Inventory changes and the closing of econometric models

by

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Abstract - Inventory changes can help econometric models to balance the supply and the demand side and to endogenize utilization variables without resorting to an arbitrary potential output level. Both results stem from formulating inventory-augmented production functions in which inventory changes act as a stationary ECM between value added and inputs on one side and value added and final sales on the other. This happens because factors or prices may adjust too slowly to productivity and sales shocks. The empirical implementation refers to the Italian Treasury Econometric Model (ITEM) in which inventory changes are obtained as a residual from endogenous value added and spending components.

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1. *Introduction*

Until the early 70s the prototypical econometric model was based on an IS/LM framework where real gdp was obtained by adding the endogenous income/spending components. This short-run approach was basically intended to account for the cyclical fluctuations characterizing the economy for a given capacity level. Even if this framework was usually enriched by wage and price blocs and by more or less detailed transmission channels for fiscal and monetary policies, the overall picture admittedly failed to get over a number of challenges all appearing around the mid-70s: i) coping with the implications of such major supply shocks as the oil crisis and the real wage resistance in most industrialized countries ii) facing the crisis in the IS/LM paradigm and its econometric counterpart iii) filling the gap between a generally poor macroeconometric practice and the ongoing developments in time-series and dynamic econometrics.

This paper focuses on the importance of inventory investment in replacing slow factor or price adjustment to productivity and sales shocks and in providing a tentatively new perspective for closing the structure of an aggregate macroeconometric model. In Section 2, I shall present a simple theoretical scheme leading to an inventory-augmented value added production function

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which is equivalent to formulating an error correction (ECM) type of adjustment (Hendry, 1995). In Section 3, I will estimate the resulting value added equation which is also part of the Italian Treasury Econometric Model (Favero-Fiorito-Nucci-Padrini-Ricchi, 2000). In Section 4, I shall briefly discuss the relevance of inventory adjustment for balancing the supply and the demand side of an aggregate econometric model. Section 5 concludes by referring to the main implications for inventory and business cycle research.

2. *The model*

Let us assume that the n-identical agents differ only in the purely random choice of producing either a final or an intermediate storable good. The resulting aggregate output will be:

(1) $Y_t = S_t + \Delta HF_t,$

where Y, S and HF denote output sales and the beginning-of-period inventory stock of finished goods, respectively, and where $\Delta = (1 - L)$ is the first-difference operator in the lag operator class $L^j X_t = X_{t-j}$, for any integer j. All variables are in volume.

Equation (1) applies to the inventory buffering role for output and sales but is not relevant for evaluating value added (VA) - or GDP - components that exclude intermediate consumption (IC):

(2) $VA_t = Y_t - IC_t.$

For simpler analysis, the inventory stock is made by finished goods and raw materials (HM) only, work-in-process stocks being ascribed to one of the two components, depending on the stage of completion. Hence, the total inventory stock (H) is defined as

(3) $H_t = HF_t + HM_t,$

and is contrained to be non-negative in both components.

The changes in raw materials stocks are defined as the difference between intermediate purchases (IP) and consumption:

(4) $\Delta HM_t = IP_t - IC_t.$

By combining equations (1)-(4) we obtain the value added definition in terms of the final sale variables (Fiorito, 1991) and the total changes in inventories reported by the NIPA and typically used in the aggregate income determination models:

(5) $VA_t = FS_t + \Delta H_t,$

where the final sales variable (FS = S - IP) sums up consumption, fixed investment and net exports.

What should be noted in equation (5) is that total inventory changes ($\Delta H_t = \Delta HF_t + \Delta HM_t$) buffer both the supply and demand for intermediate inputs (4) and the supply and demand for finished goods (1). Most of the macroeconomic research on inventory cycles focuses instead on finished goods only (Blinder-Maccini, 1991), neglecting the role of inventory changes as an utilization variable related to the actual use of materials and supplies into production. Yet, stressing the role of finished goods only is appropriate when inventory adjustment refers to single firms or industries but is definitely misleading when GDP or business cycle is investigated.

Inventory buffering

If production plans cannot be quickly adapted, quantities only adjust to match unforeseen sales. In turn, output decisions depend on expected sales:

$$(6)\ \ Y_t = E_{t-j}(S_t/\Omega_{t-j}), \qquad (j = 1, 2, ...).$$

where the expectation is formed j-periods before on the basis of some information set Ω.[2] Conversely, the equilibrium output equates actual sales in the same period:

$$(7)\ \ Y_t^* = S_t.$$

Hence, if factor and/or prices cannot be quickly adapted to match the difference between actual and expected sales, finished goods inventories are the only immediate balancing device. By combining equations (1) and (6) we have:

$$(8)\ \ \Delta HF_t = \alpha[E_{t-j}(S_t/\Omega_{t-j}) - S_t], \qquad (\alpha > 0),$$

where $\alpha = 1$ describes the case of inflexible plans in the given production period, whereas $\alpha = 0$ indicates that plans are flexible enough to make any quantity adjustment unnecessary.

Value-added production functions

As stated before, actual output deviates from equilibrium because of forecasting errors that cannot be immediately corrected by adapting production via price or factor changes. In the light of equation (2) and of the assumption of value added separability, output deviations from equilibrium can be decomposed into value added[3] and intermediate consumption shares:

$$(9)\ \ (Y_t - Y_t^*) = (VA_t - VA_t^*) + (IC_t - IC_t^*).$$

This model ignores prices and, therefore, no speculation can occur. Hence, equilibrium requires only that production demand for materials - i.e. the utilization of materials into the production process - equates the supply made

[2] In a competitive environment, Ω could include the past values of s_t only.

[3] Value-added production functions, using raw material inventory flows as an input, are analyzed by Humphreys-Maccini-Schuh (2000).

available from purchases. Yet, most of the inventory literature was motivated by explaining why purchases are not entirely or instantaneously used into production[4]. Whatever the reasons are, the usefulness of holding some raw material inventory can be merged with the existence of an one-period production lag by assuming that equilibrium intermediate consumption equates previous period purchases:

$$(10)\quad IC_t^* = IP_{t\text{-}1}.$$

In turn, purchases can be expressed as a random walk process where the stochastic drift $\mathrm{d}_t = d + e_t$ accounts for the increasing scale of the economy:

$$(11)\quad IP_t = IP_{t-1} + d_t.$$

By combining equations (1)-(5) and (6) with equation (7), the finished-goods inventory changes can be expressed for $\alpha = 1$ as follows:

$$(12)\quad \Delta HF_t = (VA_t - VA_t^*) - \Delta HM_t + d_t,$$

which implies

$$(13)\quad VA_t^* = VA_t - \Delta H_t + d_t.$$

Thus, once is taken into account the increasing scale of the economy, the total inventory changes reported by the NIPA can be interpreted as deviations from value added (GDP) equilibrium values.

The positive drift entering the purchases equation allows inventory changes to have a (small) positive rather than a zero-mean value which is consistent with the G-7 evidence reported by Ramey and West (1999). Moreover, a positive drift prevents the equilibrium value-added data from being systematically lower than the realized data as it would result from considering all changes in inventories wasteful.

Equilibrium conditions apply then to two different markets (materials, goods) and imply two different adjustment mechanism in the short run: finished goods inventory changes buffer final sales that cannot be predicted or faced by flexible production plans, while raw material stocks reflect the imbalances between the demand and supply of the intermediate inputs but include a stochastic trend component that parallels the growth in the economy.

The equilibrium condition (13) suffers, however, from two related limitations: the first is that value added is exogenous and no behavioral relation is involved; the second is that no dynamics can be specified. Both limitations can be tackled by assuming a behavioral relation for value added and by obtaining equilibrium values from its long-run dynamics. Then, the value-added equilibrium path can

[4] In the case of materials and supplies, the most typical reasons are cost minimization and the necessity of non stopping production when demand peaks (e.g., seasonal) require that more goods are delivered.

be described by a linearized Cobb-Douglas function where lowercase symbols denote the logs of the original variables.

If starred values indicate the unobservable equilibrium capital (k) and labor inputs (n) moving along their steady-state path we have:

(14) $va_t^* = \theta_t^* + \alpha k_t^* + (1-\alpha)n_t^*.$

The θ_t variable is the time-varying and serially correlated TFP shifter reaching θ_t^* when the long-lasting productivity shock η_t is absorbed. The stochastic process driving θ_t is supposed to be AR(1) and characterized by a root smaller but close to one:

(15) $\theta_t = (1-\rho)\theta + \rho\theta_{t-1} + \eta_{t,} \quad \mid \rho \mid < 1, \;\; \eta_t \sim iid(0, \sigma_\eta^2).$

If the actual value added is produced by utilizing the observable input levels for capital (K) and labor (N):

(16) $va_t = \theta_t + \alpha k_t + (1-\alpha)n_t.$

the total inventory changes express the cyclical utilization variables

(17) $\Delta h_t = \alpha(k_t - k_t^*) + (1-\alpha)(n_t - n_t^*) + (\theta_t - \theta_t^*) + d_t,$

where $\Delta h_t = \log(H_t/H_{t-1})$.

Equation (17) is a reformulation of equation (12), showing that inventory changes are used to buffer both the final and the intermediate sales for a given output level. While equation (12) shows that inventory changes are related to sales fluctuations, equation (17) shows that inventories are used to replace the slow adjustment in the demand for factors. A further implication is that inventory changes can make observable some aggregate utilization variable without the necessity of resorting to arbitrary measurement for inputs or potential capacity.

Error and inventory correction mechanism

The partial adjustment mechanism between the short-run and the long-run path of the economy

(18) $\Delta va_t = \lambda(va_t^* - va_t), \qquad 0 < \lambda < 1,$

can be obtained by minimizing with respect to the relevant variable (value added) the one-period quadratic cost function

(19) $C = a_1(\Delta va_t)^2 + a_2(va_t^* - va_{t-1})^2.$

This implies that $\lambda = a_2(a_1 + a_2)^{-1}$, i.e. that the adjustment speed reflects in equation (18) the relative weight between the cost of being out of the target and the adjustment cost. However, the partial adjustment mechanism can be seen as a special case of the more general error correction model:

$$(20)\quad \Delta va_t = \lambda_1 \Delta va_t^* + \lambda_2 (va_{t-1}^* - va_{t-1}),$$

which has the same interpretation except for the fact that λ_1 does not have to be equal to λ_2.

Equation (20) renders explicit the difference between correcting the deviation from equilibrium and moving along the equilibrium path.[5] Likewise, the ECM can be obtained by minimizing a quadratic cost function where equation (19) is augmented by a cross term pointing that that the cost of adjustment falls (rises) if the economy moves in the right (wrong) direction.[6]

Regardless of which type of adjustment is chosen, we do not follow here the common practice of specifying some exogenous variable to make observable the target in the resulting reduced form. Instead, we prefer estimating a dynamic version of the observed value-added equation (16) since the equilibrium target (14) cannot differ from the long-run value implied by the estimated dynamics.

To do so, we shall use the outlined model for obtaining an inventory-augmented reduced form and then for showing that our specification is equivalent to an ECM that does not use extraneous information. This equivalence between the inventory-augmented (value added) production functions and the ECM is possible since inventory changes is a stationary variable acting as an equilibrium correction term.

Supposing for simpler analysis that an ADL(1,2) model is sufficient to produce white noise residuals, we specify first the unrestricted dynamic model:

$$(21)\quad va_t = \theta + \alpha_1 k_t + \alpha_2 k_{t-1} + a_3 n_t + a_4 n_{t-1} + a_5 va_{t-1} + \eta_t/(1-\rho L),$$

which under constant returns requires $\sum_{i=1}^{5} a_i = 1$ and also $\alpha = (a_1 + a_2)/(1-a_5), (1-a) = (a_3+a_4)/(1-a_5)$, $\theta^* = \theta/(1-a_5)$ or else that $\text{va}_t = \text{va}_t^*$ along the steady-state growth path.

After accounting for the common factor $(1-\rho L)$ and for a convenient reparameterization of (21), the ECM formulation consistent with constant returns becomes:

$$\begin{aligned}(22)\quad \Delta va_t = \; & \theta(1-\rho) + \eta_t + \\ & [\alpha_1(1-\rho L)\Delta k_t + a_3(1-\rho L)\Delta n_t + \rho \Delta va_{t-1}] + \\ & -(1-\rho L)[(1-a_5)va_{t-1} - (a_1+a_2)k_{t-1} - (a_3+a_4)n_{t-1}],\end{aligned}$$

which implies white noise residuals (1st row), transitory dynamics (2nd row) and, finally, an error correction term which is equal to the equilibrium condition once the short-run deviations are absorbed.

[5] In a sense, this point was informally anticipated in the inventory literature by Feldstein and Auerbach (1976) when disentangling between the cost of changing and the cost of reaching the inventory target.

[6] This was first shown in an intertemporal setting by Nickell (1985).

By assuming that both capital and labor grow at some constant rate σ, the long-run solution of (21) will be:

$$(23)\quad (VA_t/N_t)^* = \Theta^*(K_t^*/N_t^*)^\alpha,$$

where $\Theta^* = \exp(\theta^+)$, $\theta^+ = [\theta^* - \sigma(1-a_1-a_3)/(1-a_5)]$.[7]

The relation between the ECM and the inventory adjustment model can be seen by combining the logged equivalent of equation (13)[8]

$$(24)\quad va_t^* = va_t - \Delta h_t + \delta_t, \qquad (\delta_t = \delta + \epsilon_t,\ \epsilon_t \sim iid[0, \sigma_\epsilon^2]),$$

with equations (16) and (20) whose second term corrects the previous-period difference (16) between the equilibrium and the actual realization:

$$(25)\quad \Delta va_t = \lambda_1(\Delta va_t - \Delta^2 h_t + \Delta\delta_t) + \lambda_2(\delta_{t-1} - \Delta h_{t-1}).$$

This formulation corresponds to the transient dynamics

$$(26)\quad \Delta va_t = \tfrac{\lambda_2}{1-\lambda_1} d - (\tfrac{\lambda_2}{1-\lambda_1}\Delta h_{t-1} + \tfrac{\lambda_1}{1-\lambda_1}\Delta^2 h_t) + v_t,$$

where $\mathrm{v}_t = [\frac{\lambda_1\epsilon_t + (\lambda_2-\lambda_1)\varepsilon_{t-1}}{1-\lambda_1}]$ is a shortly decaying MA(1) process that allows us to introduce some autoregressive term if the implied dynamics is not sufficient for filtering out the regression residuals.[9]

By renormalization, equation (26) can be solved in term of the observed production function. Further, by assuming that the drift in the economy (d) is somehow related to the productivity shock, the lagged TFP variable can be updated to the current value in the light of equation (15). As a result, we obtain the following reduced form:

$$(27)\quad va_t = \theta_t + \alpha k_{t-1} + (1-\alpha)n_{t-1} - (\tfrac{\lambda_2}{1-\lambda_1}\Delta h_{t-1} + \tfrac{\lambda_1}{1-\lambda_1}\Delta^2 h_t) + v_t,$$

that will provide the benchmark for our estimates.

The fact that no long-lasting dynamics appears in v_t reflects the role of inventories in filtering out most of the high-frequency shocks while the TFP term primarily accounts for the accumulation of the productivity shocks since $\theta_t = \theta + \sum_{i=0}^{\infty}\rho^i\eta_{t-i}$.

The dynamic, inventory-augmented, production function can then be expressed as:

[7] This expression further simplifies if the size of the economy (d) and the TFP term grow at the same rate.

[8] This would imply only that the expected value of $\mathrm{E}(\mathrm{e_t}) = 1$ rather than zero and that the drift term (δ) should be calibrated accordingly, if necessary.

[9] This also implies that inventory changes do not capture all the high-frequency cycles for unit-root detrended value added data.

(28) $(VA_t/N_t) = \Theta(K_{t-1}/N_{t-1})^{\alpha}\hat{H}_{t-1}^{-\gamma}$,

where $\hat{H}_{t-1}^{-\gamma} = \exp[[(\lambda_1 + (\lambda_2 - 2\lambda_1)L + (\lambda_1 - \lambda_2)L^2]/(1-\lambda_1)]h_t = 1$ in the long run. Hence, we have the corresponding long-run solution which also establishes the equivalence with the ECM formulation (23):

(29) $(\mathrm{VA}_t/\mathrm{N}_t)^* = \Theta(K_t/N_t)^{\alpha}$.

What should be noted in equation (28) is that the inventory adjustment terms capture the short-run cycles and correct the short-run value-added imbalances since $\gamma > 0$. Moreover, in both the ECM and in the inventory-augmenting case, we are estimating production functions from actual data: when using the inventory augmented equation, however, less lags should be required if the inventory terms capture the short-run dynamics not accounted for by the TFP induced fluctuations. As a result, inventory changes allow to estimate the "true" parameter α by using directly the observed data (K,N,H) and without losing many degrees of freedom as it might be needed in an unrestricted ECM approach. In the meantime, the ECM equilibrium (23) should suffer from omitted variable bias as long as inventory changes reflect short-run deviations that are not fully captured by the extra-lags in the included variables.

3. *Empirics*

In Italy's national accounts, inventory data are available in the aggregate and for the inventory changes only, no official stock measure being reported. Moreover, these data include statistical discrepancies while neither provide a distinction between the stages of production nor between the sectors of origin.

In the Italian Treasury econometric model variants of equation (26) have been estimated for those sectors holding both input and output inventories, i.e. for agriculture and industry only.[10] To avoid unnecessary detours from the main argument, I shall report here the industry value-added equation only.

In the *Appendix* three estimates are compared: the inventory-augmented value added equation (Col. 1), the corresponding level equation in which the inventory terms are omitted (Col. 2) and the ECM formulation in which the same constant return restriction holds (Col. 3).

The empirical counterpart of the inventory-augmented production function (27) explains factor-cost industry value added in Italy in terms of TFP, capital and labor inputs in the same sector, and aggregate inventory changes[11]:

(27') $(va_t/n_t) = \pi_0 + \pi_1\theta_t + \pi_2(k_{t-1}/n_{t-1}) + \pi_3(va_{t-1}/n_{t-1}) + \pi_4\Delta h_{t-2} + \pi_5\Delta^2 h_{t-1} + u_t$.

[10] The industry definition does not include constructions.

[11] All data are in volume and stem from official NIPA sources (ISTAT) except for the TFP variable that have been reconstructed by using NIPA information.

Equation (27') is estimated for quarterly NIPA, seasonally adjusted, data. ranging from 78:1 through 96:4. The OLS estimates are legitimate since the lagged regressors produce, along with the contemporaneously exogenous TFP term, residuals that are free from both serial correlation and heteroskedasticity. The MA(1) term in (27) was accounted for by introducing a single autoregressive term. Given the lack of information on the inventory changes by sector, I weighted this variable by the industry value added share on the total share holding both types of inventories.

Despite the fact that we must use a proxy for the relevant, industry, inventory variable, results are quite satisfactory both in absolute and comparative terms: in fact, when comparing this equation with the level estimate in which the inventory terms are omitted (Col 2), it appears that the latter suffers from cyclical residuals and an inferior fit. Finally, the reported ECM estimate produces serially uncorrelated residuals that are, however, plagued by heteroskedasticity, probably reflecting the volatility of the omitted inventory investment.

From the reported estimates, it can be found (see Eq. 20) that $\lambda_1 = 0.47$ while $\lambda_2 \simeq 1$. Both results are plausible and seem to confirm the Feldstein and Auerbach (1976) hypothesis that inventory adjustment is completed in about one quarter. This also implies that is much more costly (λ_1) changing the value added growth since the latter involves changing inputs to accomodate, long-lasting, productivity shocks rather than adjusting inventories to match unforeseen sales.

Overall, the high volatility of inventories can be accounted for similarly to Christiano (1988) when pointing out the residual role of inventory adjustment in a general dynamic equilibrium model: however, a major difference is that here inventories are not a substitute input for fixed capital (Kydland-Prescott, 1982), instead being an utilization variable accomodating productivity or sales shocks that factors and/or prices are unable to absorb in the short run. This happens because most of the inventory changes are *outside* of the production function, though the inventory dynamics helps to obtain the unobservable long-run production function path.

In this respect, it might be interesting to compare the long-run solution of the three estimated equations in terms of the parameters of interest. The steady-state solution for the inventory-augmented equation is:

$$\text{(A1)}\ (\mathrm{va}_t/\mathrm{n}_t) = 0.578\ \theta_t^{.754}(\mathrm{k}_t/\mathrm{n}_t)^{.336},$$

where the labor and capital share are correctly measured, amounting to about 2/3 and 1/3, respectively, of the industry value added.

Conversely, it should be noted that - in the other cases - these shares are inconsistent with the stylized facts evidence[12]: either in the steady state implied by the same equation without the inventory terms

[12] The industry labor share has a sample average value of .646 and a standard deviation of .026. This share includes the imputed labor component of the self-employees.

(A2) $(\mathrm{va}_t/\mathrm{n}_t) = 0.424\ \theta_t^{.532}(\mathrm{k}_t/\mathrm{n}_t)^{.490}$

or, even more, in the ECM solution:

(A3) $(\mathrm{va}_t/\mathrm{n}_t) = 0.318\ \theta_t^{.309}(\mathrm{k}_t/\mathrm{n}_t)^{.602}$,

which certainly overstates the capital share as - almost surely - underestimates TFP.

When comparing the expressions (A2) and (A3), it should be noted that inserting the inventory terms does not increase the value added adjustment velocity but corrects the factor share parameters while increasing the role of TFP in explaining the value added production functions.

To evaluate the empirical plausibility of the equilibrium path and of the related business cycle components, I used in Fig. 2 equation (A1) by replacing the sectoral factor ratio $(\mathrm{k}_t/\mathrm{n}_t)$ with the calculated values $(\hat{k}_t/\hat{n}_t)$ in the one-period-ahead simulation of the whole model.[13] This procedure evaluates - without implying large forecasting errors (see Fig. 1) - an equilibrium path which is model-consistent, i.e. wide-sense rational, and that produces a smooth and plausible labor productivity path in the simulation (85:1-96:4) horizon.

4. *Inventory changes and the closing of econometric models*

The previous sections have shown how inventory changes can be used to estimate equilibrium production functions from actual data. The next step is seeing how inventory changes can be used as a balancing item for closing an econometric (or else a macroeconomic) model including an inventory equation.

In the standard approach real GDP is determined by the endogenous spending components:

(1) $\mathrm{GDP}_t = \mathrm{C}_t(.) + \mathrm{G}_t + \mathrm{I}_t(.) + \Delta\mathrm{H}_t(.) + \mathrm{X}_t(.) - \mathrm{M}_t(.)$

where all symbols have the textbook meaning and where inventory investment is usually explained by some variant of the production smoothing and buffer sales approach (Lovell, 1961).

More recently, the spending approach is often supplemented by some production function determining the supply side as follows:

(2) $\mathrm{GDP}_t^* = \phi(K_t^*, N_t^*)$.

The latter expression corresponds to fully utilized capital and labor inputs, usually obtained by apriori knowledge or else by graphical or statistical methods. This allows to obtain utilization rates that reflect, however, only the factor utilization imposed to the production function or to the inputs.

[13] The total factor productivity is an exogenous variable of the model. Thus, in order to evaluate θ_t^*, I applied the Hodrick-Prescott filter to the 'observed' θ_t variable.

From this point of view, having a model does not imply any improvement with respect to the single-equation approach in which 'desired' or target values are necessarily exogenous. On the other hand, the use of growth models to determine the supply side of the economy by definition refers to a longer horizon in which business cycle is unimportant so that the applied macroeconomist is eventually left with the three following, unfortunate, alternatives:

i) determining real gdp from the demand side only
ii) fixing an exogenous or inconsistent capacity level
ii) focusing on growth factors only, i.e. leaving unexplained the sources and the possible effects of spending.

The approach followed by the Italian Treasury Econometric Model (ITEM) tries to avoid these alternatives by determining real GDP via the endogenous value-added components:

(3) $\text{GDP}_t = \sum_{i=1}^{n} VA_{it} + Z_t,$

where Z is a small balancing item, made by net indirect taxes and subsidies. The spending components are still endogenous, except government consumption which is assumed to be a policy-controlled variable. Hence inventory changes are obtained as a residual buffering aggregate supply and demand (Section 2):

(4) $\Delta H_t = GDP_t(.) + M_t(.) - [C_t(.) + G_t + I_t(.) + X_t(.)].$

In a sense, this way of closing the model implies *two* types of ECM: the first drives the value added towards its equilibrium value, while the second helps the economy (the model) to equate aggregate supply and demand: then, if the model predicts - say - an excessive volume of spending, the excess demand will result in an inventory decumulation that will increase the supply of storable goods in the next period because of the inventory-augmented term. The opposite case of an excess supply can also be dealt through the general structure of the model:

$$(5)\ \Delta H_t = [\sum_{i=1}^{n} VA_{it}(\overset{+}{K}_{it}, \overset{+}{N}_{it}; \overset{+}{\theta}_{it}; \Delta \overset{-}{H}_{it-1}) + M_t + Z_t] -$$
$$[C_t(.) + G_t + I_t(.) + X_t(.)].$$

However, this mechanism should be intended as acting mostly in the short period, it being implausible than an exogenous productivity shock will eventually result in an unintended inventory accumulation. Actually, this possibility is prevented not only from the transitory role of inventory investment but also from the specification of the spending components that include asset variables which - unlike incomes - can be affected by prices: this implies, e.g., that - when prices will fully respond to the relevant shocks - the real value of the assets will be modified accordingly, allowing spending to approach equilibrium without the necessity of adjusting inventories.

5. *Conclusions*

In this paper I tried to show that inventory changes are not a model's nuisance, it being on the contrary possible that their volatility helps the convergence between the demand and the supply side.

The suggested formulation could account for two of the major stylized facts of the inventory behavior: their procyclicality and their extreme volatility.

In principle, procyclicality should not be a problem if inventories are not confined to the finished goods but include raw materials and supplies as NIPA data actually do. Yet, procyclicality is only a positive correlation that needs some structure to be understood: in this respect, it is difficult to account for procyclicality if inventory changes are seen as an *ultimate* source of the business cycle. Conversely, procyclicality can be easily accounted for if inventories mostly reflect a residual variable, balancing supply and demand before - say - price or factor changes equate spending to the higher output following a productivity shock.

Hence, if inventory changes reflect both factor utilization and sales shocks, it is the slow adjustment in factors and prices that produces inventory fluctuations, though inventories can in turn affect next-period value added which propagates business cycle as it is mostly found in the single-equation inventory approach.

Utilization of labor might imply some labor hoarding story while utilization of materials is at the core of the traditional reasons for holding stocks of intermediate products. Buffering unpredictable sales by changing the stock of finished goods is only one of the issues at stake and it is difficult to say how important it might be without having detailed information by sector and stage of production.

In the meantime, the buffering role of inventory changes does not depend necessarily on price rigidity and can well be maintained in an RBC framework in which labor takes time to adjust even if prices are ready to clear.

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Appendix A. Industry value added per unit of labor in Italy (78:1-96:4)

	(1)		(2)		(3)		
va/n			va/n		Δ(va/n)		
	coeff	t-stat	coeff	t-stat		coeff	t-stat
c	-.174	-2.88	-.284	-3.92	c	-.095	-1.68
θ_t	.240	4.92	.176	3.94	$\Delta\theta_t$	.433	13.6
					$\Delta(\text{k/n})_t$	.382	2.82
$(\text{k/n})_{-1}$	.107	3.26	.162	3.97	$\Delta(k/n)_{-1}$	-.355	-2.41
$(\text{va/n})_{-1}$	.682	12.4	.669	9.96	$(\text{va/n})_{-1}$	-.083	-2.21
$\Delta^2(h_{-1})$	-.874	-2.51			θ_{-6}	.026	2.05
Δh_{-2}	-1.94	-4.97			$(\text{k/n})_{-1}$	.050	1.83
see	.0129		.0143		.008		
lhs	-2.93		-2.93		.017		
LM4	F=1.68	p=.164	F=2.97	p=.025	F=0.52	p=.72	
ARCH4	F=0.32	p=.857	F=.475	p=.738	F=3.04	p=.02	

Legend: va= factor-cost value in industry (ISTAT); k = capital stock in industry (ISTAT); n = labor units (ISTAT);TFP = total factor productivity; Δh = inventory changes (ISTAT); see= standard error of estimate;lhs= mean of the dependent variable; LM4 = F-test version of the Lagrange Multiplier statistics (4 lags) on residuals; ARCH4 = F-test version of the ARCH statistics (4 lags) on residuals; the t-stats are calculated from the Newey-West covariance matrix. All data are transformed in logs.

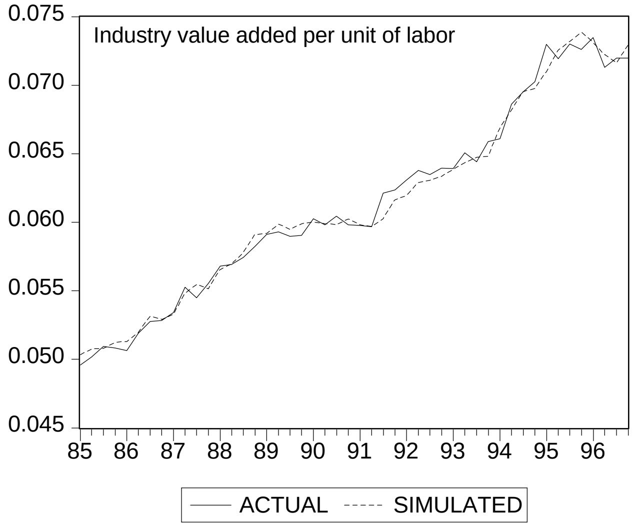

Figure 1:

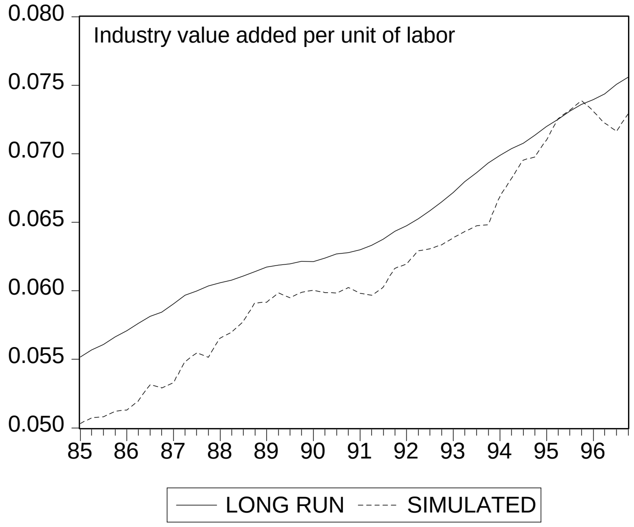

Figure 2: