Environmental regulation of urban informal manufacturing firms: In search of appropriate policies

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ENVIRONMENTAL REGULATION OF URBAN INFORMAL MANUFACTURING FIRMS: IN SEARCH OF APPROPRIATE POLICIES

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Abstract

The Urban Informal Sector (UIS) is a major and expanding part of developing economies both in terms of employment and output. However, they cause substantial environmental damages and worsen living conditions, prompting authorities to impose rigid environmental regulations. Yet, these steps have been mostly arbitrary and based on adhoc popular sentiment or political exigencies and not on rigorous econometric analysis. Positive gains from the UIS in terms of employment, supply of cheap commodities, and recycling wastes have to be carefully weighed before delegating them to the city-fringes or closing them down. In this paper, we try to model the reactions of the firms faced with a regulation regime and the consequent impact on both individual firms and social welfare to arrive at certain parametric guidelines regarding appropriateness of various polices. It emerges that policy regulations should follow empirical estimation of the parameters and not be based on normative generalisation.

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ENVIRONMENTAL REGULATION OF URBAN INFORMAL MANUFACTURING FIRMS: IN SEARCH OF APPROPRIATE POLICIES

I. INTRODUCTION

The Urban Informal Sector (UIS) is a major part of national economies, especially in the developing countries, at present. Coming to limelight in 1971, it has not only survived, but has expanded both in terms of employment and share in national output in these countries, thereby falsifying the claim that it was a transitory phenomenon. Though various types of services in the urban areas are the main arenas of informal activities, a major part of UIS is engaged in manufacturing activities – catering both to final consumers as well as other producers. One of the major characteristics of these units is that they are generally not registered under any set of institutional rules. As a result, they are outside the purview of the rules regarding urban land use and environmental regulation. Even if they are registered, their sheer numbers and small size have prompted authorities to bypass them while formulating such regulations. However, as with any other production process, they do cause substantial environmental damages in their small ways. These damages are not too obvious, as they do not have towering chimneys bellowing black smoke into the blue sky turning it grey. The total quantum of water, air, noise and soil pollution that they create add up to substantial level, because, what they lack in individual contribution, they more than make up by their sheer numbers. Moreover, formal sector firms, faced with regulatory prohibitions, maintain a backyard of subcontractors (Gupta, 2002) and pass on a number of environmentally *'dirty'* jobs to them, thereby escaping investment in Environmentally Sound Technology (EST). Also, a major part of the production process is *'put out'* and shifted to urban slums to take advantage of the services of cheap labour available therein, including child labour. Most of these subcontractors, mainly informal sector units, lack Pollution Control Devices (PCDs), are devoid of basic sanitation and sewerage facilities, and therefore are more pollution intensive (Bartone & Benavides, 1993). It is also argued that workers and entrepreneurs in the UIS have little awareness of health and environmental impacts of pollution, and therefore have no incentive or ability to curb those (Kent, 1991). Historically, the towns and cities in developing countries have grown up sans plans and policies. Industries, tending to be located on the basis of proximity to raw materials, human resources, transport nodes, financial hubs and market, have concentrated in and around these urban centres. Gradually, because of space congestion and urban sprawl, residential space and industrial space began to cohabit. This has effectively lead to deterioration in living conditions and substantial damage to the environment, thereby questioning the sustainability of many of these urban centres. Recently there has been wide concern over such issues, especially in urban areas, where environmental regulation is becoming a common practice. The reaction from the authorities has been to introduce both Market Based Instruments (MBI – like pollution permits, per unit pollution charges, etc.) and Regulatory Instruments (RI - like enforcing strict emission norms for vehicles and manufacturing units, fixing upper limits of noise-level, earmarking land use pattern etc.). On part of the State, improved sewerage disposal practices and streamlined traffic management systems have also been introduced. However, in a developing country like India, the design of policy instruments for industrial pollution is not only complex but also very daunting. In principle, the authorities have an array of physical, legal, monetary, and other instruments at their disposal (Baumol & Oates, 1988; Kathuria & Sterner, 2002), but the presence of a large number of informal manufacturing firms that lack knowledge, funds, technology and skills to treat their effluent frustrates any instrument applied and leads to overall failure. Regulators are also constrained by meagre resources to monitor, measure and impose pollution charges. Additionally, low remuneration rates invite corruption. These problems are compounded by information failures. The MBIs tend to fail under such circumstances because of sub-optimal pollution charges and emission norms. If the charges are low nobody will comply, especially the big firms. If the charges are raised beyond a point, many UIS firms may go out of business. This has prompted the authorities to go for rigid command-and-control policies where emission norms are fixed and the punishment of the guilty takes the form of either clampdown and outright closure, or shifting them to the peripheral regions, or forcing them to install PCDs, or a combination of these. However, the steps taken in reality has been mostly arbitrary and based on adhoc popular sentiment or political exigencies, rather than on sound economic and econometric analysis. Consequently, every time a *'green'* policy has been initiated in any city in India there has been a uproar over the beneficial and detrimental effects of it with each party claiming to be to be the champion of the masses. In absence of rigorous cost benefit analysis decision making in the end has been erratic and knee-jerking. The regulations regarding relocation of industrial units from Delhi and tanneries from Kolkata, replacing diesel run commercial vehicles by CNG driven ones in Delhi, and the furore over imposition of vehicular emission norms in the cities and towns speak of this systematic haphazardness and messy politicking. It has been forgotten that each of the steps available to the authorities have different impacts on the individual firms and faced with these regulations, they behave differently. Moreover, it can not be denied that the UIS firms provide employment to a large number of people, supply cheap consumer products (mainly processed foods, ready-made garments and handicrafts) and services (transport, petty trading etc.) to the urban society, and produces goods and services which satisfy the special needs of the households at the lowest step of the income ladder. They also play an important role in recycling the wastes. Consequently, the informal sector has emerged as a vast sea of socially beneficial entrepreneurship and innovativeness also. These positive gains have to be carefully weighed before delegating them to the fringes of human settlement or closing them down. Thus, the impact of environmentally regulatory policies on social welfare may be vastly different from what the authorities presume while imposing certain types of policies. In this paper, we try to model the reactions of the firms faced with a regulation regime and the consequent impact on both individual firms and the social welfare to arrive at certain parametric guidelines regarding appropriateness of various types of polices.

The paper has eight sections. In the next section we outline the assumptions of the model. The formal model is deduced in the third section. In the fourth section possible outcomes of regulatory policies are analysed. The consequent impacts on social welfare and profit level of the firms are studied in the fifth section. A few conjectures are put forward in the sixth section while the seventh section indicates the actual outcomes under different parametric situations. The last section provides the conclusion and some policy implications.

II. ASSUMPTIONS OF THE MODEL

The environmental regime imposed on the UIS must recognise the fact that these firms usually operate outside the regulatory framework. They are not registered under any institutional body and, officially, they do not exist. As a result, imposing tax on them is not a realistic proposition. The authorities seem to recognise this and the regulation regime for the UIS generally asks them either to control emission or to shift out from the urban centre to some peripheral regions that are less congested and less inhabited. The State also carries out periodical surveys and raids, and units found to be polluting above permissible limits are shut down and penalised. We can model the situation in a simplistic way as follows.

There is substantial number of informal manufacturing units within city limits. The objective of the State is to maximise Social Welfare (SW) and it is concerned not only about Pollution level (Z), but also about adequate Employment (L) and Output (Q). It has a threshold level of Z ($\bar{Z}$), beyond which the firm is termed '*Polluting'*. A polluting firm, if found out, is penalised by imposing a fine F and confiscating all its products. They are also asked to either relocate, or pull down pollution levels below Z. Firms with Z lower than this threshold level $\bar{Z}$ are ignored by the State.

The firms operate under Monopolistic competitive product market with differentiated but similar products facing perfectly competitive factor markets. Being small firms they can not upwardly revise prices but can cut prices by small margins in a bid to increase market share. However, such an action forces the competitors to follow suit and so there is an overall price-decrease without any effect on individual shares, though total market size does increase. The firms are thus price takers for all practical purpose. The objective of the firms is to maximise profit.

The environmental damage (Z) caused by a firm depends on the amount of output (Q) it produces and the technology used, represented by the capital-labour ratio (k = K/L) of the firm.

Imposition of environmental regulation does not affect firms with Z lower than threshold level but affects those with higher Z. These units can take any of the five alternate steps –

Case - 1: Continue production as before and run the risk of detection and penalty;

Case - 2: Shift to specified peripheral region;

Case - 3: Scale down production to bring down Z below $\bar{Z}$;

Case - 4: Upgrade technology to bring down Z below $\bar{Z}$;

Case - 5: Shut down.

The decision that a firm takes depends on its expected pay-off from the alternatives, which in turn depends on various parameters, as we shall shortly see. Thus, the impact on SW also depends on the decisions taken by the firms. In the following sections we try to model the possible outcomes and the impact on SW.

III. FORMAL MODEL

The situation can be depicted by the following set of equations.

Social Welfare Function:

$$SW = f(L,Q,Z) \quad f'_L, f'_Q > 0, f'_Z < 0 \qquad \text{(1)}$$

Pollution Function of the Sector:

$$Z = g(Q,\lambda) \quad g'_\theta, g'_Q > 0, g'_\lambda < 0 \qquad \text{(2)}$$

λ = Probability of being penalised, dependent on Effort by the State to impose environmental standards.

Sectoral Pollution can also be seen as sum total of the Pollution level of individual firms and therefore –

$$Z_j = \sum_i z_{ij} \qquad \text{(3)}$$

z_{ij} being the pollution level of the i^{th} firm at the j^{th} period, i = 1,2,…,N; j = 0,1, i.e. initial (pre-regulation) and final (post-regulation) period.

Again, pollution level of the i^{th} firm depends on its output level and technology used. So,

$$z_{ij} = h(q_{ij}, k_{ij}), h'_q > 0, h'_k < 0 \qquad \text{(4)}$$

q_{ij} and k_{ij} are output and technological level of i[th] firm at the j[th] period, i = 1,2,…,N; j = 0,1, i.e. initial (pre-regulation) and final (post-regulation) period. It is assumed that a more environment friendly technology would be more capital intensive.

The firms have fixed coefficient type production function and so –

$$a_L = \frac{q_i}{L_i},\ a_K = \frac{q_i}{K_i},\ \frac{a_L}{a_K} = \frac{K_i}{L_i} = k_i \qquad \text{(5)}$$

L_i and K_i are Labour and Capital respectively, used by the i[th] firm.

Therefore,

$$\text{Total Employment in j}^{\text{th}}\text{ period} = L_j = \sum_i L_{ij} \qquad \text{(6)}$$

$$\text{where, } L_{ij} = l(q_{ij}, k_{ij}) \qquad \text{(7)}$$

i.e. employment n the I[th] firm depends on its output level and technology.

$$\text{Total Output in j}^{\text{th}}\text{ period} = Q_j = \sum_i Q_{ij} \qquad \text{(8)}$$

Costs incurred by the firms depend on their output and technology. So, assuming that Capital is more costly than Labour, we have

$$C_{ij} = c(q_{ij}, k_{ij}),\ c'_q > 0,\ c'_k > 0. \qquad \text{(9)}$$

The cost function for a given technology can be reformulated as

$$C_{ij} = a + b.q_{ij} + c.q_{ij}^2 \qquad \text{(10)}$$

where a = A(k_{ij})

Let initial Price situation be P. Therefore, Profit Function of the firms will be given by -

$$\Pi_{ij} = P \bullet q_{ij} - c(q_{ij}, k_{ij}). \qquad \text{(11)}$$

Initial profit maximising output is therefore obtained at the point where MR = MC, i.e.

$P = b + 2cq_{i0}$

$$\text{So, } q_{i0} = \frac{P-b}{2c}. \qquad \text{(12)}$$

This gives us the initial output level of the i[th] firm.

IV. POSSIBLE OUTCOMES

Let us explore what happens after environmental regulation is imposed. This may take any of the alternate courses as already noted. We go through them one by one.

Case 1: Firms continue production as before and run the risk of detection and penalty

The probability of detection, confiscation and penalty is λ. Hence the firm incurs all the costs but the probability of retaining that and selling in the market is (1 – λ). So expected revenue is P. (1 – λ), and expected profit of the i[th] firm will be

$$Pq_{i0} \bullet (1-\lambda) - C_{i0} - \lambda \cdot F \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \quad (11)$$

Since there is no change in MC, equilibrium output, employment, and pollution level of the i[th] firm will not change, only their profit will be decreased.

However, the state would be able to detect and shut down λ proportion of the firms. So there will be decline in total output by $\lambda.N.q_{i0}$.

This will result in decline in employment by $\dfrac{\lambda.N.q_{i0}}{a_L}$,

and decline in pollution level by λZ. The state will additionally mop up resource of the magnitude λNF as penalties and can use that for environment clean-up drive, leading to an increase of SW by u(λNF).

Therefore, the positive impact on SW will be $f_z'.\lambda Z + u(\lambda NF) - f_Q'.\lambda Nq_{i0} - f_L'.\dfrac{\lambda Nq_{i0}}{a_L}$.

<u>Case 2</u>: Firms shift to specified peripheral region

If polluting firms decide to shift to specified peripheral region, they have to bear two additional costs – a Fixed Cost related to Relocation (RC); and a Variable Cost related to transportation of commodities from city proper (TC per unit of output).

Thus the profit of the firm now would be

$$\Pi_{ij} = P \bullet q_{ij} - c(q_{ij}, k_{ij}) - TC.q_{ij} - RC \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \quad (12)$$

As MC has changed, equilibrium output will also change. Profit maximising condition is given by P = b + 2cq_{i1} + TC;

Hence, $q_{i1} = \dfrac{P-b}{2c} - \dfrac{TC}{2c}$. $\qquad$ ________________________ (13)

Therefore, output per firm declines by $\dfrac{TC}{2c}$ units, and total decline in output would be $N.\dfrac{TC}{2c}$ units.

Employment will decline by $\left[N.\dfrac{TC}{2c}\right].\dfrac{1}{a_L}$ units.

Therefore, the impact on SW will be $f_z'.Z - f_Q'.\dfrac{N \bullet TC}{2c} - f_L'.\left[\dfrac{N \bullet TC}{2c}\right]\dfrac{1}{a_L}$, i.e. $f_z'.Z - \frac{N \bullet TC}{2c}\left[f_Q' + f_L'.\frac{1}{a_L} \right]$

<u>Case 3:</u> Firms scale down production to bring down Z below $\overline{Z}$

The firms may decide to scale down output to bring down Z below $\overline{Z}$. Decline in output required to come down to permissible limit would be $\frac{(Z - \overline{Z})}{h_q'}$.

So total output declines by $N.\frac{(Z - \overline{Z})}{h_q'}$ units;

Employment declines by $N.\frac{(Z - \overline{Z})}{h_q'.a_L}$ units.

Impact on SW will be $f_z'.(Z - \overline{Z}) - f_Q'.\frac{N(Z - \overline{Z})}{h_q'} - f_L'.\left[\frac{N(Z - \overline{Z})}{h_q'.a_L} \right]$,

i.e. $f_z'.(Z - \overline{Z}) - \frac{N(Z - \overline{Z})}{h_q'}\left[f_Q' + f_L'.\frac{1}{a_L} \right]$

<u>Case 4:</u> Firms install pollution control device to bring down Z below $\overline{Z}$

If the firms decide to install certain gadgets to control pollution, then they have to bear two additional costs – a Fixed Cost related to Installation (IC); and a variable Preventive Cost related to operational charges of the device (PC per unit of output). The results will be identical to Case-2, except that Z will not be completely eliminated but will come down to Z_4, lower than $\overline{Z}$.

Thus the profit of the firm now would be

$$\Pi_{ij} = P \bullet q_{ij} - c(q_{ij}, k_{ij}) - PC.q_{ij} - IC \qquad (14)$$

As MC has changed, equilibrium output will also change. Profit maximising condition is given by $P = b + 2cq_{i1} + PC$;

Hence, $q_{i1} = \frac{P - b}{2c} - \frac{PC}{2c}$.

Therefore, output per firm declines by $\frac{PC}{2c}$ units, and total decline in output would be $N.\frac{PC}{2c}$ units.

Employment will decline by $\left[N.\frac{PC}{2c}\right].\frac{1}{a_L}$ units.

Therefore, the impact on SW will be $f_z'.(Z-\overline{Z})-f_Q'.\frac{N\bullet PC}{2c}-f_L'.\left[\frac{N\bullet PC}{2c}\right]\frac{1}{a_L}$,

i.e. $f_z'.(Z-Z_4)-\frac{N\bullet PC}{2c}\left[f_Q'+f_L'.\frac{1}{a_L}\right]$

<u>Case 5:</u> Firms shut down

If the firms find that in each of the above cases they are facing losses, they would think of shutting down. In fact, if post regulation Average Revenue is less than post regulation Average Variable Cost, they will shut down. Let us first identify the conditions under which the firms will shut down.

<u>Case 1:</u>

Average Revenue = $P(1 - \lambda)$

Average Variable Cost = $b + cq_{i0}$.

So the shut down condition is –

$P(1 - \lambda) < b + cq_{i0}$

$$\Rightarrow P-\lambda P<b+c.\frac{P-b}{2c}$$

$$\Rightarrow \lambda P>P-b-\frac{P-b}{2}$$

$$\Rightarrow \lambda>\frac{P-b}{2P}$$

This condition can also be restated as $\lambda>\frac{1}{2}-\frac{b}{2P}$, i.e. whenever effort-parameter of the State is beyond 0.5 (50 per cent effort), firms would shut down rather than continue production as before.

<u>Case 2:</u>

Average Revenue = P

Average Variable Cost = $b + cq_{i1} + TC$.

So the shut down condition is –

$P < b + cq_{i1} + TC$

$$\Rightarrow P<b+c.\frac{P-b}{2c}-c.\frac{TC}{2c}+TC$$

$$\Rightarrow \frac{TC}{2} > P - b - \frac{P-b}{2}$$

$$\Rightarrow TC > P - b$$

Case 3:

Average Revenue = P

Average Variable Cost = b + cq_{i1}.

So the shut down condition is –

P < b + cq_{i1}

$$\Rightarrow P < b + c\left[q_{i0} - \frac{(Z-\bar{Z})}{h'_q}\right]$$

$$\Rightarrow P - b - cq_{i0} + c\frac{(Z-\bar{Z})}{h'_q} < 0$$

$$\Rightarrow \frac{P-b}{2} + c\frac{(Z-\bar{Z})}{h'_q} < 0$$

$\Rightarrow \frac{P-b}{2c} < \frac{(Z-\bar{Z})}{h'_q}$, i.e. as long as required output reduction does not exceed initial output level, the firms are not intent to close down.

Case 4:

Average Revenue = P

Average Variable Cost = b + cq_{i1} + PC.

So the shut down condition is –

P < b + cq_{i1} + PC

$$\Rightarrow P < b + c.\frac{P-b}{2c} - c.\frac{PC}{2c} + PC$$

$$\Rightarrow \frac{PC}{2} > P - b - \frac{P-b}{2}$$

$$\Rightarrow PC > P - b$$

If all these cases are valid, i.e. none of the other alternatives offer a situation above Shut Down Point the firms will stop production.

In that case the impact on SW will be $f'_z.Z - Nq_{i0}\left[f'_Q + f'_L.\frac{1}{a_L}\right]$.

V. PROFIT AND SOCIAL WELFARE UNDER DIFFERENT SITUATIONS

Assuming that shut down is the last option for the firms, they will try to choose such a step between alternatives 1 to 4 so that their expected Profit is highest.

The Expected Profit Levels are as follows –

<u>Case 1</u>: $Pq_{i0}(1-\lambda)-\lambda F-\left(a+bq_{i0}+cq_{i0}^2\right)=\Pi_{i0}-\lambda Pq_{i0}-\lambda F$

where, $\Pi_{i0}=P\bullet q_{i0}-(a+bq_{i0}+cq_{i0}^2)$.

<u>Case 2</u>: $Pq_{i1}-(a+bq_{i1}+cq_{i1}^2)-RC-TC.q_{i1}$

$$=P\left(q_{i0}-\frac{TC}{2c}\right)-(a+bq_{i0}+cq_{i0}^2)-b\left(-\frac{TC}{2c}\right)-c\left(\frac{TC^2}{4c^2}-\frac{2q_{i0}.TC}{2c}\right)-RC-TC.q_{i0}+\frac{TC^2}{2c}$$

$$=\Pi_{i0}-P.\frac{TC}{2c}+b\left(\frac{TC}{2c}\right)+\frac{TC^2}{4c}-RC$$

$$=\Pi_{i0}-\frac{TC}{2c}\left(P-b-\frac{TC}{2}\right)-RC$$

<u>Case 3</u>: $Pq_{i1}-(a+bq_{i1}+cq_{i1}^2)$

$$=P\left(q_{i0}-\frac{Z-\bar{Z}}{h'_q}\right)-(a+bq_{i0}+cq_{i0}^2)-b\frac{Z-\bar{Z}}{h'_q}-c\left(\left(\frac{Z-\bar{Z}}{h'_q}\right)^2-2q_{i0}\frac{Z-\bar{Z}}{h'_q}\right)$$

$$=\Pi_{i0}-P.\frac{Z-\bar{Z}}{h'_q}+b\left(\frac{Z-\bar{Z}}{h'_q}\right)-c\left(\left(\frac{Z-\bar{Z}}{h'_q}\right)^2-2q_{i0}\frac{Z-\bar{Z}}{h'_q}\right)$$

$$=\Pi_{i0}-\frac{Z-\bar{Z}}{h'_q}\left(P-b\right)+2q_{i0}\frac{c(Z-\bar{Z})}{h'_q}-\frac{c(Z-\bar{Z})^2}{(h'_q)^2}$$

$$=\Pi_{i0}-\frac{Z-\bar{Z}}{h'_q}\left(P-b\right)+2.\frac{P-b}{2c}.\frac{c(Z-\bar{Z})}{h'_q}-\frac{c(Z-\bar{Z})^2}{(h'_q)^2}$$

$$=\Pi_{i0}-\frac{c(Z-\bar{Z})^2}{(h'_q)^2}$$

<u>Case 4</u>: $Pq_{i1}-(a+bq_{i1}+cq_{i1}^2)-IC-PC.q_{i1}$

$$=P\left(q_{i0}-\frac{PC}{2c}\right)-(a+bq_{i0}+cq_{i0}^2)-b\left(-\frac{PC}{2c}\right)-c\left(\frac{PC^2}{4c^2}-\frac{2q_{i0}.PC}{2c}\right)-IC-PC.q_{i0}+\frac{PC^2}{2c}$$

$$=\Pi_{i0}-P.\frac{PC}{2c}+b\left(\frac{PC}{2c}\right)+\frac{PC^2}{4c}-IC$$

$$=\Pi_{i0}-\frac{PC}{2c}\left(P-b-\frac{PC}{2}\right)-IC$$

Case 5: One time Sale proceeds from selling of Fixed Assets.

The corresponding impacts on SW are as follows –

Case 1: $f_z'.\lambda Z + u(\lambda NF) - f_Q'.\lambda Nq_{i0} - f_L'.\dfrac{\lambda Nq_{i0}}{a_L}$.

Case 2: $f_z'.Z - \dfrac{N \bullet TC}{2c}\left[f_Q' + f_L'.\dfrac{1}{a_L}\right]$

Case 3: $f_z'.(Z - \bar{Z}) - \dfrac{N(Z - \bar{Z})}{h_q'}\left[f_Q' + f_L'.\dfrac{1}{a_L}\right]$

Case 4: $f_z'.(Z - Z_4) - \dfrac{N \bullet PC}{2c}\left[f_Q' + f_L'.\dfrac{1}{a_L}\right]$

Case 5: $f_z'.Z - Nq_{i0}\left[f_Q' + f_L'.\dfrac{1}{a_L}\right]$.

This is like a 2-person - Non-zero sum - Pure strategy game, and stable equilibrium requires Nash equilibrium. The outcome would depend on the magnitude of the parameters λ, F, TC, RC, IC, PC, P, b, c, h_q', f_Z', f_Q', f_L', a_L, and $\bar{Z}$. In the short to medium run, P, b, c, h_q', and $\bar{Z}$ are given by Market and Technological factors, and are non-manipulatable. Let us now make some conjectures regarding the possible outcomes under different situations.

VI. FEW CONJECTURES

If the state is very strict and efficient with λ = 1, Case 1 and Case 5 becomes almost identical in terms of effect on SW, with Case 1 having an additional benefit of resource mobilisation in the hands of the state. But with very high λ, firms would certainly not take Case 1 as that will lead to loss. In fact, with λ = 1, if the firms continue production as before, they would loose all the revenue and in addition will have to pay penalty F. So, λ = 1 precludes Case 1, and drives the firms to Case 5. In fact, any λ greater than 0.5 would force the firms to shut down rather than continue production as before. So they will move on to Case 2, Case 3, or Case 4 depending on where their expected profitability is highest. The aim of the state therefore, would be to provide enough signals and adequate pressure so that the firms choose an option between Case 2 – Case 4, where both SW and Π are highest.

The alternates can be summarised in the following table –

Case	Profit	Impact on Social Welfare
II Relocation	$\Pi_{i0} - \frac{TC}{2c}\left(P - b - \frac{TC}{2}\right) - RC$	$f_z'.Z - \frac{N \bullet TC}{2c}\left[f_Q' + f_L'.\frac{1}{a_L}\right]$
III Output Reduction	$\Pi_{i0} - \frac{c(Z-\bar{Z})^2}{(h_q')^2}$	$f_z'.(Z-\bar{Z}) - \frac{N(Z-\bar{Z})}{h_q'}\left[f_Q' + f_L'.\frac{1}{a_L}\right]$
IV Installing PCDs	$\Pi_{i0} - \frac{PC}{2c}\left(P - b - \frac{PC}{2}\right) - IC$	$f_z'.(Z-Z_4) - \frac{N \bullet PC}{2c}\left[f_Q' + f_L'.\frac{1}{a_L}\right]$

It appears that the operative parameters are (TC, RC), $\frac{(Z-\bar{Z})}{h_q'}$, and (PC, IC). They have similar impacts on SW and Π – higher values of them reduce both SW and Π.

<u>Comparing Case 2 and Case 4</u>

1. With identical TC and PC, SW is higher in Case 2 when the units relocate. If RC < IC, firms will also find it more profitable to relocate. But if RC > IC, to provide incentive to relocate, the State should subsidise RC so that effective RC is less than IC as a lower RC compared to IC will provide higher profits to relocating firms.
2. If TC < PC, the above result holds.
3. If however, TC > PC, the firms will still relocate if

$$\Pi_{i0} - \frac{TC}{2c}\left(P - b - \frac{TC}{2}\right) - RC > \Pi_{i0} - \frac{PC}{2c}\left(P - b - \frac{PC}{2}\right) - IC$$

$$\Rightarrow \frac{TC}{2c}\left(P - b - \frac{TC}{2}\right) + RC < \frac{PC}{2c}\left(P - b - \frac{PC}{2}\right) + IC$$

$$\Rightarrow \frac{(P-b)}{2c}(TC - PC) - \frac{1}{4c}\left(TC^2 - PC^2\right) < IC - RC$$

$$\Rightarrow (TC - PC)\left[\frac{(P-b)}{2c} - \frac{1}{4c}(TC + PC)\right] < IC - RC$$

$$\Rightarrow (TC - PC) < \frac{IC - RC}{\left[\frac{(P-b)}{2c} - \frac{1}{4c}(TC + PC)\right]}$$

The denominator in the RHS is average post regulation output level of the relocated and PCD-installed firms. So the LHS multiplied by this denominator can be talen as some kind of difference between Total Transport Cost and Total Prevention Cost, using the average output as weights. In other words, if the gap between IC and RC is greater that Total Transport Cost and Total Preventive Cost, firms will still relocate. However, in this case the impact on SW will not be unambiguously higher in Case 2. SW_2 will be higher than SW_4 only if -

$$f_z'.Z - \frac{N \bullet TC}{2c}\left[f_Q' + f_L'.\frac{1}{a_L}\right] > f_z'.(Z - Z_4) - \frac{N \bullet PC}{2c}\left[f_Q' + f_L'.\frac{1}{a_L}\right]$$

$$\text{or iff, } \left[f_Q' + f_L'.\frac{1}{a_L}\right]\left[\frac{N \bullet TC}{2c} - \frac{N \bullet PC}{2c}\right] < f_z'.Z - f_z'.(Z - Z_4)$$

$$\text{or iff, (TC - PC)}\frac{N}{2c}\left[f_Q' + f_L'.\frac{1}{a_L}\right] < f_Z'(Z_4)$$

$$\text{or iff, (TC - PC)} < \frac{f_Z'(Z_4)}{\frac{N}{2c}\left[f_Q' + f_L'.\frac{1}{a_L}\right]}$$

Thus, only if (TC – PC) is sufficiently small, that Case 2 will still be better for both social welfare and the firms. Otherwise, SW will be higher for Case 4, and even the firms may decide to install pollution control devices (PCDs) rather than relocate. If however, (TC – PC) is large enough to have greater social welfare in Case 4, but not large enough to induce firms to install PCDs, then the state should subsidise Installation of PCDs to bring down effective IC for the firms.

Thus, whether the State chooses to press for Relocation or Installation of PCDs depends on the admissible limit of pollution (as Z_4 has to be below $\bar{Z}$), and the society's valuation of employment, output, and (diseconomies of) pollution, along with the relative costs of Relocation compared to Installation of PCDs, and also the relative costs of Transportation compared to Prevention. Without rigorous estimation and evaluation of these, any policy regulation would be arbitrary and sub-optimal for the society.

Comparing Case 3 and Case 4

We assume that Z_4 is just equal to $\bar{Z}$ for simplicity's sake. This is a realistic assumption as the firms install and run PCDs only up to that level where they barely reach below the maximum permissible pollution level.

1. If $\frac{(Z-\bar{Z})}{h'_q}=\frac{PC}{2c}$, then impact on SW are identical for both the cases. The firms will choose Case 4 if $\Pi_{i0}-\frac{c(Z-\bar{Z})^2}{(h'_q)^2} < \Pi_{i0}-\frac{PC}{2c}\left(P-b-\frac{PC}{2}\right)-IC$

or iff, $\frac{c(Z-\bar{Z})^2}{(h'_q)^2} > \frac{PC}{2c}\left(P-b-\frac{PC}{2}\right)+IC$

or iff, $c.\frac{(PC)^2}{(2c)^2} > \frac{PC}{2c}\left(P-b-\frac{PC}{2}\right)+IC,$ as $\frac{(Z-\bar{Z})}{(h'_q)}=\frac{PC}{2c}$

or iff, $\frac{PC}{2c}\left[\frac{PC}{2}-\left(P-b-\frac{PC}{2}\right)\right] > IC$

or iff, $IC < \frac{PC}{2c}\left[PC-(P-b)\right]$

or iff, $IC < PC\left[\frac{PC}{2c}-\frac{P-b}{2c}\right]$

Now, $\frac{P-b}{2c}=q_{i0}$ = initial output, while $\frac{PC}{2c}$ is the drop in output due to installation of PCDs. Hence, $\frac{P-b}{2c}=q_{i0} > \frac{PC}{2c}$, i.e. $\frac{PC}{2c}$-$\frac{P-b}{2c}<0$. Therefore, the condition under which firms will choose Case 4 now becomes IC < 0, which is implausible. Thus as long as $\frac{(Z-\bar{Z})}{h'_q}=\frac{PC}{2c}$, firms will chose Case 3, which has identical impact on SW.

2. Again if $\frac{(Z-\bar{Z})}{h'_q} < \frac{PC}{2c}$, SW is higher in Case 3. Now, firms will choose Case 4 if

$\Pi_{i0}-\frac{c(Z-\bar{Z})^2}{(h'_q)^2} < \Pi_{i0}-\frac{PC}{2c}\left(P-b-\frac{PC}{2}\right)-IC$

or iff, $\frac{c(Z-\bar{Z})^2}{(h'_q)^2} > \frac{PC}{2c}\left(P-b-\frac{PC}{2}\right)+IC$

or iff, $c.\frac{(PC)^2}{(2c)^2} > \frac{PC}{2c}\left(P-b-\frac{PC}{2}\right)+IC,$ as $\frac{(Z-\bar{Z})}{(h'_q)}<\frac{PC}{2c}$

or iff, $\frac{PC}{2c}\left[\frac{PC}{2}-\left(P-b-\frac{PC}{2}\right)\right] > IC$

or iff, $IC < \frac{PC}{2c}\left[PC - (P - b)\right]$

or iff, $IC < PC\left[\frac{PC}{2c} - \frac{P - b}{2c}\right]$

Now, $\frac{P-b}{2c} = q_{i0}$ = initial output, while $\frac{PC}{2c}$ is the drop in output due to installation of PCDs. Hence, $\frac{P-b}{2c} = q_{i0} > \frac{PC}{2c}$, i.e. $\frac{PC}{2c} - \frac{P-b}{2c} < 0$. Therefore, the condition under which firms will choose Case 4 now becomes IC < 0, which is implausible. Thus as long as $\frac{(Z-\bar{Z})}{h'_q} < \frac{PC}{2c}$, firms will choose Case 3, which has higher impact on SW.

Thus in both these cases, the SW maximising step is also the best step for the firms, and they choose it, i.e. they reduce output.

3. Again if $\frac{(Z-\bar{Z})}{h'_q} > \frac{PC}{2c}$, SW is higher in Case 4. Now, firms will choose Case 4 if

$$\Pi_{i0} - \frac{c(Z-\bar{Z})^2}{(h'_q)^2} < \Pi_{i0} - \frac{PC}{2c}\left(P - b - \frac{PC}{2}\right) - IC$$

or iff, $\frac{c(Z-\bar{Z})^2}{(h'_q)^2} > \frac{PC}{2c}\left(P - b - \frac{PC}{2}\right) + IC$

To ensure this, the State has to subsidise PC and IC so that firms do not reduce output but install PCDs instead.

Thus, as long as $\frac{Z-\bar{Z}}{h'_q}$ is less than or equal to $\frac{PC}{2c}$, the firms reduce output, and that is best for SW also, relative to installing PCDs. On the other hand, if the State is stricter and has a very low $\bar{Z}$, installing PCDs emerges to be better than reducing output, and the State may provide incentive by subsidising IC and PC.

Comparing Case 2 and Case 3

1. If $\frac{(Z-\bar{Z})}{h'_q} = \frac{TC}{2c}$, then impact on SW is higher in Case 2.

   The firms will choose Case 2 if

   $$\Pi_{i0} - \frac{c(Z-\bar{Z})^2}{(h'_q)^2} < \Pi_{i0} - \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) - RC$$

   or iff, $\frac{c(Z-\bar{Z})^2}{(h'_q)^2} > \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) + RC$

   or iff, $c.\frac{(TC)^2}{(2c)^2} > \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) + RC$, as $\frac{(Z-\bar{Z})}{(h'_q)} = \frac{TC}{2c}$

   or iff, $\frac{TC}{2c}\left[\frac{TC}{2} - \left(P-b-\frac{TC}{2}\right)\right] > RC$

   or iff, $RC < \frac{TC}{2c}\left[TC-(P-b)\right]$

   or iff, $RC < TC\left[\frac{TC}{2c} - \frac{P-b}{2c}\right]$

   Now, $\frac{P-b}{2c} = q_{i0}$ = initial output, while $\frac{TC}{2c}$ is the drop in output due to installation of PCDs. Hence, $\frac{P-b}{2c} = q_{i0} > \frac{TC}{2c}$, i.e. $\frac{TC}{2c} - \frac{P-b}{2c} < 0$. Therefore, the condition under which firms will choose Case 2 now becomes RC < 0, which is implausible. Thus as long as $\frac{(Z-\bar{Z})}{h'_q} = \frac{TC}{2c}$, firms will chose Case 3, while optimum for SW would have been Case 2.

2. Again if $\frac{(Z-\bar{Z})}{h'_q} < \frac{TC}{2c}$, SW is higher in Case 3. Now, firms will choose Case 2 if

   $$\Pi_{i0} - \frac{c(Z-\bar{Z})^2}{(h'_q)^2} < \Pi_{i0} - \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) - RC$$

   or iff, $\frac{c(Z-\bar{Z})^2}{(h'_q)^2} > \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) + RC$

   or iff, $c.\frac{(TC)^2}{(2c)^2} > \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) + RC$, as $\frac{(Z-\bar{Z})}{(h'_q)} < \frac{TC}{2c}$

or iff, $\frac{TC}{2c}\left[\frac{TC}{2}-\left(P-b-\frac{TC}{2}\right)\right] > RC$

or iff, $RC < \frac{TC}{2c}\left[TC-(P-b)\right]$

or iff, $RC < TC\left[\frac{TC}{2c}-\frac{P-b}{2c}\right]$

Now, $\frac{P-b}{2c} = q_{i0}$ = initial output, while $\frac{TC}{2c}$ is the drop in output due to installation of PCDs. Hence, $\frac{P-b}{2c} = q_{i0} > \frac{TC}{2c}$, i.e. $\frac{TC}{2c}$-$\frac{P-b}{2c} < 0$. Therefore, the condition under which firms will choose Case 2 now becomes RC < 0, which is implausible. Thus as long as $\frac{(Z-\bar{Z})}{h'_q} < \frac{TC}{2c}$, firms will choose Case 3, which also has higher impact on SW.

3. Now if $\frac{(Z-\bar{Z})}{h'_q}$ > $\frac{TC}{2c}$, SW is higher in Case 2. Firms will also choose Case 2 if

$$\Pi_{i0} - \frac{c(Z-\bar{Z})^2}{(h'_q)^2} < \Pi_{i0} - \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) - RC$$

or iff, $\frac{c(Z-\bar{Z})^2}{(h'_q)^2} > \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right) + RC$

To ensure this, the State has to subsidise TC and RC so that firms do not reduce output but relocate instead.

Thus, as long as $\frac{Z-\bar{Z}}{h'_q}$ is less than $\frac{TC}{2c}$, the firms reduce output, and that is best for SW also, relative to relocating themselves. However, if $\frac{Z-\bar{Z}}{h'_q}$ is equal to $\frac{TC}{2c}$, the firms reduce output, whereas the optimum would have been relocation. On the other hand, if the State is stricter and has a very low $\bar{Z}$, relocating emerges to be better than reducing output, and the State may provide incentive by subsidising RC and TC.

VII. ACTUAL OUTCOME

The actual outcome would thus depend on the relative magnitudes of $\frac{TC}{2c}$, $\frac{PC}{2c}$, and $\frac{Z-\bar{Z}}{h'_q}$.

1. If $\frac{TC}{2c} = \frac{PC}{2c} = \frac{Z-\bar{Z}}{h'_q}$

   SW is highest in Case 2, i.e. when the firms relocate themselves to peripheral regions. But firms will choose Case 2 only if RC < IC and RC < 0. The second condition being implausible, they move to Case 3, and reduce output. Only if the State provides positive incentive for relocation so that effective RC is less than zero that the SW maximising outcome will also be Profit maximising outcome and the firms will take it. If the State values SW highly, it will provide such incentives. Otherwise, a SW sub-optimal step of reduced output, employment and pollution will emerge.

2. If $\frac{TC}{2c} < \frac{Z-\bar{Z}}{h'_q} = \frac{PC}{2c}$

   In this situation also, SW is highest in Case 2, i.e. when the firms relocate themselves to peripheral regions. The firms will relocate if $\frac{c(Z-\bar{Z})^2}{(h'_q)^2} > \frac{TC}{2c}\left(P-b-\frac{TC}{2}\right)+RC$.

   This may be facilitated by subsidising RC and TC. Thus, SW Maximising and Profit maximising outcomes will be identical if subsidised Relocation and Transport Costs are introduced, and the firms will relocate themselves.

3. If $\frac{PC}{2c} < \frac{TC}{2c} = \frac{Z-\bar{Z}}{h'_q}$

   The outcome will depend on the relative differences between RC and IC, compared to TC and PC. Also, if (TC – PC) is large enough to have greater social welfare in Case 4, and as $\frac{PC}{2c} < \frac{Z-\bar{Z}}{h'_q}$, the State may actually choose to subsidise installation and operation of PCDs.

4. If $\frac{Z-\bar{Z}}{h'_q} < \frac{TC}{2c} = \frac{PC}{2c}$

In this situation, SW is maximised in Case 3, and for the firms, profit maximisation is ensured at this option too. Hence, output reduction takes place. The State may avoid this by lowering $\bar{Z}$ further down, so that relocating emerges to be better than reducing output, and the State may provide incentive by subsidising RC and TC.

VIII. CONCLUSION

The results may be summarised in terms of the following table –

Parameter Constraints	Social Welfare Maximises at	Profit of Firms Maximises at	Steps to ensure Optimality
$\frac{TC}{2c} = \frac{PC}{2c} = \frac{Z-\bar{Z}}{h'_q}$	Relocation of Firms to peripheral regions (Case 2)	Reduction of Output (Case 3)	Provide firms with cash incentive to relocate
$\frac{TC}{2c} < \frac{Z-\bar{Z}}{h'_q} = \frac{PC}{2c}$	Relocation of Firms to peripheral regions (Case 2)	Reduction of Output (Case 3) or Relocation (Case 2)	Subsidise Relocation and Transportation Costs
$\frac{PC}{2c} < \frac{TC}{2c} = \frac{Z-\bar{Z}}{h'_q}$	Installing PCDs (Case 4) or Relocation of Firms to peripheral regions (Case 2)	Installing PCDs (Case 4) or Reduction of Output (Case 3)	Subsidise Installation and Operation Costs of Pollution Control Devices
$\frac{Z-\bar{Z}}{h'_q} < \frac{TC}{2c} = \frac{PC}{2c}$	Reduction of Output (Case 3)	Reduction of Output (Case 3)	Optimality is ensured. But the state may avoid this by imposing stricter regime with lower $\bar{Z}$, so that Relocation is ensured.

The above schema therefore reveals that whenever the State chooses to impose Environmental Standards to reduce pollution created by Urban Informal Manufacturing units, the firms may react in a host of alternate ways. The final outcome will depend on an Action-Reaction pattern based on Signals, Pressures, and Policy Announcements that will determine the magnitude of the determining parameters. The impact on Social Welfare will also depend on the prevailing values of these parameters.

The single most significant policy conclusion that one may arrive from the above analysis is that the likely impact on Social Welfare depends both on the steps taken to reduce pollution (e.g. imposing penalties, relocating firms, reducing output, and installing pollution control devices) and on the magnitude of the associated parameters. In fact, the optimum step depends on the values of these parameters and hence the State should not decide a-priori on adopting a particular solution for reducing pollution. Only proper estimation of the values of the different parameters would reveal the Social Welfare maximising option, and whether the firms may be persuaded to follow that option too. Policy regulations should therefore follow empirical stocktaking and not be based on normative generalisation.

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