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# OPEN-ECONOMY IMPLICATIONS OF TWO MODELS OF BUSINESS FLUCTUATIONS

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## ABSTRACT

This paper shows how open-economy implications of alternative business-cycle models can be used to discriminate between those models. Open-economy versions of two well-known models are presented: a model with predetermined nominal wages and a model in which nominal disturbances are misperceived as real disturbances. In the former model applied to a small economy with flexible exchange rates, an unanticipated increase in the money supply increases output of both traded and nontraded goods, lowers the relative price of nontraded goods, and induces a current-account surplus. In the latter model, an unperceived increase in the money supply increases output of nontraded goods but reduces output of traded goods, raises the relative price of nontraded goods, and induces a current-account deficit.

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This paper shows how the open-economy implications of alternative models of aggregate business fluctuations can be exploited to test those models. Most research on models of business cycles has been concentrated on closed economies. Open-economy versions of those models have been developed primarily for discussions of policy implications. However, much more can be learned about business cycles by applying these models to open economies in order to develop and test implications about the cyclical comovements of "international" variables such as the current account of the balance of payments, relative prices of nontraded and traded goods, the terms of trade, and the exchange rate. By examining open-economy models of business cycles, we can learn more not only about open economies but about business fluctuations in relatively closed economies.

We discuss a concrete example. Section II develops a model of a small open economy with flexible exchange rates that can be used to contrast a "nominal-wage-contract" model based on work by Gray (1976), Fischer (1977), and Taylor (1980) with a "misperceptions" model based on work by Lucas (1972, 1975), and Barro (1980). In the former model, monetary disturbances can have real effects because the nominal wage is at least partly predetermined. In the latter model, monetary disturbances can have real effects because they are misperceived by agents as real disturbances. While both of these models have been citizicized as being inadequate in various ways (with issues such as observability of money, optimality of the nominal contracts, and implications for real wages), these two classes of models are still widely discussed, and no alternative model of real effects of money is as widely-accepted or discussed. So it seems useful to develop additional implications of these models that can be used to evaluate their consistency with the data. We show that extensions of these models to a small open economy lead to contrasting implications for the effect of a monetary disturbance on the current account of the balance of payments, the relative price of nontraded in terms of traded goods, and output and consumption of traded goods. In addition, the models have different implications for the subsequent dynamics of relative and nominal prices, output of nontraded goods, consumption of traded goods, and the exchange rate.

## II. A Common Model

This section sets out common features of the wage-contract and misperceptions models that we study. We consider a small open economy with flexible exchange rates that produces and consumes two nonstorable goods, one traded and one nontraded. There are two assets available: domestic money and bonds denominated in foreign currency. In the misperceptions version of the model, the domestic economy is divided into local goods markets or "islands" as in Lucas (1972, 1975) and Barro (1976, 1980), to which individuals are randomly allocated at the start of each period. The traded good and the two assets can be traded both with individuals in other islands and in the rest of the world. However, the nontraded good cannot be traded either across islands or internationally. Our open-economy extension of the misperceptions model thus differs from the earlier works by Saidi (1980, 1982), Lawrence (1981), and Kimbrough (1983). Our open-economy extension of the nominal-wage contract model is similar to that of Marston (1984) and Flood and Marion (1982), though its focus is different.

The demands for traded and nontraded goods are, in log-form,

$$T_t^d(z) = \gamma_1^d(P_{N_t}(z)-P_{T_t}) + \gamma_2^d a_t(z) + \gamma_3^d(m_t-E_{z_t}m_t) \tag{1}$$

and

$$N_t^d(z) = -\alpha_1^d(P_{N_t}(z)-P_{T_t}) + \alpha_2^d a_t(z) + \alpha_3^d(m_t-E_{z_t}m_t) + \varepsilon_t(z) \tag{2}$$

In the misperceptions version of the model, (1) and (2) give demands by individuals on each island, indexed by z. In the wage-contract version of the model, the index z can be ignored in (1) and (2).[1] $P_{N_t}(z) - P_{T_t}$ is the (log) relative price of the nontraded good (in z). $a_t(z)$ is a wealth term showing the net level of foreign-currency assets held by the domestic country (in z) at the beginning of period t. $m_t = M_t - M_{t-1}$ is the change in the (log) money supply at time t, which occurs through transfer payments from the government. $E_{z_t} m_t$ is the expectation of $m_t$ conditional on information available at time t (in z). $m_t - E_{z_t} m_t$ is then the unperceived (in z) change in the money supply. As explained in Barro (1980), variations in this term produce wealth effects: an increase in $m_t$ given $E_{z_t} m_t$ raises wealth because each individual interprets his own transfer payment as a transfer of (money) resources to him from other individuals. On the other hand, if $m_t$ and $E_{z_t} m_t$ rise together, the individual correctly sees that increase in his own money holding reflects a general increase in the money supply which, because it raises nominal prices, does not add to his real money stock. The term $m_t - E_{z_t} m_t$ is an approximation of this wealth effect; the derivation is discussed in Barro (1980).

A random disturbance to the demand for nontraded goods, $\varepsilon_t(z)$, has been included in (2). For simplicity, we have omitted a similar term in (1), and we assume that $\varepsilon_t(z)$ sums to zero across z.[2]

We assume that the demand for money is

$$M_t = \phi P_{T_t} + (1-\phi)P_{N_t} + \Omega N_t^s + (\eta-\Omega)T_t^s \tag{3}$$

where $N_t^s(z)$ and $T_t^s(z)$ are outputs of nontraded and traded goods (in z), and $P_{N_t}$, $N_t^s$, and $T_t^s$ are averages (over z) of $P_{N_t}(z)$, $N_t^s(z)$, and $T_t^s(z)$.[3] It is straightforward to include a nominal interest rate in (3) but it complicates the model's solution without changing its qualitative characteristics. The supply of money is

$$M_t^s = M_{t-1}^s + m_t \tag{4}$$

where $m_t$ is an i.i.d. normal random variable with mean zero and variance $\sigma_m^2$ and is independent of $\varepsilon_t(z)$.

The domestic country faces an exogenous foreign-currency price of traded goods $P^*_{T_t}$, and the domestic-currency price is assumed to be

$$P_{T_t} = e_t + P^*_{T_t} + \xi_t \tag{5}$$

where $\xi_t$ is i.i.d. normal with mean zero, variance $\sigma_\xi^2$ (possibly zero), and is independent of $\varepsilon_t(z)$ and $m_t$.

Supplies of traded and nontraded goods are obtained by equating the marginal product of labor in each sector to the (own-product) real wage. In log form,

$$T^s_t(z) = -\lambda_T(W_t(z)-e_t-P^*_{T_t}-\xi_t) + \mu_t(z) \tag{6}$$

and

$$N^s_t(z) = -\lambda_N(W_t(z)-P_{N_t}(z)). \tag{7}$$

We have assumed that the nominal wage $W_t(z)$ is equated across industries (in z) and have included a random disturbance term, $\mu_t(z)$, to (6). We assume $\mu_t(z)$ is i.i.d. normal with mean zero, variance $\sigma_\mu^2$, and is independent of $\varepsilon_t(z)$, $m_t$, and $\xi_t$. As in (1) and (2), the index z can be ignored in the wage-contract version of the model.

## III. Differences in Supply

While (6) and (7) characterize output supply in both the nominal-wage-congract and misperception versions of the model, wage determination differs in the two models.

### A. The Nominal-Contracts Model

In this model we assume that the nominal wage $W_t$(or $W_t(z)$) is fixed in t-1, before the realization of random variables in t. Incomplete indexation would not affect the main features of the model. Employment is assumed, following Gray (1976) and Fischer (1977), to be determined on the demand side. A more realistic wage-setting process, following the work of Taylor (1980), might involve longer-term overlapping contracts and other features. Although it is not required for our purposes, one might assume that the wage $W_t$ is set in t-1 at the conditional expectation (based on t-1 information) of the nominal wage in (8) below.

### B. The Misperceptions Model

Labor supply is a function of the real wage in terms of the consumption bundle and of wealth, so the equilibrium wage in z is assumed to be

$$W_t(z) = \omega_1 P_{T_t} + (1-\omega_1)P_{N_t}(z) + \omega_2 a_t(z) + \omega_3(m_t - E_{z_t} m_t). \quad (8)$$

Substituting into (6) and using (5) we have

$$T_t^s(z) = -\lambda_T(1-\omega_1)(P_{N_t}(z)-e_t-P_{T_t}^* -\xi_t) - \lambda_T\omega_2 a_t(z)$$

$$-\lambda_T\omega_3(m_t-E_{z_t}m_t) + \mu_t(z) \tag{9}$$

$$\equiv -\gamma_1^s(P_{N_t}(z)-e_t-P_{T_t}^* -\xi_t) - \gamma_2^s a_t(z) - \gamma_3^s(m_t-E_{z_t}m_t) + \mu_t(z),$$

and, similarly,

$$N_t^s(z) = \alpha_1^s(P_{N_t}(z)-e_t-P_{T_t}^* -\xi_t) - \alpha_2^s a_t(z) - \alpha_3^s(m_t-E_{z_t}m_t). \tag{10}$$

The misperceptions model differs from the nominal-wage contracts model in two ways. First, the nominal wage $W_t(z)$ is determined by labor market equilibrium in period t and is given by (8) rather than being set in period t-1. Second, while individuals in the nominal-wage contracts model know, in period t, all variables dated t and earlier, in the misperceptions model an individual in z at date t knows only variables dated t-1 and earlier, plus the prices on economy-wide markets $e_t$ and $P_{T_t}$ and the price of the nontraded good in his own local market, $P_{N_t}(z)$. From this information he extracts estimates of $P_{T_t}^* + \xi_t$, $m_t$, $\mu_t(z)$, and $\varepsilon_t(z)$; there are misperceptions in the sense that these estimates are not perfect, *i.e.*, generally, $E_{z_t}m_t \neq m_t$.

## IV. Solutions of the Model

### A. With Nominal-Wage Contracting

Conditional on the predetermined nominal wage $W_t$, equating $N_t^s$ and $N_t^d$ gives[4]

$$P_{N_t} = (\lambda_N+\alpha_1^d)^{-1}[\lambda_N W_t + \alpha_1^d e_t + \alpha_1^d(P_{T_t}^* + \xi_t) + \alpha_2^d a_t]. \tag{11}$$

Note that the money-wealth term, $m_t - E_{z_t} m_t$, is zero because individuals can observe all current prices and infer the money supply exactly. (Alternatively, we can think of individuals as having direct observations on the money supply.) Equating money supply to money demand and using (5)-(7) and (11), one obtains

$$\begin{aligned} e_t = \delta^{-1}\{&(\lambda_N+\alpha_1^d)(M_{t-1}+m_t) - (\eta-\Omega)(\lambda_N+\alpha_1^d)\mu_t \\ &- W_t[(1-\phi)\lambda_N - \Omega\lambda_N\alpha_1^d - (\eta-\Omega)\lambda_T(\lambda_N+\alpha_1^d)] \\ &- a_t[(1-\phi)\alpha_2^d + \Omega\lambda_N\alpha_2^d]\} - P_{T_t}^* - \xi_t \end{aligned} \tag{12}$$

where

$$\delta \equiv \phi\lambda_N + \alpha_1^d + \Omega\lambda_N\alpha_1^d + (\eta-\Omega)\lambda_T(\lambda_N+\alpha_1^d) > 0. \tag{13}$$

Then combining (11) and (12),

$$\begin{aligned} P_{N_t} = \delta^{-1}\{&\alpha_1^d(M_{t-1}+m_t) - \alpha_1^d(\eta-\Omega)\mu_t \\ &+ W_t[\phi\lambda_N + \Omega\lambda_N\alpha_1^d + (\eta-\Omega)\lambda_T(\lambda_N+\alpha_1^d)] \\ &+ a_t[\phi\alpha_2^d + (\eta-\Omega)\lambda_T\alpha_2^d]\}. \end{aligned} \tag{14}$$

Since an increase in $m_t$, given the predetermined $W_t$, raises both $e_t$ and $P_{N_t}$, (6) and (7) imply that it raises outputs of both traded and nontraded goods. While consumption of the nontraded good rises with its output, the relative price of the nontraded good falls since

$$P_{N_t} - P_{T_t} = -\delta^{-1}\lambda_N(M_{t-1}+m_t) + \delta^{-1}\lambda_N W_t + \delta^{-1}\alpha_2^d[1 + \Omega\lambda_N + (\eta-\Omega)\lambda_T]a_t + \delta^{-1}(\eta-\Omega)\lambda_N\mu_t. \tag{15}$$

(1) then implies that an increase in $m_t$ given $W_t$ lowers the demand for traded goods. Since an increase in $m_t$ raises $T_t^s$ but lowers $T_t^d$ it creates a balance-of-trade surplus (relative to the initial situation). In sum, an increase in the money supply in t that was unexpected as of t-1 and not reflected in the nominal wage established then raises output of both traded and nontraded goods, lowers the relative price of nontraded goods (while raising the nominal price) and creates a trade surplus.

## B. With Misperceptions

Equating $N_t^d(z)$ with $N_t^s(z)$ gives

$$P_{N_t}(z) - P_{T_t} = \frac{\alpha_3}{\alpha_1}(m_t - E_{z_t}m_t) + \frac{\alpha_2}{\alpha_1}a_t(z) + \frac{1}{\alpha_1}\varepsilon_t(z) \tag{16}$$

where $\alpha_i \equiv \alpha_i^d + \alpha_i^s$ and $\gamma_i \equiv \gamma_i^d + \gamma_i^s$. Then

$$N_t(z) = A(m_t - E_{z_t}m_t) + A'a_t(z) + \frac{\alpha_1^s}{\alpha_1}\varepsilon_t(z) \tag{17}$$

where

$$A \equiv \frac{\alpha_1^s\alpha_3^d-\alpha_1^d\alpha_3^s}{\alpha_1}$$

$$A' \equiv \frac{\alpha_1^s\alpha_2^d-\alpha_1^d\alpha_2^s}{\alpha_1}.$$

We assume that $A > 0$ so that an increase in $m_t - E_{z_t}m_t$ raises output of nontraded goods. This assumption corresponds to a similar one made in the closed-economy models to which this model corresponds.[5] Note that, in any case, (16) implies that an increase in $m_t - E_{z_t}m_t$ raises $P_{N_t}(z) - P_{T_t}$.

The demand for traded goods, using (16), is

$$T_t^d(z) = (\gamma_1^d\frac{\alpha_3}{\alpha_1}+\gamma_3^d)(m_t-E_{z_t}m_t) + (\gamma_1^d\frac{\alpha_2}{\alpha_1}+\gamma_2^d)a_t(z) + \frac{\gamma_1^d}{\alpha_1}\varepsilon_t(z) \tag{18}$$

so that an increase in $m_t - E_{z_t}m_t$ raises the demand for traded goods. Output of traded goods is

$$T_t^s(z) = -(\gamma_1^s\frac{\alpha_3}{\alpha_1}+\gamma_3^s)(m_t-E_{z_t}m_t) - (\gamma_1^s\frac{\alpha_2}{\alpha_1}+\gamma_2^s)a_t(z) - \frac{\alpha_1^s}{\alpha_1}\varepsilon_t(z) + \mu_t(z) \tag{19}$$

so a monetary disturbance unambiguously lowers the production of traded goods.

Using (16) and money-market equilibrium, one can obtain results for nominal prices:

$$P_{N_t} = M_t + [\phi\frac{\alpha_3}{\alpha_1} - \Omega A + (\eta-\Omega)(\gamma^s_1\frac{\alpha_3}{\alpha_1}+\gamma^s_3)](m_t-E_tm_t)$$
$$+ [\phi\frac{\alpha_2}{\alpha_1} - \Omega A' + (\eta-\Omega)(\gamma^s_1\frac{\alpha_2}{\alpha_1}+\gamma^s_2)]a_t \qquad (20)$$
$$- (\eta-\Omega)\mu_t$$

where $P_{N_t}$, $E_tm_t$, $a_t$, and $\mu_t$ are the economy-wide averages (over z) of $P_{N_t}(z)$, $E_{z_t}m_t$, $a_t(z)$ and $\mu_t(z)$. The term in $\varepsilon_t(z)$ drops out of (20) as we have aggregated over z. Similarly,

$$e_t = M_t + [(\phi-1)\frac{\alpha_3}{\alpha_1} - \Omega A + (\eta-\Omega)(\gamma^s_1\frac{\alpha_3}{\alpha_1}+\gamma^s_3)](m_t-E_tm_t)$$
$$+ [(\phi-1)\frac{\alpha_2}{\alpha_1} - \Omega A' + (\eta-\Omega)(\gamma^s_1\frac{\alpha_2}{\alpha_1}+\gamma^s_2)]a_t \qquad (21)$$
$$- (\eta-\Omega)\mu_t - P^*_{T_t} - \xi_t.$$

Notice that the coefficient of $m_t - E_tm_t$ in (21) can be either positive or negative. Because $M_t$ enters (21) separately with a unit coefficient, a positive coefficient of $m_t - E_tm_t$ implies that the exchange rate overshoots its long-run equilibrium level in response to an unperceived increase in the money supply (i.e. holding fixed $E_tm_t$). Similarly, a negative coefficient implies undershooting.

The method of undetermined coefficients can be used to solve the model in the presence of rational expectations. In the general case, no closed-form solution to the model is possible. However, we consider the restricted case in which

$$(\phi-1)\frac{\alpha_3}{\alpha_1} - \Omega A + (\eta-\Omega)(\gamma^s_1\frac{\alpha_3}{\alpha_1}+\gamma^s_3) = 0 \qquad (22)$$

so that, in (21), a monetary disturbance that is not currently perceived has a unit effect on the exchange rate (neither overshooting nor undershooting). Given (22), the solution is given in the Appendix. A monetary disturbance raises the relative price of nontraded goods and, therefore, raises output along with consumption. But the wealth effect of the monetary shock and the fall in the relative price of the traded good both increases demand for the traded good and reduces its output, creating a balance-of-trade deficit.

## V. Discussion

An unanticipated increase in the money supply in the nominal-wage-contract version of the model raises output of both traded and nontraded goods, lowers the relative price of nontraded goods, raises the exchange rate (by a greater amount than predicted by purchasing power parity, because of the fall in the relative price of nontraded goods) and the nominal price of nontraded goods, and lowers consumption of traded goods. The higher output and lower demand for traded goods show up as a trade or current-account surplus relative to the original situation. The current-account surplus raises wealth and, by (15), leads to a higher relative price of nontraded goods in subsequent periods. In a fuller model with overlapping contracts, the subsequent dynamics (which are trivial in the simple model presented above) would depend on the magnitude of this wealth increase through the current account and on the dynamics of wage changes. The increase in $a_{t+1}$ also leads to greater output of nontraded goods in subsequent periods as long as $A' > 0$, and to a greater demand for traded goods in subsequent periods.

An increase in the money supply in the misperceptions version of the model is not fully perceived by individuals. As a result, the relative price of nontraded goods rises, output of nontraded goods rises, but output of traded goods falls, both because of the wealth effect on aggregate labor supply and because the relative price change induces factors to move from the traded goods sector to the nontraded goods sector. The money supply increase also leads to an increase in consumption of traded goods. Both the fall in supply and increase in demand for traded goods operate to produce a trade or current-account deficit relative to the original situation. This current account deficit reduces the net stock of foreign assets in subsequent periods, and this reduces the demands for both traded and nontraded goods in subsequent periods, lowering the relative price of nontraded goods and their output, and turning the original current-account deficit into a current account surplus.

The effects of an increase in the money supply on the nominal price of nontraded goods and on the exchange rate are ambiguous. Given the demand for money (e.g. if $\eta = \Omega = 0$), the nominal price of nontraded goods initially rises--see (20). But the increased output of nontraded goods could increase the demand for money enough that $P_{N_t}$ falls, if $\Omega$ and A are sufficiently large. The effect of unperceived money on the exchange rate is ambiguous even if the demand for money is fixed (e.g. $\eta = \Omega = 0$). While nominal variables such as the exchange rate rise to the extent the money supply increase is perceived, unperceived money raises $P_{N_t} - P_{T_t}$, and this occurs partly through a rise in $P_{N_t}$ and a fall in $P_{T_t}$, which in turn occurs through a fall in the exchange rate. Greater output of nontraded goods tends to lower the exchange rate through an increase in the demand for money, while lower output of traded goods tends to raise the exchange rate.

The inference problem in the misperceptions model involves sorting out $m_t$, $P^*_{T_t} + \xi_t$, $\varepsilon_t(z)$, and $\mu_t$ from observations on $e_t$, $P_{T_t}$, and $P_{N_t}(z)$. By (5), this reduces trivially to the problem of extracting estimates of $m_t$, $\varepsilon_t(z)$, and $\mu_t$ from $P_{T_t}$ (or $e_t$) and $P_{N_t}(z)$. Since a rise in $P_{T_t}$ can be due to either a rise in $m_t$ or a fall in $\mu_t$, and a rise in $P_{N_t} - P_{T_t}$ can be due to increases in $m_t$, $\mu_t$, or $\varepsilon_t(z)$, changes in $m_t$ are partly misperceived as changes in $\mu_t$ and $\varepsilon_t(z)$, and this leads to the results discussed above.

One should be careful not to reject the implications of either version of the model on the basis of casual evidence, since the discussion here has held fixed disturbances originating in the rest of the world. Econometric analysis of the implications of the model must account for the effects of foreign disturbances. It should be clear, for example, that simultaneous unexpected increases in the money supply in the rest of the world, but not in the domestic country, would induce a current account deficit in the nominal contract version of the model.

The nominal-wage-contract and misperception models of aggregate business fluctuations have similar implications in closed economies, though they can be tested by distinguishing empirically between unanticipated money and (currently) unperceived money, or in ways pursued by Ahmed (1983). However, these models have strikingly different implications when extended to an open economy. Thus, the example presented in this paper both suggests a new set of tests to which these two models of business cycles can be subjected, and illustrates a procedure for obtaining new testable implications from other closed-economy macroeconomic models.

## Footnotes

1. Two alternative interpretations of the wage-contract model are possible. First, one can ignore the index z and think of the domestic country as not being divided into local markets or islands. In that case, the nontraded good can be traded domestically but not internationally. Alternatively, if the reader wishes to make the wage-contract model more similar to the misperceptions model, he can retain the notion of islands in the wage-contract model. As long as individuals observe the current level of the money supply, the existence of islands--which limit domestic trade of the nontraded good--will not produce the confusion of nominal and real shocks that is the main feature of the misperceptions model.
2. We have also omitted intertemporal relative prices from our demand and supply functions for simplicity. Closed-economy versions of the misperceptions model have generally focused on intertemporal rather than intratemporal relative prices. Intertemporal substitution is discussed in an earlier, longer version of this paper. If substitution over time is large enough, some of the results reported in this paper can be changed. Most empirical studies have, however, failed to find substantial intertemporal substitution.
3. Assuming a nil response of the demand for money to the nominal interest rate in (3) simplifies the model without affecting the qualitative behavior of real variables.
4. We ignore the index z here. Alternatively, (11) describes $P_{N_t}(z)$. But as long as each island z is identical _ex ante_, (11) describes $P_{N_t}$, the average price of nontraded goods, and (12)-(15) follow.

5. Barro and King (1983) have shown that in a closed-economy model with identical consumers, no investment, and a time-separable utility function, the number corresponding to A must be zero. Without time-separable utility, that magnitude can be positive, but then many intertemporal relative prices should be included in the demand functions. While this argument may pose a problem for the closed-economy models, it poses no problem in an open economy.

## Appendix

Given (22), the misperceptions model has the solution

$$P_{N_t}(z) - P_{T_t} = \frac{(1-b_2)\alpha_3}{\alpha_1+b_1\alpha_3} m_t + \frac{\alpha_2}{\alpha_1} a_t(z) + \frac{b_2\alpha_3(\eta-\Omega)}{\alpha_1+b_1\alpha_3} \mu_t + \frac{1}{\alpha_1+b_1\alpha_3} \varepsilon_t(z) \tag{A1}$$

and, with $P_T = e_t + P^*_{T_t} + \xi_t$,

$$e_t = M_{t-1} + m_t + [(\phi-1)\frac{\alpha_2}{\alpha_1} - \Omega A' + (\eta-\Omega)(\gamma^s_1 \frac{\alpha_2}{\alpha_1}+\gamma^s_2)]a_t - (\eta-\Omega)\mu_t - P^*_{T_t} - \xi_t. \tag{A2}$$

where

$$b_1 \equiv \alpha_1[\frac{1}{(\eta-\Omega)^2\alpha_3\sigma^2_\mu} + \frac{1}{\alpha_3\sigma^2_m}]^{-1} \sigma_\varepsilon^{-2} > 0 \tag{A3}$$

$$b_2 \equiv [1 + (\eta-\Omega)^2\frac{\sigma^2_\mu}{\sigma^2_m}]^{-1} \in (0,1). \tag{A4}$$

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