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Prove  $Z$  using weakest preconditions.

Out:  $I: \exists x = \prod_{k=1}^i k^k \wedge i \geq 0$   
 inner:  $J: \exists x = i \cdot j * \prod_{k=1}^{i-1} k^k \wedge i \geq 0 \wedge j \geq 0$

证明:

①  $WP(I, j=1 \wedge i=0) = i \cdot j * \prod_{k=1}^{i-1} k^k \wedge i \geq 0 \wedge j \geq 0 \equiv A$   
 注:  $j \geq 1 \Leftrightarrow j > 0$

②  $WP(I, x = x * i \wedge i=1) = i \cdot j * \dots \equiv B$

③  $WP(I, j > 0 \wedge i=1) \equiv \dots \Leftrightarrow j \vee$

④ 同理:  
 $J \rightarrow C \rightarrow D \rightarrow E \in I$   
 $C \Rightarrow F \Rightarrow J \rightarrow true$

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graph TD
    Start((Start)) --> X1[x = 1]
    X1 --> I0[i = 0]
    I0 --> Read[n = read()]
    Read --> Loop1{ }
    Loop1 -- yes --> Write[write(x)]
    Write --> Z["Z := x = \prod_{k=1}^n (k)^k"]
    Z --> Stop((Stop))
    Loop1 -- no --> Iplus[i = i + 1]
    Iplus --> Jassign[j = i]
    Jassign --> Loop2{ }
    Loop2 -- yes --> B["x = x * i"]
    B --> A["j = j - 1"]
    A --> Loop2
    Loop2 -- no --> Loop1
  
```

Hint: If you have to find invariants for nested loops, it is usually easiest to work from outermost loop to innermost loop.

prove  $Z$  using weakest pre-conditions.