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Lifestyle Taxes in the Presence of Profit Shifting

Abstract

Non-communicable diseases (NCDs) cause about 71% of all deaths globally and a considerable increase in health care costs. To tackle this problem, several Governments have designed “sin taxes”, i.e, extra payments related to the quantity of unhealthy contents of specific goods. However, unhealthy food and soda drinks are often produced by multinational companies for which also profit shifting is a serious issue. The international dimension of these markets may have a dramatic impact on the actual implementation of sin taxes. This article contributes to the literature by analysing the effectiveness of sin taxes levied on a good produced by a multinational company. Our analysis shows that a trade off between profit shifting and lifestyle taxes may exist. In general, the First Best sin tax cannot be levied if Governments are also interested in corporate tax revenue. This is a quite interesting policy issue: countries that today benefit from profit shifting may find it harder to impose significant lifestyle taxes. We also provide some insights about the effects that the international effort to fight profit shifting may have on lifestyle taxes.

JEL-Codes: H210, H320, D110, D620, I180.

Keywords: optimal lifestyle tax, multinational industry, profit shifting, health care costs, tax competition.

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1 Introduction

According to WHO (2017), non-communicable diseases (NCDs) kill about 40 million people each year, equivalent to 70% of all deaths globally.[1] Tobacco use, physical inactivity, the harmful use of alcohol and unhealthy diets all increase the risk of dying from a NCD. In the EU, they are responsible for about 25% of total health care spending (Vandenberghe & Albrecht (2019)). In the quest to reduce this epidemics, Governments are introducing policies ranging from incentives to healthier lifestyle to information on the risks related to unhealthy behaviour to the introduction of "lifestyle taxes", i.e., extra payments related to the quantity of unhealthy contents of specific goods. Examples of sin taxes are tobacco, alcohol, fat, junk food and soda taxes. The use of lifestyle taxes is quite controversial and has received a great attention in the recent past. Most of the literature has focused on its effectiveness in improving health (Briggs (2019); Chaloupka *et al.* (2019); Goiana-da Silva *et al.* (2018); Rees-Jones & Rozema (2019)), on the distributional consequences of soda and junk food taxes (Allcott *et al.* (2019a,b); Griffith *et al.* (2019, 2018)) and on the consumption of these products (Taillie *et al.* (2017); Pomeranz *et al.* (2018); Cawley *et al.* (2019b,a); Rees-Jones & Rozema (2019); Smith *et al.* (2018)). For soda taxes, Cornelsen & Smith (2018) have pointed out four of the questions that economists should address: a better understanding of what drives changes in consumption patterns after the introduction of the tax, its effects on health and distribution (of income and wealth), and the principles that should be used to determine the tax rate.

In this article we argue that there is also another dimension that should be taken into account: the supply side of this market, which is predominantly controlled by multinational industries. As concerns the market for soda drinks, in 2015, Coca-Cola Co. controlled just under 50 percent of the global carbonated beverage market, while Pepsi Co controlled just over 20 percent of the market; the rest is only partially controlled by nationally based companies. The global fast food market, one of the leading sources of junk food, was capitalized at more than USD 539.63 Billion in 2016. Brands as Burger King, McDonald's, Domino's Pizza, KFC, Jack in the Box and Yum! are the major players in this market and are all multinationals. For these industries, profit allocation among countries is standard practice, and a change in the local demand may also change profit shifting incentives. Profit shifting is indeed a serious issue: according to OECD (2013), BEPS (Base Erosion and Profit Shifting) practices cost countries 100-240 billion USD in yearly revenue losses, that is, 4-10% of the global corporate income tax revenue.

The model presented in this paper aims at answering a policy questions that the literature has ignored so far: is there a relationship between the optimal lifestyle tax and the supply side? In particular, which are the limits a Government may find in setting an effective lifestyle tax if the good is produced by a multinational firm?

[1] More recent estimates show an increase in these figures. See https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases.

We show that, if Government cares about corporate tax revenue, the optimal lifestyle tax is always sub-optimal. In particular, a trade off is expected to exist between profit shifting and lifestyle taxes. Countries with higher profit tax rates may impose higher lifestyle taxes and vice-versa. The reason is quite simple: under tax competition, countries with higher tax rates will be hit less by the tax increase because multinational companies have already explored all the avenues to shift profit away. On the contrary, a reduction in the demand in countries using lower corporate tax rates may sensibly reduce their tax base (through a reduction in profit shifting). This in turn causes big corporate tax revenue losses. In this case, a north-south divide may emerge. Developing countries rely more than developed ones on company tax revenues; these are also the countries where obesity is relatively higher and causes relatively more deaths. In the quest to reduce profit shifting, over 130 countries are developing common strategies to reduce tax avoidance, following different strategies (Devereux & Sorensen (2006); Bunn *et al.* (2019)). Once the tax base has been determined, it will be allocated among countries with an apportionment formula on which the discussion is very lively (DeMooij *et al.* (2019); Eichner & Runkel (2008); Faccio & FitzGerald (2018)). We show that the reforms proposed to fight profit shifting allow countries to set a lifestyle tax closer to FB. In particular, if a sales apportionment formula is chosen, the multinational aspect may be ignored in setting the tax rate. In this respect, we suggest that in choosing the base for apportionment, the interaction among several types of taxes should be considered.

The article is organised as follows in Section 2 we present the model and the our main result while in section 4 we discuss the policy implications of our findings.

2 The model

Let us assume two countries, 1 and 2. Consumers derive utility from the consumption of a good Q whose price is equal to p. For simplicity, price is equal in both countries. Consumers surplus for good Q in each country can be written as:

$$W_i = \int_0^{Q_i^d} \left(\left(a_i - b_i Q^d \right) - p \right) dQ)$$

with $i = 1, 2$. However, the consumption of Q reduces the health stock, which in turn produces an increase in heath care costs at some later stage. The discounted expected value of these costs is proportional to the quantity of good Q and is equal to $h_i Q_i$, with $h_i > 0$. This future cost gives rise to an externality since it is not perceived by consumers at the time they decide the quantity of good Q to demand.

Good Q is produced by a profit-maximising multinational firm. Corporate profit in country 1 and 2 are taxed at rate τ_i and the cost to produce a unit of Q is equal to c, independently of where the good has been produced. The industry gross profit is $(p-c)\left(Q_1^d+Q_2^d\right)$, while the net profit depends on the allocation of the gross profit among the two countries. In this simple context we will show how profit shifting affects the optimal rate of lifestyle taxes.

2.1 Profit shifting and production location choices

Let us first consider the decision choices of a multinational company that wants to maximise its net profit under the assumption that production can be shifted across countries to a certain extent. While total demand $Q^d = Q_1^d + Q_2^d$ should be equal to the quantity produced $Q^s = Q_1^s + Q_2^s$, the industry has some margin to allocate production among the two countries, although it faces costs that are increasing in the difference between local demand and local supply and proportional to the level of production.

We also assume that the multinational shifts a share q of the profit to the country where taxation is lower by incurring a cost that is proportional to the amount shifted. The net profit can be written as:

$$\begin{aligned} \Pi_N &= m\left(Q_1^s+Q_2^s\right) - m\left(\tau_1 Q_1^s + \tau_2 Q_2^s\right) + \left(\tau_1-\tau_2\right) q \left(Q_1^s+Q_2^s\right) \\ &\quad -\frac{\alpha}{2} q^2 m \left(Q_1^s+Q_2^s\right) - \frac{\beta}{4}\left(\left(\frac{Q_1^s-Q_1^d}{Q_1^d+Q_2^d}\right)^2 + \left(\frac{Q_2^s-Q_2^d}{Q_1^d+Q_2^d}\right)^2\right)\left(Q_1^d+Q_2^d\right) \end{aligned} \quad (1)$$

where $\frac{\beta}{4}\left(\left(\frac{Q_1^s-Q_1^d}{Q_1^d+Q_2^d}\right)^2 + \left(\frac{Q_2^s-Q_2^d}{Q_1^d+Q_2^d}\right)^2\right)\left(Q_1^d+Q_2^d\right)$ is the cost due to the mismatch in the local production-consumption market and $\frac{\alpha}{2} q^2 m \left(Q_1^s+Q_2^s\right)$ is the cost incurred for profit shifting activities. The optimal solution can be written as:[2]

$$\begin{aligned} Q_1^s &= Q_1^d - m\left(Q_1^d+Q_2^d\right)\frac{\Delta}{\beta} \\ Q_2^s &= Q_2^d + m\left(Q_1^d+Q_2^d\right)\frac{\Delta}{\beta} \\ q &= m\frac{\Delta}{\alpha} \end{aligned} \quad (2)$$

where $\Delta \equiv \tau_1 - \tau_2$ determines the direction of profit shifting. If $\Delta > 0$ ($\tau_1 > \tau_2$), profit is shifted from country 1 to country 2. On the contrary, if $\Delta < 0$ ($\tau_1 < \tau_2$) profit is shifted from 2 to 1.

2.2 Optimal sin tax with profit shifting

In a public health care system, where health care is mostly financed out of income taxes, Governments may have to consider the effects of the introduction of a lifestyle tax on their fiscal revenue. A trade off may emerge in this context: the lifestyle tax allows to obtain resources that can be used to reduce the future

[2]See Appendix B.

burden on health care due to unhealthy behaviour. However, the introduction of this lifestyle tax may reduce the corporate tax revenue. Hence, Government may consider the joint effects on consumer welfare and the revenue of such tax. Country i maximises the following welfare function:

$$W_i = \int_0^{Q_i^d} (A_i - b_i Q)\, dQ - h_i Q_i^d + \delta_i \tau_i m \left(Q_i^s - q(Q_1^d + Q_2^d)\right)$$

where $A_i = a_i - p$; $\tau_i m \left(Q_i^s - q(Q_1^d + Q_2^d)\right)$ is the revenue from profit taxes and δ_i is the relative weight that Government attaches to the revenue derived from the corporate tax. The latter may depend on the importance of corporate tax revenue in the composition of tax revenue for that country (the higher the importance the higher δ_i) and on the actual share of profit that the company allocates in that specific country. The optimal lifestyle tax can be written as:

$$t_i \quad = \quad h_i - \delta_i \tau_i m + \delta_i \tau_i m \Delta \left(\frac{1}{\alpha} + \frac{m}{\beta}\right) \tag{3}$$

This formula above is quite interesting. h_i would be the First Best (FB) level of the lifestyle tax, i.e., the Pigouvian tax that would allow to fully internalise the future health costs of the present consumption of good Q. The second part, $-\delta_i \tau_i m$, measures the adjustments that are necessary to take into account that the lifestyle tax reduces demand, profit and tax revenue. Hence, $t_i = h_i - \delta_i \tau_i m$ is the optimal lifestyle tax for a national producer.[3] In an open economy, there is also a third term, $\delta_i \tau_i m \Delta \left(\frac{1}{\alpha} + \frac{m}{\beta}\right)$, which measures the effect of profit shifting and production reassignment. Its sign depends on Δ, i.e. on the tax rate differential. In particular, if $\Delta > 0$ the country 1 may impose lifestyle tax higher than if the industry was nationally based and vice-versa if $\Delta < 0$. For $\Delta > 0$, it is interesting to note that if $\Delta \left(\frac{1}{\alpha} + \frac{m}{\beta}\right) > 1$, namely, the optimal lifestyle tax is higher than the FB one. On the other hand, for $\Delta < 0$, if $-\Delta \left(\frac{1}{\alpha} + \frac{m}{\beta}\right) > 1$, the optimal lifestyle tax for that country will be 0.

This is a quite interesting result from a policy point of view: countries that today benefit from profit shifting ($\Delta < 0$) are those may be more reluctant to impose significant lifestyle taxes. In other words, there is a trade off between the revenue that can be raised through the lifestyle and the corporation tax. This result seems to be in line with actual data. In Europe, France (the country with the highest corporate tax) the marginal sweet tax is one of the highest; overall, the correlations between the sugar tax and company tax rate is about 30%. A more formal analysis is not possible since the number of countries is limited, and the sugar tax itself is quite different across countries Cornelsen & Smith (2018). However, our results allow us to draw some interesting policy conclusions. According to OECD (2019), corporate tax revenues are an important

[3] See Appendix A.1for a formal proof.

share of total revenue in developing countries (15.3% in Africa; 15.4 in Latin America against 9% of OECD countries). With Central and Eastern Europe these are also the areas where deaths from obesity are at its highest (Ritchie & Roser, 2019). From these preliminary results an important policy conundrum may emerge: countries which would benefit most from a reduction in the use of junk food and sugary beverages may be able to impose an effective lifestyle tax.

3 The impact of policies to reduce profit shifting

In order to reduce profit shifting, over 130 countries are developing strategies to determine a global tax base (Devereux & Sorensen (2006); Bunn *et al.* (2019)). Once the latter is determined, it will be allocated among countries according to some apportionment formula (DeMooij *et al.* (2019); Eichner & Runkel (2008); Faccio & FitzGerald (2018)). If this collaboration is successful, multinational industries will find it quite difficult to shift profits across countries. Indeed, the total consolidated profit of the firm $m\left(Q_1^s + Q_2^s\right)$ will be known by the tax authorities and it will then be apportioned among countries. According to our model, this means that $\alpha = \infty$ and $q = 0$, while the incentive to allocate production will depend on the apportionment formula. Here we extend our framework by introducing two different formulas: sales apportionment (AS) and production apportionment (AP) apportionment which represent extreme cases where the firm cannot act strategically (sales apportionment) or it may try to reduce its fiscal burden by a strategic choice of where to locate production. The optimal lifestyle taxes , derived in Appendix D, can be written as:

$$\begin{aligned} t_i^{AS} &= h_i - \delta_i \tau_i m \\ t_i^{AP} &= h_i - \delta_i \tau_i m + \delta_i \tau_i m^2 \frac{\Delta}{\beta} \end{aligned} \tag{4}$$

As shown in equation 4 , when profit cannot be shifted ($q = 0$), if a AS is used, the optimal lifestyle tax is equal to the one obtained for a domestic industry. In other words, the multinational dimension of the firm is irrelevant. If however profit is distributed according to the AP, the company can still strategically decide where to reduce production (due to a decrease in demand in the country where the lifestyle tax has been introduced). This means that optimal lifestyle tax still depends on the tax differential Δ, although the effect of profit shifting is smaller than the one obtained in Section 2. For $\Delta>0$, it is interesting in fact to note that only if $\Delta \frac{m}{\beta} > 1$ the optimal lifestyle tax will be higher than the FB level. On the other hand, if $-\Delta \frac{m}{\beta} > 1$ the lifestyle tax will be equal to 0.

4 Conclusions

Obesity has almost tripled since 1975. Although it is widespread phenomenon, its consequences are far greater in developing countries because obesity coexists with malnutrition/under-nutrition; furthermore, because the limited resources of health care systems, obesity and related non communicable diseases cause a larger number of deaths than in developing countries. In order to face this problem, most countries are introducing lifestyle taxes: the idea behind this tax is that by increasing the price of unhealthy goods consumers will substitute the latter with healthier options. The change in consumer demand may however have a rather pervasive effect on the tax revenue of the country implementing this policy, especially when the goods that are taxed are provided by multinational. We show that in general the optimal tax level cannot be imposed if Government is also interested in the corporate tax revenue.

So far, the literature has discussed the equity implications of this tax. Cheaper food is usually less healthy and this suggest that the tax may be regressive; on the other hand since it taxes unhealthy behaviours, the reduction in consumption should improve health of exactly the same population that pays more. Although these arguments are quite important, we argue that the international dimension of some of these markets may have a dramatic impact on the actual implementation of these taxes that the literature has not fully studied. In general the FB level cannot be levied if Governments are also interested in the fiscal revenue from corporate taxes. Furthermore, profit shifting activities may create a barrier to the introduction of effective lifestyle taxes by those countries that would benefit most from a reduction in the consumption of junk food and sugary beverages.

The reforms that are currently under review to reduce profit shifting will be able to mitigate this problem and in this respect the choice of the apportion rule is not neutral. In particular, the use of sales as a possible base would allow to cancel all the effects of strategic allocation of profit and production by multinational. We think that this dimension should be considered in defining the profit apportionment rules for the tax base of multinational firms. For federal governments for the European Union, another interesting policy question arises, i.e. the level at which the tax can be more effectively imposed. In this respect, the most recent literature seem to show that the European Union has a stronger negotiating power than (for example) the US federal government (see, e.g., Gutiérrez & Philippon (2018)) and that is more effective in reducing the power of lobbies. This evidence can be an interesting starting point for a discussion on setting a lifestyle tax at EU level.

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A Derivation of optimal sin tax

Consumers do not perceive the harm from the consumption of the good. The optimal quantity they buy is the one that maximises their consumer surplus:

$$CS_i = \int_0^{Q_i^D} ((a_i - b_i Q) - p)\, dQ$$

The optimal quantity may be found by solving the following problem:

$$Max_{Q_i^D} \int_0^{Q_i^D} ((a_i - b_i Q) - p)\, dQ$$

The FOC for the problem can be written as:

$$\frac{\partial CS}{\partial Q_i^D} : a_i - b_i p_i - Q_i^D = 0$$

.

Rearranging it gives $Q_i^D = \frac{a_i - p}{b_i}$.

The consumption of such good causes a future monetary cost whose expected value is equal to $h_i Q_i = h_i \frac{a_i - p}{b_i}$. To make consumer perceive this damage government introduces a tax; the price increases to $p + t_i$ and the quantity that consumers are open to buy is equal to

$$Q_i^D = \frac{a_i - p - t_i}{b_i}$$

The Government aims at finding the optimal level of t_i that maximises welfare, which is given by the sum of consumer surplus and the net endowment of health:

$$W_i = \int_0^{Q_i^D} ((a_i - b_i Q) - p)\, dQ - h_i Q_i^D)$$

where $Q_i^D = \frac{a_i - p - t_i}{b_i}$ is the consumers demand. The FOC for the problem can be written as

$$\frac{\partial W_i}{\partial t_i} : \frac{-t_i + h_i}{b_i} = 0$$

which gives

$$t_i = h_i$$

A.1 Derivation of the optimal sin tax, national producer

$$W_i = \int_0^{Q_i^D} ((a_i - b_i Q) - p)\, dQ - h_i Q_i^D) + \delta_i \tau_i (p - c) Q_i^D$$

The F.O.C. can be written as

$$\frac{\partial W_i}{\partial t_i} : \frac{-t_i + h_i + \delta_i \tau_i (p-c)}{b_i} = 0$$

and the optimal sin tax would be equal to

$$t_i = t_i = d_i - \delta_i \tau_1 m \tag{5}$$

where $m = (p - c)$.

B Derivation of the optimal $Q_1^s, Q_{2,}^s, q$

The net profit can be written as:

$$\begin{aligned}
\Pi_N &= m\left(Q_1^s + Q_2^s\right) - m\left(\tau_1 Q_1^s + \tau_2 Q_2^s\right) + \left(\tau_1 - \tau_2\right) q \left(Q_1^s + Q_2^s\right) \\
&\quad -\frac{\alpha}{2} q^2 m \left(Q_1^s + Q_2^s\right) - \frac{\beta}{4}\left(\left(\frac{Q_1^s - Q_1^d}{Q_1^d + Q_2^d}\right)^2 + \left(\frac{Q_2^s - Q_2^d}{Q_1^d + Q_2^d}\right)^2\right)\left(Q_1^d + Q_2^d\right) \\
s.t. &\quad \left(Q_1^s + Q_2^s = Q_1^d + Q_2^d\right)
\end{aligned}$$

The Lagrangean can be written as:

$$\begin{aligned}
\mathcal{L} &= m\left(Q_1^s + Q_2^s\right) - m\left(\tau_1 Q_1^s + \tau_2 Q_2^s\right) + \left(\tau_1 - \tau_2\right) qm \left(Q_1^s + Q_2^s\right) \\
&\quad -\frac{\alpha}{2} q^2 m \left(Q_1^s + Q_2^s\right) - \frac{\beta}{4}\left(\left(\frac{Q_1^s - Q_1^d}{Q_1^d + Q_2^d}\right)^2 + \left(\frac{Q_2^s - Q_2^d}{Q_1^d + Q_2^d}\right)^2\right)\left(Q_1^d + Q_2^d\right) - \lambda\left(Q_1^s + Q_2^s - Q_1^d - Q_2^d\right)
\end{aligned}$$

The F.O.C.s are:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial Q_1^s} &: \quad m\left(1 - \tau_1\right) + qm\left(\tau_1 - \tau_2\right) - \tfrac{1}{2}\alpha q^2 m + \tfrac{1}{2}\beta - \lambda - \beta \tfrac{Q_1^s + Q_2^d}{2Q_1^d + 2Q_2^d} &= 0 \\
\frac{\partial \mathcal{L}}{\partial Q_2^s} &: \quad m\left(1 - \tau_2\right) + qm\left(\tau_1 - \tau_2\right) - \tfrac{1}{2}\alpha q^2 m + \tfrac{1}{2}\beta - \lambda - \beta \tfrac{Q_2^s + Q_1^d}{2Q_1^d + 2Q_2^d} &= 0 \\
\frac{\partial \mathcal{L}}{s} &: \quad m\tau_1 Q_1^s + m\tau_1 Q_2^s - m\tau_2 Q_1^s - m\tau_2 Q_2^s - \alpha qm \left(Q_1^s - Q_2^s\right) &= 0 \\
\frac{\partial \mathcal{L}}{\partial \lambda} &: \quad Q_1^s + Q_2^s - Q_1^d - Q_2^d &= 0
\end{aligned}$$

,

C Derivation of the optimal sin tax with tax competition

Let us define $\Delta \equiv \tau_1 - \tau_2$, $Q_2^s \equiv Q_2^d +\ m\left(Q_1^d + Q_2^d\right)\frac{\Delta}{\beta}$, $Q_1^s \equiv Q_1^d -\ m\left(Q_1^d + Q_2^d\right)\frac{\Delta}{\beta}$, $Q_1^d \equiv \frac{A_1 - t_1}{b_1}$, $Q_2^d \equiv \frac{A_2 - t_2}{b_2}$ and $s \equiv \frac{\Delta}{\alpha}$. Country i maximises the following utility function:

$$W_i = \int_0^{Q_i^d} (A_i - b_i Q)\, dQ - h_i Q_i^d + \delta_i \tau_i m \left(Q_i^s - q(Q_1^d + Q_2^d)\right)$$

The F.O.C. can be written as:

$$\frac{\partial W_i}{\partial t_i} : -\frac{\beta\alpha t_i - h_i\beta\alpha + \delta_i\tau_i m\beta\alpha - \delta_i\tau_i m^2\Delta\alpha - \delta_i\tau_i m\Delta\beta}{b_i\beta\alpha}$$

Rearranging it gives

$$t_i = h_i - \delta_i\tau_i m + \delta_i\tau_i m\Delta\left(\frac{1}{\alpha} + \frac{m}{\beta}\right)$$

D Optimal sin tax with international coordination

D.1 Sales apportionment

Under sales apportionment profit are allocated according to where the good has been sold using the following formula

$$z_i = \frac{Q_i^d}{Q_1^d + Q_2^d}$$

Country i sets t_i in order to maximise the following welfare function

$$Max_{t_i}\ W_i = \int_0^{Q_i^d} (A_i - b_i Q)\, dQ - h_i Q_i^d + \delta_i z_i \tau_i m \left(Q_1^d + Q_2^d\right)$$

The F.O.C can be written as:

$$\frac{\partial W_i}{\partial t_i} : -\frac{t_i - h_i + \delta_i\tau_i m}{b_1} = 0$$

which gives

$$t_i = h_i - \delta_i\tau_i m$$

D.2 Production apportionment

In this case total profit is allocated according to where the good is produced using the following formula

$$w_i = \frac{Q_i^s}{Q_1^d + Q_2^d}$$

Country i sets t_i in order to maximise the following welfare function

$$Max_{t_i}\ W_i = \int_0^{Q_i^d} (A_i - b_i Q)\, dQ - h_i Q_i^d + \delta_i w_i \tau_i m \left(Q_1^d + Q_2^d\right)$$

Using 2we can write $w_i = \frac{Q_i^d - m\left(Q_1^d + Q_2^d\right)\frac{\Delta}{\beta}}{Q_1^d + Q_2^d}$ hence the maximisation problem can be written as

$$Max_{t_i}\ W_i = \int_0^{Q_1^d} (A_i - b_i Q)\, dQ - h_i Q_i^d + \delta_i \left(Q_i^d - m\left(Q_1^d + Q_2^d\right)\frac{\Delta}{\beta}\right) \tau_i m \left(Q_1^d + Q_2^d\right)$$

The F.O.C is:

$$\frac{\partial W_i}{\partial t_i} : -\frac{\beta t_i - h_i \beta + \delta_i \tau_i m \beta - \delta_i \tau_i m^2 \Delta}{b_1 \beta} = 0$$

and hence we have

$$t_i \quad = \quad h_i - \delta_i \tau m + \delta_i \tau_i m^2 \frac{\Delta}{\beta}$$