# *A Note on NNS models:*

# *Introducing Physical Capital ; Avoiding Rationing* [*]

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**Abstract**

This note makes two comments on recent NNS models. First, it disputes the way physical capital has been introduced into these models arguing that this leads to the dubious postulate that the cost of adjusting physical capital stock is an order of magnitude lower than the cost of changing prices. Second it warns against a possible logical inconsistency whereby calibrated NNS models are implicitly assuming that some (price-constrained) firms are willing and able to sell their output below cost.

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## 1. Introduction

New Neo-classical Synthesis (NNS) models are at the heart of recent and promising developments in modern macroeconomics. NNS models provide the theoretical foundations to the New Philips curve as put forth by, e.g., Clarida et al. (1999). They have also been used to make the case for a monetary policy aiming at price stability (Goodfriend and King, 2000). Altogether, as the labeling indicates, they have the ambition of being recognized as the much sought-after successor to the IS-LM model (Danthine and Donaldson, 2001).

NNS models supplement the dynamic, micro-based general equilibrium approach of Real Business Cycle models with three additional key ingredients: money introduced into the model via a cash-in-advance constraint or a similar device, imperfect competition of the Dixit-Stiglitz variety, and costly price adjustment. The latter feature is often introduced by postulating that a fraction of randomly determined firms is not allowed to optimize its output price in the current period (Calvo, 1983). Alternatively, the Taylor (1980) staggered pricing assumption is sometimes adopted.

This note makes two comments on recent NNS models. First, it disputes the way physical capital ownership has been introduced into these models arguing that this leads to the dubious postulate that the cost of adjusting physical capital stock is an order of magnitude lower than the cost of changing prices. Second, it documents a potential logical inconsistency underlying this model class whereby certain calibrated NNS models implicitly assume that some (price-constrained) firms are willing and able to sell their output below cost. We take these two points in turn.

## 2. **NNS models with physical capital: printing new menus vs. unbolting the capital equipment**

With one exception (Woodford, 2000), known attempts at completing NNS models with capital stock (Hairault and Portier, 1993; Kimball, 1995; King and Waston, 1996; Yun, 1996; King and Wolman, 1996; Chari et al., 2000) borrow a fiction productively used in most adaptations of the neo-classical stochastic growth model to dynamic macroeconomics: they make the assumption that consumers-workers carry the physical capital stock – which represents their savings – and rent it period after period at competitive rates to business firms. In the standard real business cycle context, this assumption significantly facilitates the modeling because it results in the existence of a single agent category with a dynamic optimization problem. It is also innocuous in the sense that this model is isomorphic to another, more realistic one where infinitely-lived firms make the investment decisions and own the physical capital, while consumer-workers hold shares in these firms and unanimously approve their investment plans. That is, firm managers maximizing the unambiguously defined firm market value effect the same aggregate investment plans as in the alternative, simpler, model specification, where they rent capital on a period by period basis from consumers.

The assumption that consumer-workers own the physical capital similarly facilitates the modeling in the NNS context because it leads to a clear separation between two important dynamic decisions: investing, a decision made by consumers, and fixing the current price, a decision made by the firm. The latter is a dynamic decision in the NNS context because the firm may find itself prevented from adjusting its price in subsequent future time periods. Indeed, it is the essence of the Calvo price fixing scheme at the heart of NNS models that the price optimization decision is

forward looking. At first sight, the separation of the pricing and investment decisions is judicious given the complexity of the former in particular.

We argue that this separation is, in fact, not innocuous in the NNS context. Such a modeling device implies that firms rent a quantity of capital that is optimal given the constraints they face regarding their anticipated price adjustments and their technology. Consider a more realistic model where firms would make the investment decisions and carry the physical capital stock. It is one in which, once again, consumer-workers are shareholders and their identical IMRS guides the maximization of market value by firm managers. To be isomorphic to the model where consumer-workers perform the investment decisions and firms' capital stock is optimal in the sense above, one must, however, make the less natural assumption that the market for capital good reopens at each date after firms have observed their productivity shock and have been designated as either free to adjust their price or constrained to last period's price. It is only in this case that those firms constrained to a price that is too low and having to meet a large demand for their output can acquire the additional capital necessary for them to meet the extra demand at minimum cost. Conversely, firms that are constrained to a price that is too high can then unbolt their unnecessary machines and sell them to their competitors on the market for capital goods.

One may question the realism of such a story and reevaluate the concept of menu costs in this light. The NNS builds on the idea of nominal rigidities associated with the concept of (broadly interpreted) menu costs. To make it operational in a complete dynamic general equilibrium model one is forced to weight the importance of these menu costs with the more traditional costs of adjusting the stock of capital. And the approach overwhelmingly adopted thus far necessarily amounts to postulating that the costs which prevent firms from adjusting their prices are an order

of magnitude larger than the costs of adjusting the stock of capital instantaneously or within the period. In effect, it is feasible for price constrained firms, at the last minute, to unbolt machines and ship them to the market while it is too costly for them to print new price lists!

Some authors further combine this modeling device with the assumption that there are cost-of-adjusting the capital stock. The latter assumption, in line with a long tradition, helps prevent consumption from being excessively smooth over the business cycle. Yet, we view it as paradoxical to claim, on the one hand, that it takes time to adjust the level of the capital stock – or is costly to do it rapidly –, while on the other to assume that each firm can freely adjust its own stock of machines after being informed of its market share of output. Again it is possible to make the two contradictory hypotheses consistent by assuming that, while building factories takes time and thus the size of the total stock of capital available cannot be adjusted costlessly, there is a fluid and frictionless market for ownership of this perfectly fungible capital. This market meets at the beginning of every quarter enabling firms with insufficient demand to sell excess production capacities to those stuck with low prices. In this fiction, buying and selling production capacity is an order of magnitude less costly than printing new menus!

The message of this section is that the current practice of assuming that consumer-workers carry the physical capital is a poor modeling practice and should give way, in the logic of the NNS, to a set-up where the two dynamic decisions – the investment decision and the price adjustment decision – are intertwined. The usual forward looking pricing formulas underlying the New Keynesian Phillips curve will, however, not remain unaffected.

3. **Rationing**

We now come to our second point which is that calibration of NNS models is delicate if one wants to avoid situations where price-constrained firms are forced to produce and sell below cost. To make this point let us be a bit more specific. Let the production possibility of firm *z* in period *t* be represented by the production function

$$f(k_t(z),n_t(z))\,l_t$$

where $l_t$ is the productivity shock and $k_t(z)$ and $n_t(z)$ are, respectively, capital stock and labor inputs.

In a NNS model, the demand facing firm *z* is a function of the ratio of its price $p_t(z)$ to the general price level $p_t$:

$$d_t(z) = \left(\frac{p_t(z)}{p_t}\right)^{-e} d_t$$

where $e$ >1 is the elasticity of substitution between the different goods and $d_t$ is the aggregate demand.

If it is constrained to its last period's price, firm *z* cannot influence the demand it faces and the following equation applies:

$$f(k_t(z),n_t)\,l_t = d_t(z) = \left(\frac{p_{t-1}(z)}{p_t}\right)^{-e} d_t. \qquad (1)$$

If we assume, plausibly, that the firm's capital stock is constrained by investment decisions made one period previously, or that labor is the only input, then there is only one unknown variable in this equation, the level of labor input necessary for firm *z* to meet the demand it faces. Let us label this uniquely determined input level $\hat{n}_t$. Now the problem is that nothing insures, at this level of labor input, that the marginal product of labor covers the unitary cost of that input, the market determined (nominal) wage rate, $W_t$:

(2) $p_{t-1}(z) f_n(k_t(z), \hat{n}_t) l_t \geq W_t$ ?

Equations (1) and (2) may simply be jointly inconsistent for some firms. This signifies that, under normal assumptions, these firms will not be willing to meet the demand they face. To do so would require hiring labor to a point where its marginal product would not cover its cost. Of course, if a given firm *z* does not meet the demand it faces, we enter a whole different world where consumers must entertain the possibility of being rationed and/or flexible firms should envisage that their demand may not be simply in proportion to the ratio of the price they charge to the general price index (because of spillover effects).

How severe is this problem? The partial way-out is to observe that NNS models are models with imperfect competition where there is a mark-up of price over marginal cost which translates into a marginal product of labor – in equilibrium – that exceeds the going wage. The issue then is quantitative: if the equilibrium mark-up is high enough, the length of price fixity relatively small, and the disturbing shocks – inflationary and productivity – are of a small enough order of magnitude, it is plausible that no firm will ever be in a situation of not covering its cost. One knows that with the Calvo pricing mechanism, however, a not-insignificant fraction of business firms may find themselves constrained to their fixed price for a relatively long time interval. It is then very likely, especially in periods of accelerating inflation, that these firms will not be willing to meet the demand they face, contrary to what is systematically assumed – without qualification – in the literature. This particular criticism may be re-interpreted as a call in favor of state-dependent pricing rather than time-dependent pricing (see Dotsey, King and Wolman, 1999).

4. **Summary and Conclusion**

To summarize, extending NNS models in their current form to a fully dynamic set-up with physical capital accumulation is not straightforward unless one accepts the extreme view that menu costs are an order of magnitude higher than the costs of adjusting physical capital or of transferring ownership rights. Time-dependent pricing, furthermore, can easily lead to situations where it is implicitly assumed that business firms are willing and able to sell below cost, an hypothesis that is in clear contradiction with the rationality hypotheses underlying the overall approach.

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