Comparative Statics under Variable Returns to Scale Once Again

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Abstract

With an introduction of variable returns to scale (VRS), various paradoxical comparative statics results are observed. Among these paradoxical results, Jones's assumptions (1968) play an important role to obtain the usual form of the Stopler-Samuelson and Rybczynski theorems. However, since Panagariya (1980) has made some critics on Jones's assumptions, the above two theorems seem to lose their robustness under (VRS). This paper provides a condition in which the above two theorems hold in the usual form under (VRS) when Jones's assumptions are not imposed. It is shown that the perversity of the two theorems can occur only when scale diseconomies exist. That is, Panagariya's critics can only be applied for the case of scale diseconomies. Thus, our new condition implies Jones's assumptions, hence providing another economical interpretation of Jones's assumptions. In addition, it can be seen that Jones's assumptions tend to fail only when scale diseconomies work strongly. Therefore, we may conclude that Panagariya's critics

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can be applied in a very limited situation, and that Jones's assumptions under VRS are plausible.

Keywords : Variable returns to scale ; Scale diseconomies ; Marshallian stability ; Stolper-Samuelson theorem ; Rybczynski theorem ;

1. INTRODUCTION

Since the assumption of constant returns to scale technology is dropped, and scale economies and diseconomies [i.e., variable returns to scale (VRS)] is introduced in Heckscher-Ohlin model, it has been shown in the literature that various paradoxical comparative statics results can occur. The problem of VRS and trade is by no means new as indicated by survey articles by Chipman (1965, pp.736-749) and Helpman (1984), and has attracted a great deal of attention, producing contributions such as Takayama (1967), Jones (1968), Herberg and Kemp (1969), Kemp (1969), Mayer (1981), Panagariya (1980), Markusen and Melvin (1981), Ethier (1982), Ide-Takayama (1988), some of which are surveyed in Helpman (1984) and Krugman (1987). Among many contributions on this topic, we focus our attention on Jones (1968), more specifically we focus on assumptions imposed in his paper. It has been shown that the normal Stolper-Samuelson and Rybczynski theorems can be obtained under these assumptions [i.e., Jones's assumptions 2 (A2) and 3 (A3)]. However, Panagariya (1980, p.500) has argued that "(A2) and (A3) impose severe restrictions on the general equilibrium system, and that as a result of these assumptions, many interesting implications of VRS are left out of consideration." He has also given some numerical examples in which (A2) and (A3) fail (pp.516-518). If we can not impose (A2) and (A3), we have to abandon the robust results of the above two theorems. In order to avoid these to happen, we are interesting to find a condition in which the two theorems hold in the usual form without imposing Jones's assumptions. In other words, we look for a criterion in which Jones's assumptions are satisfied. As we find such a new condition, then we can ask a question whether (A2) and (A3) are restrictive or not.

Throughout this paper we assume an incomplete specialization. For obtaining the stability condition, we assume Marshallian adjustment process which corresponds to capital adjustment process. [For a discussion of Marshallian stability under VRS, see Ide-Takayama (1991).] Also, in order to obtain the robustness of the above two theorems, we focus our attention on an economy where scale diseconomies are excluded from VRS. We will then show that (A2) and (A3) do not fail in such an economy, provided the equilibrium is Marshallian stable. In other words, (A2) and (A3) hold automatically, so that Jones's assumptions do not impose any restrictions on the system, and that the Stolper-Samuelson and Rybczynski theorems can be obtained in the usual form in such an economy. Only when we allow scale diseconomies in the model, it is possible that (A2) and (A3) can fail. Thus, our new condition implies Jones's assumptions, hence providing another economical interpretation of Jones's assumptions. In addition, it can be seen that Jones's assumptions tend to fail only when scale diseconomies work strongly. Therefore, we may conclude that Panagariya's critics can be applied in a very limited situation, and that Jones's assumptions under VRS are plausible.

The structure of the paper follows. Section 2 presents the basic model. Section 3 introduces Jones's Assumptions 2 and 3, and the normal sign patterns for the Stolper- Samuelson and Rybczynski theorems. Section 4 presents the main results of this paper : (A2) and (A3) hold automatically under the economy with no scale diseconomies, so that the normal sign patterns can be obtained. Section 5 provides the concluding remarks.

2. MODEL

We consider an economy consisting of two industries, X and Y, each using the same two factors of production, labor (L), and capital (K). Following Panagariya (1980), we write the production function as :

$$X = h_X(X)f(L_X,K_X) \equiv F(L_X,K_X) \tag{1a}$$

$$Y = h_Y(Y)g(L_Y,K_Y) \equiv G(L_Y,K_Y) \tag{1b}$$

where L_j and K_j, respectively, denote the amounts of labor and capital used in the jth industry. It is assumed that f and g are homogeneous of degree one with respect to inputs, labor and capital. The argument X in h_X and the argument Y in h_Y capture variable returns to scale, and F and G are homothetic with respect to inputs, labor and capital. For a discussion of the general form of (1), see Ide-Takayama (1991).

Let a_{ij} denote the quantity of factor i required to produce one unit of good j. The requirement that both factors are fully employed is given by :

$$a_{LX}X + a_{LY}Y = L, \qquad a_{KX}X + a_{KY}Y = K \tag{2}$$

where L and K, respectively, denote the endowment of labor and capital. In addition, we have the following zero-profit condition :

$$a_{LX}w + a_{KX}r = p, \qquad a_{LY}w + a_{KY}r = 1 \tag{3}$$

where p denotes the price of good X in terms of good Y, and where w and r, respectively, denote the wage rate and the rental rate in terms of good Y. The four equations (2) and (3), in rate of change terms, are shown in :

$$\lambda_{LX}\hat{X} + \lambda_{LY}\hat{Y} = \hat{L} - [\lambda_{LX}\hat{a}_{LX} + \lambda_{LY}\hat{a}_{LY}] \tag{2'a}$$

$$\lambda_{KX}\hat{X} + \lambda_{KY}\hat{Y} = \hat{K} - [\lambda_{KX}\hat{a}_{KX} + \lambda_{KY}\hat{a}_{KY}] \tag{2'b}$$

$$\theta_{LX}\hat{w} + \theta_{KX}\hat{r} = \hat{p} - [\theta_{LX}\hat{a}_{LX} + \theta_{KX}\hat{a}_{KX}] \tag{3'a}$$

$$\theta_{LY}\hat{w} + \theta_{KY}\hat{r} = -[\theta_{LY}\hat{a}_{LY} + \theta_{KY}\hat{a}_{KY}] \tag{3'b}$$

where (^) signifies the rate of change, λ_{ij} is the fraction of the ith factor used in the jth production, and θ_{ij} signifies the ith cost share of the jth industry.

The coefficients of production, a_{ij} values, are chosen so as to minimize the cost in the usual fashion. Furthermore, denoting the Hicks-Allen elasticities of factor substitution of the jth industry by σ_j, we may obtain :

$$\hat{a}_{LX} = -\theta_{KX}\sigma_X\hat{\omega} - R_X\hat{X}, \qquad \hat{a}_{KX} = \theta_{LX}\sigma_X\hat{\omega} - R_X\hat{X} \tag{4a}$$

$$\hat{a}_{LY} = -\theta_{KY}\sigma_Y\hat{\omega} - R_Y\hat{Y}, \qquad \hat{a}_{KY} = \theta_{LY}\sigma_Y\hat{\omega} - R_Y\hat{Y} \tag{4b}$$

where $\omega \equiv w / r$ and where :

$$R_X \equiv (X / h_X)(dh_X / dX) \quad \text{and} \quad R_Y \equiv (Y / h_Y)(dh_Y / dY)$$

Let AC_j and MC_j, respectively, denote the average and marginal costs in the jth industry, and let $\varepsilon_j \equiv AC_j/MC_j$. The ε_j measures the cost elasticity of output. It can be shown that $\varepsilon_j = 1/(1-R_j)$. Hence $0 < Rj < 1$ captures increasing returns to scale and $R_j < 0$ captures decreasing returns to scale. If constant returns to scale prevail in industry j, we have $R_j = 0$. We exclude the case of $R_j > 1$ to avoid the negative marginal cost.

Substituting (4) into (2), we obtain :

$$\lambda'_{LX}\hat{X} + \lambda'_{LY}\hat{Y} = \hat{L} + \delta_L\hat{\omega} \tag{5a}$$

$$\lambda'_{KX}\hat{X} + \lambda'_{KY}\hat{Y} = \hat{K} + \delta_K\hat{\omega} \tag{5b}$$

where $\lambda'_{ij} \equiv \lambda_{ij}(1-R_j) > 0$ and where $\delta_L \equiv \lambda_{LX}\theta_{KX}\sigma_X + \lambda_{LY}\theta_{KY}\sigma_Y > 0$ and $\delta_K \equiv \lambda_{KX}\theta_{LX}\sigma_X + \lambda_{KY}\theta_{LY}\sigma_Y > 0$.

Solving (5) for $\hat{X}$ and $\hat{Y}$, we may obtain :

$$\hat{X} = \frac{1}{|\lambda'|}\left[\mu_X\hat{\omega} + (\lambda'_{KY}\hat{L} - \lambda'_{LY}\hat{K})\right] \tag{6a}$$

$$\hat{Y} = \frac{-1}{|\lambda'|}\left[\mu_Y\hat{\omega} + (\lambda'_{KX}\hat{L} - \lambda'_{LX}\hat{K})\right] \tag{6b}$$

where $|\lambda'| \equiv \lambda'_{LX}\lambda'_{KY} - \lambda'_{LY}\lambda'_{KX} = (1-R_X)(1-R_y)\,|\lambda|$, and where $\mu_X \equiv \lambda'_{KY}\delta_L + \lambda'_{LY}\delta_K > 0$ and $\mu_Y \equiv \lambda'_{KX}\delta_L + \lambda'_{LX}\delta_K > 0$.

Note that X industry is marginally labor-intensive if and only if $|\lambda|$ is positive, and that X industry is labor-intensive if and only if $|\lambda|$ is positive. Due to specification of production functions by (1), marginal and average factor intensities correspond (i.e., sign $|\lambda'|$ = sign $|\lambda|$). See Jones (1968, pp.267-268) for the concept of marginal factor-intensity. Substituting (4) into (3'), we obtain :

$$\theta_{LX}\hat{w} + \theta_{KX}\hat{r} = \hat{p} + R_X, \qquad \theta_{LY}\hat{w} + \theta_{KY}\hat{r} = R_Y \tag{7}$$

Suppose that the endowment of each factor remains constant. Then substituting (6) into (7) with $\hat{L}=\hat{K}=0$, we obtain :

$$\theta'_{LX}\hat{w}+\theta'_{KX}\hat{r}=\hat{p}, \qquad \theta'_{LY}\hat{w}+\theta'_{KY}\hat{r}=0 \tag{8}$$

where θ'_{ij} values are defined by :

$$\theta'_{LX}\equiv\theta_{LX}-\frac{R_X\mu_X}{|\lambda'|}, \qquad \theta'_{KX}\equiv\theta_{KX}+\frac{R_X\mu_X}{|\lambda'|} \tag{9a}$$

$$\theta'_{LY}\equiv\theta_{LY}+\frac{R_Y\mu_Y}{|\lambda'|}, \qquad \theta'_{KY}\equiv\theta_{KY}-\frac{R_Y\mu_Y}{|\lambda'|} \tag{9b}$$

Solving (8) for $\hat{w}$ and $\hat{r}$, we obtain :

$$\hat{w}=\frac{\theta'_{KY}|\lambda'|\hat{p}}{A}, \qquad \hat{r}=-\frac{\theta'_{LY}|\lambda'|\hat{p}}{A} \tag{10a}$$

$$\hat{\omega}=\frac{|\lambda'|\hat{p}}{A} \tag{10b}$$

where A is given by :

$$A\equiv|\lambda'||\theta'|=|\lambda'||\theta|-(R_X\mu_X-R_Y\mu_Y) \tag{11}$$

and where $|\theta'|\equiv\theta'_{LX}\theta'_{KY}-\theta'_{LY}\theta'_{KX}$ and $|\theta|\equiv\theta_{LX}\theta_{KY}-\theta_{LY}\theta_{KX}$.

Observe that $\theta'_{LX}+\theta'_{KY}=1$ and $\theta'_{LY}+\theta'_{KX}=1$, and that $|\theta'|=\theta'_{LX}-\theta'_{LY}=\theta'_{KY}-\theta'_{KX}$.

Expressing the real wage rate and the real rental rate in terms of good X, and letting $\hat{w}^X=\hat{w}-\hat{p}$ and $\hat{r}^X=\hat{r}-\hat{p}$, we obtain from (10) :

$$\hat{w}^x = \frac{\theta'_{KX}|\lambda'|\hat{p}}{A}, \qquad \hat{r}^x = -\frac{\theta'_{LX}|\lambda'|\hat{p}}{A} \tag{10'}$$

Next consider a change in factor endowments with a constant commodity price ratio (i.e., $\hat{p} = 0$). Solving (7) for $\hat{w}$ and $\hat{r}$ with $\hat{p} = 0$, and substituting $\hat{\omega} = \hat{w} - \hat{r}$ into (6), we obtain :

$$\lambda''_{LX}\hat{X} + \lambda''_{LY}\hat{Y} = \hat{L}, \qquad \lambda''_{KX}\hat{X} + \lambda''_{KY}\hat{Y} = \hat{K} \tag{12}$$

where λ''_{ij} values are defined by :

$$\lambda''_{LX} \equiv \lambda'_{LX} - \frac{\delta_L R_X}{|\theta|}, \qquad \lambda''_{KX} \equiv \lambda'_{KX} + \frac{\delta_K R_X}{|\theta|} \tag{13a}$$

$$\lambda''_{LY} \equiv \lambda'_{LY} + \frac{\delta_L R_Y}{|\theta|}, \qquad \lambda''_{KY} \equiv \lambda'_{KY} - \frac{\delta_K R_Y}{|\theta|} \tag{13b}$$

Rearranging the terms in A, we have the following relation :

$$A = |\lambda''||\theta| = |\lambda'||\theta| - (\delta_L \mu_L + \delta_K \mu_K) \tag{11'}$$

where $|\lambda''| \equiv \lambda''_{LX}\lambda''_{KY} - \lambda''_{LY}\lambda''_{KX}$, $\mu_L \equiv \lambda'_{KY}R_X + \lambda'_{KX}R_Y$ and $\mu_K \equiv \lambda'_{LY}R_X + \lambda'_{LX}R_Y$. Solving (12) for $\hat{X}$ and $\hat{Y}$, we obtain :

$$\hat{X} = \frac{|\theta|(\lambda''_{KY}\hat{L} - \lambda''_{LY}\hat{K})}{A} \tag{14a}$$

$$\hat{Y} = -\frac{|\theta|(\lambda''_{KX}\hat{L} - \lambda''_{LX}\hat{K})}{A} \tag{14b}$$

In the case of constant returns to scale, we have the following relation :

$$|\lambda| < 0 \quad \text{and} \quad |\theta| < 0 \quad \text{if and only if} \quad k_X > k_Y, \tag{15}$$

where $k_X \equiv K_X/L_X$ and $k_Y \equiv K_Y/L_Y$.

To close the model, we assume that the country is a small open economy. Assuming an incomplete specialization equilibrium, we write the Marshallian output adjustment process as :

$$\dot{Z} = a\left[\frac{p*}{p_S(Z)} - 1\right] \equiv \Phi(Z), \qquad a > 0 \tag{16}$$

where $Z \equiv X/Y$ and p^* is an exogenously given world commodity price ratio, and where $p_S(Z)$ is the supply price ratio in which we replace p in (3) by p_S.

It can be shown that the equilibrium is Marshallian stable if and only if A is positive. See Ide-Takayama (1991) for a detailed discussion of the Marshallian stability.

3. COMPARATIVE STATICS

In this section we discuss the Stolper-Samuelson and Rybczynski theorems for a small open economy under variable returns to scale (VRS). It has been shown in the literature that paradoxical results can be obtained under such an economy (e.g., Jones, 1968 : Panagariya, 1980).

We first look at the Stolper-Samuelson theorem. This theorem states that a rise in the price of a commodity leads to a rise in the relative and real returns to the factor used more intensively in the production of that commodity and a fall in the returns to the other factor. We may express this theorem in terms of the rate of change.

Without loss of generality, we may assume $k_X > k_Y$. The normal sign pattern for this theorem is then specified by :

$$\frac{\hat{w}}{\hat{p}} < 0, \quad \frac{\hat{r}}{\hat{p}} > 0, \quad \frac{\hat{\omega}}{\hat{p}} < 0, \quad \frac{\hat{w}^X}{\hat{p}} < 0, \quad \frac{\hat{r}^X}{\hat{p}} > 0 \tag{17}$$

Since $|\lambda| < 0$ if and only if $k_X > k_Y$, we may conclude from (10) and (10') that the above sign pattern is obtained if θ'_{ij} is positive for all i and j, provided that the equilibrium is Marshallian stable (i.e., $A > 0$). From the definition of θ'_{ij} in (9), it is apparent that θ'_{ij} can take negative value for some i and j. Being aware of this, Jones (1968) has imposed the following assumption :

> ASSUMPTION 2 (A2) (Jones, 1968, p.264). In an economy with a fixed set of factor endowments, an increase in any factor price must increase the (average) cost of producing each commodity.

From (8), it can be seen that this assumption is equivalent to assuming $\theta'_{ij} > 0$ for all i and j. Thus, given (A2), the normal Stolper-Samuelson theorem holds under VRS, provided $A > 0$.

Next we look at the Rybczynski theorem. This theorem states that given constant commodity prices, an increase in the supply of a factor results in an expansion of the industry using it more intensively and a contraction of the other industry.

Assuming $k_X > k_Y$, the normal sign pattern for this theorem is then specified by :

$$\frac{\hat{X}}{\hat{L}} < 0, \quad \frac{\hat{Y}}{\hat{L}} > 0, \quad \frac{\hat{X}}{\hat{K}} > 0, \quad \frac{\hat{Y}}{\hat{K}} < 0 \tag{18}$$

Since $|\theta|<0$ if and only if $k_X>k_Y$, we may conclude from (14) that this sign pattern is satisfied if λ''_{ij} is positive for all i and j, provided $A>0$. From the definition of λ''_{ij} in (13), λ''_{ij} can be negative for some i and j. Being aware of this, Jones (1968) has imposed the following assumption :

ASSUMPTION 3 (A3) (Jones, 1968, p.265). At constant commodity prices the expansion of any industry results in an increased demand for each factor of production (when the output of other industry remains constant).

In view of (12), this assumption means that each λ''_{ij} is positive. Thus, given (A3), the normal Rybczynski theorem holds under VRS, provided $A>0$.

However, Panagariya (1980) questions the validity of (A2) and (A3). He has argued that these assumptions impose severe restrictions on the general equilibrium system, and that many interesting possibilities arise when these assumptions are relaxed. Unfortunately without Jones's Assumptions 2 and 3, we can no longer obtain the normal Stolper-Samuelson and Rybczynski theorems under VRS, even if $A>0$.

In the next section, we will show that (A2) and (A3) are satisfied automatically at the Marshallian stable equilibrium, if we exclude the existence of scale diseconomies. In other words, we will show that the stability condition guarantees the positive signs of and for all i and j, in such an economy with no scale diseconomies.

4. HOW ROBUST CAN THE STOLPER-SAMUELSON AND RYBCZYNSKI THEOREMS UNDER VRS BE?

The purpose of this section is not to reconcile the Jones-Panagariya controversy. As mentioned in Section 3, Panagariya (1980) has shown the existence of cases in which (A2) and (A3) do not hold under VRS even if the equilibrium is Marshallian stable. He has given examples in his Table 1 in which the nonnormal sign patterns are given for both theorems (p.518). Thus, under VRS, we obtain the nonnormal Stolper-Samuelson theorems, and two important theorems may lose robustness. Therefore, in order to ease this uncomfortable situation, we consider a condition in which (A2) and (A3) do not fail. In particular, we consider the economy where scale diseconomies do not exist (i.e., we restrict the range of R_X and R_Y to $0 \leq R_X < 1$ and $0 \leq R_Y < 1$). Then we will show in the following two Propositions that (A2) and (A3) hold automatically under such an economy, so that the Stolper-Samuelson and Rybczynski theorems hold in the usual fashion.

The following proposition, Proposition 1, concerns with the Stolper-Samuelson theorem :

PROPOSITION 1. Suppose that constant and/or increasing returns to scale prevails in an economy. Here the Stolper-Samuelson theorem holds in the usual fashion under the Marshallian stable equilibrium.

Proof. Let $0 \leq R_X < 1$ and $0 \leq R_Y < 1$.

Suppose first that $|\theta|$ is positive (i.e., X industry is labor intensive). By (9), we can see that $\theta'_{KX} > 0$ and $\theta'_{LY} > 0$. Since $|\lambda||\theta|$ is always positive, $|\lambda|$ and

$|\lambda'|$ are also positive as $|\lambda'| = (1 - R_X)(1 - R_Y)\,|\lambda|$. Thus, $|\theta'| = \theta'_{LX} - \theta'_{LY} = \theta'_{KY} - \theta'_{KX} > 0$ by (11) when $A = |\lambda'||\theta'| > 0$. Hence, we have $\theta'_{LX} > 0$ and $\theta'_{KY} > 0$.

Next suppose that $|\theta|$ is negative. By (9), we can see that $\theta'_{LX} > 0$ and $\theta'_{KY} > 0$. In this case, we have $|\theta'| < 0$ when $A > 0$. Thus, we obtain $\theta'_{KX} > 0$ and $\theta'_{LY} > 0$.

The rest of proof follows from (10) and (10'). (Q.E.D.)

We may now turn to the Rybczynski theorem :

PROPOSITION 2. Suppose that constant and/or increasing returns to scale prevails in an economy. Then the Rybczynski theorem holds in the usual fashion under the Marshallian stable equilibrium.

Proof. Let $0 \leq R_X < 1$ and $0 \leq R_Y < 1$, so that μ_L and μ_K in (11') are positive.

Suppose, first that $|\theta|$ is positive. Then from (13), we have $\lambda''_{KX} > 0$ and $\lambda''_{LY} > 0$. We define $B \equiv \lambda'_{LX}\lambda''_{KY} - \lambda'_{LY}\lambda''_{KX}$. Using the definition of B, we may write A as $A = |\theta|\,B - \delta_L \mu_L$. For $A > 0$, we then have $B > 0$, thus $\lambda''_{KY} > (\lambda'_{LY} / \lambda'_{LX})\,\lambda''_{KX} > 0$. Also from (11'), we see $|\lambda''| = \lambda''_{LX}\lambda''_{KY} - \lambda''_{LY}\lambda''_{KX} > 0$. Thus, $\lambda''_{LX} > 0$ since $\lambda''_{LY}\lambda''_{KX} > 0$ and $\lambda''_{KY} > 0$.

Next, suppose that $|\theta|$ is negative. Then from (13), we have $\lambda''_{LX} > 0$ and $\lambda''_{KY} > 0$. For $A > 0$, we must have $B < 0$. Thus $0 < (\lambda'_{LX} / \lambda'_{LY})\,\lambda''_{KY} < \lambda''_{KX}$. By (11'), we see $|\lambda''| = \lambda''_{LX}\lambda''_{KY} - \lambda''_{LY}\lambda''_{KX} > 0$, hence, $\lambda''_{LY} > 0$ as $\lambda''_{LX}\lambda''_{KY} > 0$ and $\lambda''_{KX} > 0$.

The rest of proof follows from (14). (Q.E.D.)

Propositions 1 and 2 show that, in the economy with no scale diseconomies, Jones's A2 and A3 hold automatically, further we are free from the perverse Stolper-Samuelson and Rybczynski theorems, provided the equilibrium is Marshallian stable. Therefore, we may conclude that the negative values of θ'_{ij} and λ''_{ij} (with A>0) can occur only when we allow scale diseconomies into an economy.

Note that the homotheticity of production functions is not required to obtain Proposition 2. If scale diseconomies is allowed, then Jones's Assumptions 2 and 3 play an important role in order to obtain the normal Stolper-Samuelson and Rybczynski theorems.

5. CONCLUSION

We have shown that if we can consider an economy where constant and/or increasing returns to scale prevail, then Jones's assumptions 2 and 3 are satisfied automatically, and that the normal Stolper-Samuelson and Rybczynski theorems hold in the usual form, given the equilibrium is Marshallian stable. In addition, it can be seen from the definitions of θ'_{ij} and λ''_{ij} that the smaller the degree of scale diseconomies are, the greater the possibility that θ'_{ij} and λ''_{ij} take positive values. In other words, (A2) and (A3) may fail only when scale diseconomies work strongly. Therefore, we may conclude that Panagariya's critics can be applied only in a limited situation, hence, Jones's assumptions 2 and 3 are plausible when we deal with a model under VRS.

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