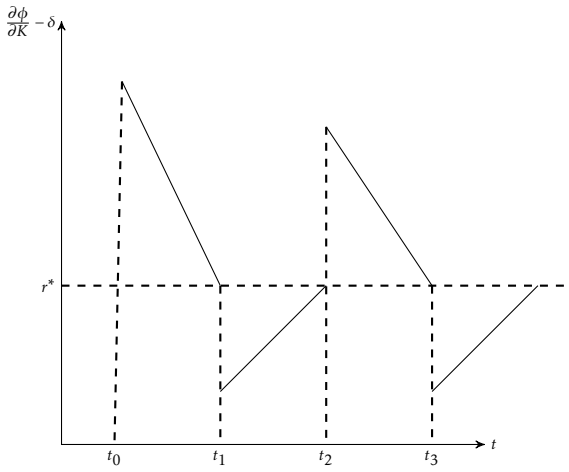
Assume for simplicity that the interest rate is constant and $\dot{H} = 0$. Under appropriate assumptions for values of the various exogenous variables, we have that:

- Under Regime A, the marginal productivity of capital *declines* because of positive net investments
- Under Regime B, the marginal productivity of capital *rises* since the capital stock is worn out by depreciation

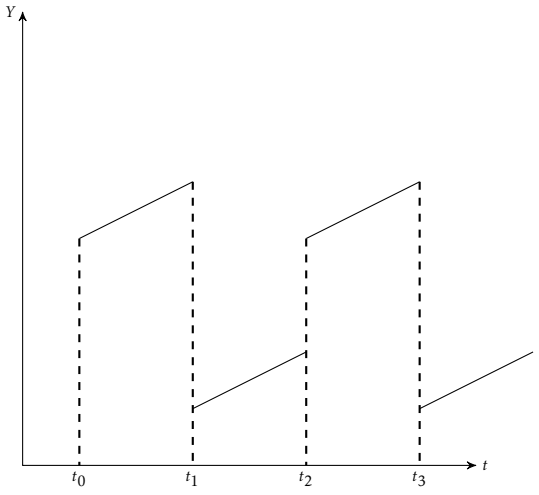
Say we start out in regime A at some point in time, t_0. Firms are investing as much as they are able to with full capacity utilisation at any given point in time. However, as capital is accumulated, the marginal productivity of capital will decrease – this is illustrated in panel (a) of Figure 5. At t_1, it has fallen to a level equal to r^*. As soon as the marginal productivity falls below this rate, there will be a switch to regime B (corresponding to point c in Figure 4). Firms stop investing, leading to a sudden drop in output and an increase in unemployment. Further, since the stock of capital is unchanged but employment has fallen, the marginal productivity of capital jumps down to a level *far below* r^*. These shifts are depicted in the three panels of Figure 5. After the sudden drop, the marginal productivity of capital recovers as the stock of capital is worn out. When we reach t_2, it has returned to the level r^*, and as soon as it is marginally above r^*, we switch back to regime A. Firms start investing again, leading to a jump in output and employment. As a result, the marginal productivity of capital jumps up, and a new cycle is initiated.

Figure 5: Haavelmo's Business Cycle Model. Replication of Figure (28.1) in SMT

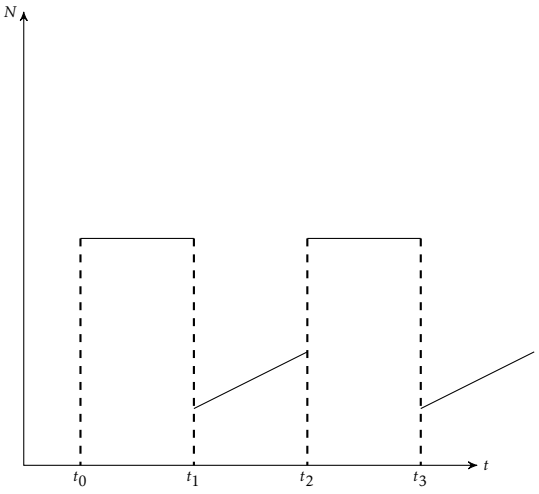
(a) MPK



(b) Output



(c) Employment



Financial crisis?

The discussion in the preceding sections has been based on the rather strict assumption that the law of indifference in the capital markets can be represented as a one-to-one mapping between the money market interest rate, i, and the required rate of return in the financial market, r^*. More generally, the functional relationship describing the law of indifference in the capital market will be a multivariate function. Realistically, one might expect the required return to also depend on transaction costs and liquidity risk. Chand (2012) has suggested a modification of the model that includes the loan-to-value ratio as measure of balance sheet risk as well as a parameter measuring the degree of optimism, which then has the effect of shifting the r^*–line in Figure 2 for a given money market interest rate, i. An additional extension would be to add effects of liquidity risk on the required return. Liquidity risk is likely to exhibit non-linearities, with only a marginal effect of liquidity risk for long periods and a strong reinforcing effect that may lead to a liquidity crisis in other circumstances, see Pedersen (2009).

A simple way of generating a liquidity crisis in the model of Haavelmo is to consider liquidity to be a shift parameter in the functional relationship between the required rate and the money market rate. In that case, an increased liquidity risk – or at least a perception that the risk has increased – will shift the r^*–line in Figure 2 upwards. This means that for an unchanged interest rate, the required return is substantially increased when liquidity risk goes up. If the liquidity shock is large in magnitude – as for example in the US following the collapse of Lehman Brothers – the high activity regime may collapse to a depression regime with zero investments, low economic activity and a high unemployment rate. By considering a relatively minor modification of Haavelmo's business cycle model, we are therefore able to see how a crisis in the financial sector can propagate into a full blown crisis in the real economy. Depending on the size of the liquidity shock, the drop in production may be substantial. With a large drop in output, it also takes a long time before the economy fully recovers and the effects of the shock may carry on for a substantial period of time. This is consistent with the observations in Reinhart and Rogoff (2009), who – in a historical context – show that the recovery from financial crises can be a long lasting affair, with the duration from peak to trough in the unemployment rate typically being almost five years. This prediction is also in sharp contrast to "New Keynesian" macro models, where the inherent stability forces the model to recover relatively rapidly in the absence of further negative shocks.

It is intriguing that Haavelmo formulated his theories under the assumption of liberalised credit markets and an unregulated economy at a time when the Norwegian credit markets were heavily regulated, with both interest rate ceilings and lending that was targeted to specific sectors. Like in most other Western countries, the Norwegian credit market went through a massive deregulation process in the 1980s (see Krogh (2010)). An interesting question to ask is therefore how Haavelmo considered the possibilities of fine tuning the economy by using monetary policy after the deregulation process had been completed. In fact, in 1987 – when most of the deregulation had been completed – Haavelmo held a presentation in Norges Bank under the title "The role of monetary pol-

icy in a deregulated credit market", see Haavelmo (1987). During this talk, he was rather explicit about what he saw as the limitations of monetary policy in such a system: "My preliminary analysis suggests that the interest rate should have as a target an average r_K and that delegating the responsibility of short run stabilisation to the monetary authorities seems to be a difficult task" (our translation). Judged by this statement, it seems that Haavelmo thought that the model he had formulated twenty years earlier finally had gained practical relevance for the conduct of monetary policy in Norway. However, Haavelmo's analysis had no tractable impact. In 2001, Norway adopted inflation targeting based on the blueprints from Sveriges Riksbank and the Bank of England.

5 Inflation

Our presentation of Haavelmo's macroeconomics has so far been directed towards his business cycle model, where he for simplicity assumed that prices were fixed. One way of reading this simplification is that it avoids unnecessary complications of a model that shows the inherent instability of modern capitalist economies. It does not, however, imply that Haavelmo was not concerned with inflation *per se*.

Indeed, as this section will show, he was deeply concerned with inflation dynamics, as well as the implications of an interest rate that is set to meet a target for the inflation rate. Furthermore, he developed a conflict theory for wage and price dynamics that preceded later theoretical developments and econometric equilibrium correction models. This approach constitute a relevant alternative to wage and price models based on the Phillips-curve model.

A Wicksellian cumulative process

During a period of 30 years, Haavelmo offered several contributions to our understanding of the inflationary process in a modern society. Early contributions can be found in his lectures on "Dynamic Price Theory" in 1951-52, see Thalberg (1952). These lectures demonstrated that Haavelmo was not only inspired by Wicksell's "cumulative process" to explain the movement in prices, but shows that he was in a position to formulate interesting and original ideas so as to explain and understand inflation under a wide range of policy assumptions and various price-wage-setting institutions. (Even inflation targeting was addressed as a monetary policy regime - to our knowledge this must have been one very early step in that direction).

His workhorse inflation model from the years after the Second World War, when price stability was put up as a main target, can be found in Chapter 10 of Thalberg (1952). This model is a short-run version of the business-cycle model from the preceding section, but with some important modifications: Neither an investment relation like (15) above, nor the law of indifference with the resulting overdeterminacy are incorporated explicitly into his inflation model. However, the discrepancy between the actual rate of return and the required rate of return, $r_K - r^*$, still plays a key role. Rather than operating through investment

demand, the discrepancy between the two interest rates now operates through a price channel. One way to interpret this is that investors are unable to affect the size of the capital stock in the short run, but that their desire for more or less capital when the law of indifference is not satisfied leads to changes in prices. This can cause the rate of inflation to be a function of $r_K - r^*$, i.e. implicitly the excess demand for capital. If the return to capital exceeds the required return, prices are 'bid up' by investors seeking to expand their capital stock. This is formalised as:[15]

$$\frac{\dot{P}(t)}{P(t)} = \varphi\,(r_K - r^*) \tag{22}$$

where φ measures the impact on inflation from some discrepancy between the actual rate of return and the required rate of return, i.e. an equilibriating mechanism. When the actual return exceeds the required return, investors will bid up prices for a given level of the capital stock, which will be manifested in an increase in the rate of inflation. As already noticed, it is assumed that investors cannot affect the flow of investments in this model. Independently of the values that r_K and r^* take, investments will therefore be equal to full employment GDP less consumption. In periods where $r_K \geq r^*$, this is consistent with the 'rationed' investors of the full employment regime in his business cycle model. However, periods with $r_K < r^*$ would in the business-cycle model give zero investment, and a deep recession. This mechanism is excluded from the inflation-model, to focus solely on inflation dynamics. Hence, one could in principle merge Haavelmo's business cycle model with his 1950s inflation theory to build a more complete 'Haavelmo-model'.

One of the many issues Haavelmo discussed in his lectures on "Dynamic Price Theory" was the possibility of keeping the price level constant in steady state, and more generally a constant rate of inflation, $\dot{P}/P = \lambda$. Letting $\bar{r}_K$ be the steady state return to capital, and ι denote the steady state nominal interest rate, we get the following steady state condition for λ:

$$\lambda = \varphi(\bar{r}_K - f(\iota - \lambda)) \tag{23}$$

From this condition, it is seen that a constant price level ($\lambda = 0$) is possible only if (as long as φ is non-zero), by coincidence, ι is chosen such that $f(\iota) = \bar{r}_K$. In the lectures, this is not even presented as a possibility – the model's steady state is simply labeled as 'overdetermined' if the policy makers are aiming for $\lambda = 0$! The conclusion is then clear: Imposing price stability as a target, as was the case in Norway at the time these lectures were held, is impossible to meet in steady state if the authorities at the same time control the nominal rate of interest. In the more general case, where the steady state inflation rate λ is set to meet a target, $\bar{\lambda}$, the model is overdetermined unless ι is set so as to satisfy equation (23). This means that ι and λ cannot be chosen independently.

Furthermore, Haavelmo discussed what kind of interest rate rules that could be used to support a given target level of the inflation rate. These involved setting

[15] Note that r^* is now defined as $r^* = f(i - \dot{P}/P)$, since i is a nominal rate.

the nominal interest rate as a function of inflation, and also the return to capital. That said, it should be noted that in Thalberg's summary it is stated that: "it seems hard to imagine that the interest rate in practice should be changed based on observations of the return to capital and inflation". This was a clear forecast failure. Today, modern monetary theory (see *e.g.* Woodford, 2003), argues for interest rates to be set almost exclusively based on observations of inflation!

The above described mechanisms depend on the assumption that the price of capital is equal to the price of consumption goods. Haavelmo also formulated a model with two sectors; one final goods sector and one capital producing sector, see Thalberg (1955). In this case, a discrepancy between the two rates of return triggers an increased demand for capital. In the short run, this demand cannot be realised due to frictions or delays in the time consuming production process in the capital goods sector. Instead, the capital price will go up so as to balance the given supply of capital and the current demand. The higher price will of course stimulate suppliers of capital goods to increase their production, and – in the long run – prices will return to a new steady state.

Price and wage determination in a conflict model

A recurrent theme in Haavelmo's work on price dynamics and inflation is that price- and wage adjustments are in part a result of conflict and disagreement about the distribution of the value added in the production process. An early example is found in Haavelmo (1949), where he formulated a macro model where both the wage and price growth are considered to be endogenous. The solution to this model is stationary only in the special case of perfect competition and no shocks. In later lectures on inflation in 1974 (see Qvigstad (1975)), Haavelmo elaborated on the conflict perspective to wage and price setting. The main idea is that firms and workers have conflicting targets for the real wage. Firms try to minimise the deviation between the actual real wage and their target level through nominal price adjustments. Workers on their part can use nominal wage adjustments in an attempt to control the real wage. In this dynamic process of nominal adjustments, none of the parties are completely satisfied with the prevailing real wage rate and Haavelmo shows that the normal outcome will be inflation.

Similar ideas were "in the air" in the 1970s and later, see e.g. Rowthorn (1977), Hirsch (1978) and Blanchard (1987), but Haavelmo's version is particularly interesting since it brings out that inflation has a "double nature": It is both a disequilibrium phenomenon (brought about by conflicting interests between workers and firms) and it serves as an equilibrating device (it "solves" the conflict).

In Haavelmo's model, there is no problem with run-away inflation (which was very much the fear of the day) even though both parties hold on to their real wage targets and ambitions. The model's equilibrium inflation rate is both a function of the two targets, as well as the relative bargaining power of the two parties. The equilibrium real-wage represents a compromise; like a "quasi peace". Neither parties get the real wage they were wishing for, but the workers avoid seeing

their purchasing power undermined by run-way price increases and firms are able to maintain a constant profit level. As a consequence, there was no need for a "natural rate of unemployment" in order to stabilise inflation in Haavelmo's model, which can be regarded as a model of inflation in a regime where the rate of unemployment was targeted by economic policies.

Returning to the point about the characteristics of the inflation models that were developed during the 1960's and early 1970's, we do not even have to look outside Norway to find an inflation model that is complementary to Haavelmo's framework. This is the "main-course model", or the Norwegian model of inflation as it was dubbed in 1977.[16] The main-course model was the outcome of two reports that an expert group of Norwegian economists (Aukrust, Holte and Stoltz) published as background material for the wage and agricultural price negotiations in 1966. The second report, dated October 20 1966 (see Aukrust, 1977), contained the long-term model that we refer to as the main-course model. Later, there were similar developments in e.g., Sweden, see Edgren et al. (1969) and the Netherlands. In later usage, the distinction between the short and long-term model seems to have become blurred, in what is often referred to as the Scandinavian model of inflation, see e.g. Rødseth (2000, Ch. 7). Bårdsen et al. (2005, Ch. 3) acknowledge the originality of Aukrust's distinction between long and short-run analyses in his 1977 paper, and use the name Norwegian main-course model for the long-term version of his theoretical framework. This model became the framework for both medium term forecasting and normative judgements about "sustainable" centrally negotiated wage growth in Norway and Sweden, and therefore became more influental than Haavelmo's model.[17] Intellectually, there is however a close relationship between the two offerings, as Haavelmo's formulation gives the short-run dynamics that is missing from Aukrust's main-course model, while the main-course model gives economic content to Haavelmo's real-wage claims equations. It is a puzzle why the possibility of a synthesis of the two approaches was not recognised at the time.

Haavelmo's and Aukrust's work have inspired econometric models of inflation. For example, it lies close at hand to re-formulate wage claims equations in terms of monopolistic competition and wage bargaining theory, see Bårdsen et al. (2005, Ch 2-6). The econometric formulation brings out the close conceptual relationship between Haavelmo's model and the equilibrium correction model applied by Sargan (1964) to model wage determination, and to a joint model of wages and prices in Sargan (1980). Interestingly, the equilibrating aspect of inflation is maintained in the generalised version of the model, which means that Haavelmo's inflation model stands apart from the natural rate model of inflation that dominates both economic text-books and the New Keynesian macro models. In many ways, it is a relevant answer to Solow's call for alternatives to the ruling accelerationist view of inflation, see Solow (1999, 2008).

[16] In fact there were two models, a short-term multisector model, and the long-term two sector model that we re-construct using modern terminology in this chapter.

[17] On the role of the main-course model in Norwegian economic planning, see Bjerkholt (1998).

6 Final Remarks

Trygve Haavelmo is well known for his important contributions to econometrics, but after returning to Norway in 1947, he spent most of his time theorising about macroeconomics to bridge what he considered to be a gap between theory and econometrics. To most Norwegians, Trygve Haavelmo was an unknown person until he was awarded the Nobel Memorial Prize in Economic Sciences in 1989, but the fact is that he was deeply concerned with political and practical economic issues at the national arena, and he is known to have been deeply opposed to a Norwegian EU membership. He also served as an advisor to the Norwegian government and was reputed for his inspiring lectures that have shaped and educated the economists that today occupy central positions in the Central Bank, the Ministry of Finance and other parts of the government. The content of his lectures were summarised in an internal publication series at the University of Oslo and has not been well known internationally since most of these lectures were held and documented in Norwegian. One of the aims of this paper has been to make Haavelmo's ideas on macroeconomics known to a broader audience. We are also convinced that Haavelmo's insights offer a fresh way of looking at the economy, as an alternative – or a complement – to the dominating theories of today.

The discussion in this paper has shown that, during a period with strict credit market regulations and state involvement in the economy, Haavelmo took the task of building theoretical models of inflation dynamics and the business cycle for a hypothetical world that comes close to the reality of today. The recent financial crisis has highlighted the importance of the interaction between financial markets and the real economy. It has also sparked a debate about the limitations of the inherently stable microfounded models that are currently dominating modern macroeconomic research and that is used as an analytical tool by many central banks, see e.g Akerlof and Shiller (2009), Colander et al. (2008), De Grauwe (2010, 2012), Frydman and Goldberg (2011), and Keen (2011) for critiques of the central assumptions regarding rational expectations, representative agents as well as the neglect (or assumed stability) of capital markets underlying these models.

Stiglitz (2011) raised a more specific critique towards the Dynamic Stochastic General Equilibrium (DSGE) models used at many Central Banks. Also Muellbauer (2010) has criticised these models. As an alternative, he suggests econometric models incorporating structural changes in the credit market and a financial accelerator for the household sector, with a key role for housing prices in transmitting shocks to the real economy. The relevance of the DSGE models has also been questioned by econometricians. Pesaran and Smith (2011) and Hendry and Mizon (2010, 2011) suggest viable alternatives to modeling the macroeconomy.

Like Gordon (2009), we believe that a study into the intellectual history of economics is a relevant response to the recent critique of macroeconomic theory and that it can provide alternative insights that may improve our understanding of the macroeconomy. Without properly accounting for the interactions between the real economy and financial markets in our models, the best we can hope for is

to explain business cycle fluctuations during relatively stable periods; a task that does not seem very ambitious. In that respect, we believe that the business cycle model of Trygve Haavelmo can be an interesting starting point for a discussion about how we can proceed to get a better understanding of the complex forces that are driving the modern economy.

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