Indexation Rules, Risk Aversion, and Imperfect Information

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Abstract: Nominal wage adjustment is modeled as resulting from bargaining between a risk neutral firm and a risk averse worker, in an environment where the rate of inflation is a random variable. Risk aversion makes for endogenous indexation arrangements, which deliver partial indexation as they exploit imperfect inflation indices; risk aversion also generates a positive correlation between indexation and inflation variance. The model suggests a distinction between complete *vs* incomplete inflation adjustment on the one hand, and perfect *vs* imperfect adjustment on the other hand. JEL Classification no: E31, J33

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1 Introduction

One of the main stylized facts regarding wage indexation is that it is generally incomplete, which is ill at ease with traders being interested in real variables only. The traditional answer to this apparent contradiction between rational behaviour and empirical regularity has emphasized the macroeconomic problem of output stabilization: the standard results in the indexation literature argue for a tradeoff between the neutralizing effects of escalator clauses with respect to nominal (demand) shocks, and the magnifying effects they exert with respect to real (supply) shocks. Hence, if welfare depends on output stabilization and shocks can be of either type, the optimal degree of wage indexation is in general positive but indeed incomplete (Gray, 1976; Fischer, 1977).

However, this approach faces an intrinsic contradiction, forcefully pointed out by Azariadis (1978): optimality is typically defined under conditions of certainty equivalence, which amounts to assuming risk neutrality – a framework where indexation is useless in the first place and, strictly speaking, its stabilization properties are immaterial. Indeed, the optimal degree of indexation is usally derived from minimizing a superimposed loss function, defined in terms of output deviations from the certainty-equivalence equilibrium; but in principle it should be derived on the basis of profit and utility maximization, and hence risk aversion.[1] In fact, escalator clauses aim at neutralizing inflation risk: firms and workers may find it optimal to enter contracts which introduce some rigidities in the economy, this being the price they are willing to pay for insuring themselves – even if there are only real shocks, some degree of indexation may still be optimal (Aziariadis, 1978).[2] A consequence of the risk aversion approach is that risk averse workers require higher insurance, the more uncertain is the environment: higher inflation uncertainty should be associated with a higher degree of indexation, which is directly confirmed the empirical evidence (*e.g.*, Holland, 1986).[3]

[1] Moreover, output stabilization is not an obvious goal for bargaining between workers and firms. In this respect, a distinction should be drawn between the optimal indexation rate for the private sector, and the social welfare maximizing indexation rate – unless a risk averse policy maker is able to impose her preferences on a risk neutral society.

[2] Imperfect indexation may also emerge when risk sharing concerns relative prices, in addition to the usual aggregate (real and nominal) risk sharing problem: see Danziger (1988).

[3] The same effect is invoked to link the increase in inflation with the shortening of

In this paper we adopt the risk sharing approach, to argue that less-than-full indexation may arise out of the informational constraints faced by risk averse agents, and hence it can occur even in the face of purely nominal shocks: the degree of indexation reflects the informational content of the available price index with respect to the 'true' cost-of-living index, an accurate measure of which may be difficult to obtain.[4] Moreover, our model predicts a link between wage indexation and inflation variance: given any (actual or expected) increase in the price level, the overall nominal wage change depends on some 'fundamentals' (like bargaining power, degree of risk aversion, etc.) *and* the indexation mechanism as such, linking wage dynamics to price dynamics *on top* of other causes of nominal adjustment – this 'pure' indexation component turns out to be higher, the higher the variance of inflation.

The simplest way to focus on these points is *via* a static, partial equilibrium contracting model, with fixed employment: the basic issue can be captured by concentrating exclusively on the responsiveness of wages to inflation, and assuming away the difficulties induced by multi-period bargaining with renegotation, as well as those due to the indexation rate being determined jointly with wage and employment.[5] No explicit distinction is made between the real or nominal source of the inflation shock: what matters to the risk averse worker is inflation risk in itself, and indeed most escalator clauses fail to make this distinction – even though in a few cases some COLAs do rule out oil prices from the reference price index. Finally, indexation arises endogenously out of risk aversion, so that, in contrast with Blanchard (1979) and Davis and Kanago (1997), there are no exogenous renegotiation costs to justify indexation clauses.

We now present in section 2 the general form of the standard bargaining model: maximization of the payoff of the bargaining unit under different informational settings allows us to draw our general implications of optimal escalator clauses. Section 3 gathers some concluding remarks.

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contract duration (Rich and Tracy, 2000). Notice that instantaneous recontracting may be likened to instantaneous indexation – in the limit, the distinction between the two is somewhat blurred, as instantaneous recontracting could in principle provide full insurance about inflation risk. Given renegotiation costs, indexation may then be seen as an imperfect but cheaper alternative, the cost of which are once and for all as standardized clauses may be applied in most cases (and revisions of indexation rules do not appear frequent).

[4]The CPI typically mis-estimates the true cost-of-living index (*e.g.*, Moulton, 1996), while better approximations (like Fisher or Törnqvist indices) are rarely available, and usually produced only for specific periods.

[5]A similar set of assumptions, concerning in particular fixed employment, has been used by Woglom (1990), Ehrenberg *et al.* (1983), and Danziger (1988).

2 The model

A risk neutral firm and a risk averse worker bargain over the increase in the nominal wage rate, given a 'base' real wage. The wage increase is to be set with no knowledge of actual inflation – the latter is modelled as a random variable, the distribution of which is known by both parties. If actual inflation were known, nominal wage setting would clearly involve an inflation-contingent arrangement, amounting to *full indexation*: however, this is very rarely seen in reality (if at all), as accurate inflation statistics are usually unavailable, or available with delay after wage contracts are settled.[6]

As realized inflation is not observable, the bargaining problem is to be solved in expected terms. We do so under two different informational settings. First, we take expectation over the unconditional distribution of the inflation rate. Strictly speaking, this is a *no indexation* case: the resulting nominal wage adjustment depends only on the parameters of the inflation distribution – *i.e.*, it reflects the parties' common understanding of the inflation-generating mechanism. Secondly, we assume instead that an imperfect inflation signal (a change in a cost-of-living index) is available, so that the relevant inflation distribution is conditioned upon it. Clearly, the optimal nominal wage change is now contingent on the inflation signal: indeed, specific inflation indices may be published almost continuosly.

We consider a simple efficient bargaining model, the outcome of which is given by maximizing a weighted average of the parties' objective functions. The latter are the workers' utility, $U\left(\frac{W}{P}\right)$, and the firm's profit, $\Pi\left(\frac{W}{P}\right)$, with obvious notation: accordingly, the objective of the bargaining unit is defined as

$$\Omega\left(\tfrac{W}{P}\right) = \lambda U\left(\tfrac{W}{P}\right) + (1-\lambda)\Pi\left(\tfrac{W}{P}\right)$$

where the firm is risk neutral while the worker (may be) risk averse, and $\lambda \in (0,1)$.[7]

This problem can be set as one concerning rates of change, by assuming that some real wage is given to start with, $w_0 > 0$. Then $\frac{W}{P}$ (the real wage

[6] A full-fledged contract-theoretic explanation would notice that full indexation cannot be incentive compatible, if the worker's consumption basket is not freely observable by the firm. In the same vein, the imperfect inflation signal alluded to in the sequel, should presumably reflect what is jointly observable by the parties. An explicit modeling of both issues is assumed away here by our definition of the real wage as simply W/P (so that, *e.g.*, no distinction is made between the production wage and the consumption wage). Some observations on these and related points are gathered in the last section of the paper.

[7] Both parties could in principle be risk averse, with no substantial effects on our results. The bargaining problem should specify outside options, here normalized to zero.

to be bargained upon) can be written as

$$\frac{W}{P} = \left(\frac{1+\omega}{1+\pi}\right) w_0 \tag{1}$$

where ω and π measure the change of the nominal wage and the cost-of-living adjustment, respectively – the latter is the true inflation rate to be considered in setting the real wage. Hence, the bargaining unit will seek to maximize a function $\Omega(\omega, \pi)$. We interpret ω as the choice variable, and π as a random variable: the parties bargain over the adjustment in nominal wages taking the inflation rate as given. Notice that w_0 being an arbitrary starting point is consistent with this approach, as the *ex-post* real wage will in general differ from the optimal one.

In order to work out extreme cases first, suppose the realization of the inflation rate is known. Then the optimal wage change is simply given by the schedule $\omega_f(\pi)$, obtained from the maximization of $\Omega(\omega, \pi)$ with respect to ω: this state contingent solution is the optimal *ex post* adjustment to inflation.

On the other hand, if the parties' information concerns only the distribution of π, the optimal wage adjustment is some function of a vector of parameters of the distribution itself – $\omega_n(a_\pi)$, say – obtained from the maximization of $E(\Omega(\omega, \pi))$, where $E(\cdot)$ is the expectation operator with respect to the random variable π. This is the unindexed wage increase, bargained upon given the available information: it depends on no realized variables, but only on the parameters of the distribution of inflation rates.

Our main contention is that available price indices, to which nominal wage increases are typically linked, convey only partial information about the inflation rate. We view the indexing rule as arising from maximizing a function $E(\Omega(\omega, \pi)|p)$, where p is an inflation signal, the correlation of which with π is not perfect: the parties will settle at a wage increase $\omega_p(p; a_\pi, a_p)$, where a_p is the vector of parameters of the distribution of p. The degree of indexation is measured along $\omega_p(p; a_\pi, a_p)$ as a function of p: we see indexation as setting *ex ante* a rule linking the wage increase to a realized inflation signal. If U is concave and Π linear in W/P, we know that

$$E(\Omega(\omega(\pi), \pi)) > E(\Omega(\omega(p; a_\pi, a_p), \pi)) > E(\Omega(\omega(a_\pi), \pi)) \tag{2}$$

Indeed, the value of information is always positive to a risk averse agent (*e.g.*, Laffont 1976): the bargaining unit would prefer *ex ante* to know the realized inflation rate, and set the wage rate accordingly. There would be an *ex ante* incentive to adjust the wage increase to true inflation (if that were possible), and there is anyway an *ex ante* incentive to link the wage increase to an imperfect inflation signal. Both incentives arise out of risk aversion – there is trivially no incentive towards indexation when both parties are risk neutral.

2.1 A general setting

In this section we elaborate upon our general setting by making the only *a priori* assumptions that the bargaining unit maximand function is concave in W/P. We consider the full information case first: as mentioned above, the bargaining unit will settle at a wage change ω_f, which satisfies

$$\omega_f = \omega_f(\pi) = \arg\max_{\omega} \{\Omega(\omega, \pi)\} \tag{3}$$

Under definition (1), the degree of indexation is measured by the elasticity of the wage increase with respect to the appropriate measure of inflation.[8] Under standard concavity conditions, it will generally be the case that

$$\eta_f \equiv \frac{d\omega_f}{d\pi} \frac{1+\pi}{1+\omega_f} = 1 \tag{4}$$

an obvious implicit differentiation result.[9]

We now take the unindexed wage increase: this is the nominal wage change ω_n which satisfies

$$\omega_n = \omega_n(a_\pi) = \arg\max_{\omega} \{E(\Omega(\omega, \pi))\}$$

A general property is that $E(\Omega(\omega, \pi))$ can be written as a function of ω and the distribution parameter vector a_π. For the purpose of this section, we take a second order Taylor-approximation around $\pi = E(\pi) \equiv \mu$. Given the variance $V(\pi) = \sigma^2$, we have:

$$E(\Omega(\omega, \pi)) \cong \Omega(\omega, \mu) + \frac{\sigma^2}{2} \frac{\partial^2 \Omega(\omega, \mu)}{\partial \pi^2}$$

Similarly to equation (4) above, ω_n obeys

$$\eta_n \equiv \frac{d\omega_n}{d\mu} \frac{1+\mu}{1+\omega_n} = 1 \tag{5}$$

while it is obviously independent of the realized inflation rate, π.

[8] This definition is implicit in Davis and Kanago (1997), who define the rate of increase ω of the nominal wage by $(1+\omega) = (1+g)(1+\gamma\pi)$, with g nominal wage growth net of indexation, π inflation, and γ indexation: the elasticity of ω with respect to π is thus equal to or less than one, as $\gamma \leq 1$.

[9] This is a straightforward implication of the parties being interested in real variables only, and $d(1+x) = dx$ $(x = \omega, \pi)$; it says nothing on the absolute nominal wage change (which depends on the bargaining strength λ and the real wage w_0).

Finally, the indexed wage change will be

$$\omega_p = \omega_p(a_\pi, a_p, p) = \arg\max_\omega \{E(\Omega(\omega, \pi)|p)\} \tag{6}$$

We can write $E(\Omega(\omega, \pi)|p)$ as a function of ω and a_p; to a second order approximation, with $E(\pi|p) = \mu_p$ and $V(\pi|p) = \sigma_p^2$, we have

$$E(\Omega(\omega, \pi)|p) \cong \Omega(\omega, \mu_p) + \frac{\sigma_p^2}{2}\frac{\partial^2\Omega(\omega, \mu_p)}{\partial\pi^2} \tag{7}$$

to be maximized to yield ω_p as the optimal wage increase under indexation. Again we have

$$\widehat{\eta}_p \equiv \frac{d\omega_p}{d\mu_p}\frac{1+\mu_p}{1+\omega_p} = 1 \tag{8}$$

However, the actual degree of indexation is measured by the elasticity of ω_p with respect to p (and not μ_p). Using (8) and the fact that $d\omega_p/dp = (d\omega_p/d\mu_p)(d\mu_p/dp)$,

$$\eta_p \equiv \frac{d\omega_p}{dp}\frac{1+p}{1+\omega_p} = \frac{d\mu_p}{dp}\frac{1+p}{1+\mu_p} \tag{9}$$

which will be lower than one, whenever so is the elasticity of $(1+\mu_p)$ with respect to $(1+p)$, and the value of which depends only on the stochastic structure of the model.

2.2 The model with normal distribution

So far we have made no assumption on the distributions of p and π. We now assume these to be normal, $\pi \sim N(\mu, \sigma^2)$ and $p \sim N(m, s^2)$.[10] This allows us to take advantage of a well known property: if m is the unconditional mean of the index p, and s^2 its unconditional variance, it will be the case that

$$\mu_p = \mu + \frac{\sigma_{p\pi}}{s^2}(p - m) \tag{10}$$

where $\sigma_{p\pi}$ is the covariance between p and π. As a consequence, (9) becomes

$$\eta_p = \frac{(1+p)\sigma_{p\pi}}{(1+\mu)s^2 + (p-m)\sigma_{p\pi}} \tag{11}$$

[10] This assumption on the distribution of inflation rates within a given time period is quite common. The one-period inflation rate is often modeled as a linear transformation of current and past money growth rates and normally distributed shocks: this does not prevent the possibility of complex dynamics (or even nonstationarity) of the inflation rate.

We now assume that p, the observable change in the CPI or PPI, be an unbiased predictor of π (i.e., $m = \mu$). We also assume $s^2 = k^2\sigma^2$, $k > 0$, so that $p \sim N(\mu, k^2\sigma^2)$. Under these assumptions, (11) can be written as

$$\eta_p = \frac{(1+p)\beta}{1 + \beta p + (1-\beta)\mu} \tag{12}$$

where $\beta = \sigma_{p\pi}/s^2 = \rho/k$, with $\rho \in [-1, +1]$ the correlation coefficient between p and π. As a result, partial or over-indexation can arise in (12) out of the sheer stochastic structure of the model, depending on the correlation between actual inflation and the inflation index. Indeed, it is easily checked that $\eta_p \leq 1$ as $\beta \leq 1$. Incomplete indexation is usually observed, which is consistent with assuming $k > 1$. In the Appendix we present a formal argument to the effect that, at least in simple cases, $k > 1$ out of the properties of the distributions of π and p. In this case incomplete indexation emerges also when the correlation between π and p is perfect. Moreover, it is clear by inspection that the *degree* of indexation is linked to the variance of inflation.

As to the latter remark, it should be noticed that according to Davis and Kanago (1997) (DK) the nominal wage change should depend on the *relative* variability of inflation, i.e. (in our notation) on $\sigma/(1+\mu)$. Now consider *e.g.* the derivation of (5): the bargaining unit's maximand can be written as:

$$\Omega(\omega,\mu) + \frac{\sigma^2}{2}\frac{\partial^2\Omega(\omega,\mu)}{\partial\pi^2} = \Omega\left(\tfrac{1+\omega}{1+\mu}w_0\right) + \frac{1}{2}\left[(1+\omega)Rw_0\right]^2\Omega''\left(\tfrac{1+\omega}{1+\mu}w_0\right) \tag{5'}$$

where $R = \sigma/(1+\mu)$ is an index of relative variability. For any given w_0, the optimal nominal wage increase from maximizing (5') will have the form $\omega_n = \omega_n(R,\mu)$ – in that sense, the wage increase does indeed depend on relative variability. However, we are interested in a pure indexation effect, which at the optimum equals one, *independently of inflation variance*:[11] the unit-elasticity results depends only on the parties being interested in real variables. Indeed, pure indexation has to be 100%, if traders are rational and inflation is known or expected with certainty. By the same token, when the inflation signal is p the optimum involves a unit elasticity of ω_p with respect to μ_p: it is because of (10) that pure indexation (i.e., the elasticity with respect to p) turns out to depend on inflation variance, since the latter affects the reliability of p as an inflation signal.

As a final observation, it may be worthwhile to enquiry about how the model behaves with a CARA specification of the workers' utility function

[11] In the DK model this effect is implicitly measured by the elasticity of ω_n with respect to μ, and would amount to $\gamma = 1$ (see f.note 7). In that model, however, the indexation parameter γ is exogenously given: the nominal wage growth *net* of (and given) indexation is determined as a function of γ, μ, and R (and depends only on R for $\gamma = 1$).

– which, under the normality assumption, obviously delivers a lognormal maximization problem which can be explictly solved. When this is done (most conveniently with a continuous-time specification), the resulting wage change as of equation (6) will take the simple form

$$\omega_p = \overline{\omega} + \beta p \tag{6'}$$

where $\overline{\omega} = \beta A + (1-\beta)\omega_n$. Hence, the unindexed component $\overline{\omega}$ is a weighted average of the wage change which would have been reached without indexation, and a term A reflecting risk aversion and the bargaining power λ; it tends to coincide with ω_n as β tends to zero: indexation is useless when the inflation signal gives no useful information. On the other hand, β will never tend to one (i.e., indexation to 100 percent), so long as the variance of p is greater than that of π.[12] The explicit CARA solution may also help clarifying the role of risk aversion: the bargaining unit's expected surpluses with and without indexation differ by an amount which is increasing with the coefficient of risk aversion.[13] It should be noticed that the degree of indexation β depends only on the stochastic structure of the model, i.e. on the informativeness of the inflation signal; by contrast, the weight of the indexed component has to depend in general on risk aversion. Indeed, it is always optimal to link the wage increase to an inflation signal, so long as the latter is informative; however, this amounts to taking some risk, the compensation of which through a noncontingent share in wage adjustment not surprisingly reflects risk aversion (as well as bargaining power).

3 Concluding remarks

Treating indexation as the optimal reaction of risk averse traders to inflation risk in the presence of an inflation signal, offers some scope for possible extensions. In particular, while the traditional macroeconomic literature focuses on *complete* vs *incomplete* indexation, focusing on the informational content

[12] Under this respect, a notable property is $E(\omega_p) = \omega_n - \frac{1}{2}\rho^2\gamma^2 w_0^2\sigma^2 = E(\omega_f) + \frac{1}{2}(1-\rho^2)\gamma^2 w_0^2\sigma^2$ (where γ is risk aversion): quite naturally, $E(\omega_p) = \omega_n$ for $\rho = 0$ and $E(\omega_p) = E(\omega_f)$ for $\rho = 1$, while $1 > \rho > 0$ implies $\omega_n > E(\omega_p) > E(\omega_f)$.

[13] Indeed, following (2), we get $E(\Omega(\omega(p; a_\pi, a_p), \pi) - E(\Omega(\omega(a_\pi), \pi) = \frac{1}{2}(1-\lambda)\gamma w_0 \sigma^2 \rho^2$ where $a_\pi = (\mu, \sigma^2)$ and $a_p = (k, \sigma_{p\pi})$. This is positive only if $\lambda < 1$ (the firm has some bargaining power).When firms have a say in setting the wage increase, some of the burden of insuring workers is shifted onto the inflation signal p: as λ tends to 1 there is no incentive towards indexation, as workers will be insured anyway. Also, this incentive is stronger, the higher the degree γ of risk aversion and the variance of inflation: it is because of risk aversion in risky situations that indexation makes sense.

of price indices suggests a distinction between *perfect* and *imperfect* indexation. The latter distinction hinges on the fact that the typical observable CPI holds for the 'representative consumer', but specific (classes of) consumers (sorted out, *e.g.*, by income level, or geographical residence) have in fact different consumption bundles, and indexation to the CPI is necessarily imperfect. In practice, we do observe consumer inflation indices, specific for (quite large) classes of households: these approximate the actual inflation rate experienced by a given worker, by referring to an 'average' bundle of goods which is typical of the class to which the household observably belongs. Our approach might then in principle explain the difference between changes in CPI (overall inflation) and in specific cost-of-living indices, as the two may differ.[14] Modeling explicitly this difference may give one additional reason, beyond that put forth in this paper (but in the same spirit) for explicit indexation never being 100 percent: if we distinguish between the firm's and the worker's relevant inflation rates (concerning their specific production and consumption bundles), the informational content of the inflation signal p considered in the bargaining process (possibly a weighted average of a CPI and a PPI, or the GDP deflator) would be limited to what is jointly observable: full insurance of the worker's real income would not be incentive compatible. A related point, within an implicit contract model, has been raised by Danziger (1988). He postulates the existence of a real relative shock, which changes the marginal rate of transformation between the product and the consumption wages, in a framework where the labor contract is indexed to the aggregate price level. As the labor contract is offered by the firm, which cares about the product wage, the proposed indexation rule is less than complete, because (due to the existence of aggregate real and nominal shocks), the price level is on average an imperfect indicator of the real relative shock. Clearly, as already pointed out, the effects of real relative shocks on the indexation rule cannot be addressed in our model, as we do not distinguish between product- and consumption-wage.

On the other hand, our approach may also account for a well known empirical regularity: among dependent workers, indexation is more likely for low-level wages than for high-level wages.Traditional macroeconomic analysis posits a uniform indexation rate for all workers; at the same time, the prevailing informal explanation for different intra-workers indexation is that wealthier households typically hold a higher-than-average proportion of non-human wealth, which is an important collateral – rich households are less liquidity constrained, and accordingly require less insurance in the form of

[14]Clearly, the same reasoning applies to risk averse firms which bargain over the PPI, an index referred to the typical firm while any given firm operates within a given industry.

wage indexation.[15] By linking risk aversion and nominal wage change, our model might offer a different explanation (a straightforward, preference-based one being that risk aversion might not be increasing in income). Because of the overwhelming weight of the low income classes and the resulting asymmetric distribution of income, the correlation between the changes in 'true' household's index and the changes in the officially published (and hence observable) consumer price index is arguably higher for low-wage earners: high-wage earners are more likely to have a consumption bundle significantly different from the official consumption basket. And indeed our model predicts that the adjustment of the nominal wage to the observable average inflation index rises with the correlation of the index with 'true' inflation – i.e., the change in the true household's cost-of-living index. This effect is strengthened by a rise in average inflation, as luxury goods exhibit a greater relative inflation volatility than inferior or subsistence goods: if the same indexation package were to be offered to high and low wage earners, the consumption bundle of the rich household should be changed more frequently (*e.g.*, Deaton and Muellbauer 1980, p.175) – these adjustment and renegotiation costs (not considered in our model) should raise the cost of indexation and hence make it less likely.

Finally, the model can in principle account for different price indices being formally included in the bargained-upon wage change – depending on the informational content of any price index with respect to the bundle of commodities the worker is interested in. One implication (to be taken up next in our research agenda) is that the cost of escalator clauses should include the distortions induced by *imperfect* indexation. In particular, given that the latter is inevitable due to sampling costs, this distortion is presumably linked to the position of the representative worker within the overall income distribution.

[15] Note however that this explanation actually predicts that low-wealth households are typically dependent workers, which is a different empirical point.

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Appendix

In this Appendix we show that, at least in simple cases, it is reasonable to assume $k > 1$, i.e. that the variance of the inflation index p is greater than that of 'true inflation' π. Let us define π as the simple arithmetic average of the n inflation rates π_i of the goods consumed (or produced) in the economy, whereas the inflation signal p is the average of m of the n inflation rates $(m < n)$:

$$\begin{aligned} \pi &= \frac{1}{n}\sum_{i=1}^{n}\pi_i \\ p &= \frac{1}{m}\sum_{i=1}^{m}\pi_i \end{aligned}$$

which implies $P = \prod_{i=1}^{n} P_i^{1/n}$, where P_i is the price level of good i. To simplify calculations assume that the π_i are random variables with mean μ and variance σ^2, for all i, and that $Cov(\pi_i, \pi_j) = \sigma_c \geq 0$ for all i and j, $i \neq j$. The variances $V(\pi)$ and $V(p)$ are, respectively:

$$\begin{aligned} V(\pi) &= \frac{1}{n^2}V\left(\sum_{i=1}^{n}\pi_i\right) = \frac{n\sigma^2 + n(n-1)\sigma_c}{n^2} \\ V(p) &= \frac{1}{m^2}V\left(\sum_{i=1}^{m}\pi_i\right) = \frac{m\sigma^2 + m(m-1)\sigma_c}{m^2} \end{aligned}$$

The condition $V(p) - V(\pi) > 0$ thus becomes $nm(n-m)(\sigma^2 + \sigma_c) > 0$, clearly verified for $\sigma_c \geq 0$.